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1876

APPLETON'S

DICTIONARY

OF

MACHINES, MECHANICS, ENGINE-WORK,

AND

ENGINEERING.

ILLUSTRATED WITH FOUR THOUSAND ENGRAVINGS ON WOOD.

IN TWO VOLUMES.

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MACHINES, MECHANICS, ENGINE-WORK, AND ENGINEERING.

HACKLE or HAX. A kind of comb or brush made of iron spikes; used for combing or pulling the fibres of wool or flax, so as to reduce them from a tangled to a smooth state.

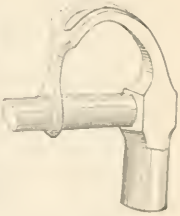
HADE. In mining, the underlay or inclination of the vein.

HALF-TIMBERED HOUSES. Buildings in which the foundations and principal supports were of stout timber, and the interstices of the fronts were filled with plaster.

HALLIARDS. In navigation, the ropes or tackles usually employed to hoist or lower any sail.

HAMMER. A well known carpenter's tool. Fig. 2243 represents a modification known as *Anderson's Patent Hammer.* In this hammer, the claw, as will be seen by the cut, extends to the handle and clasps it with a strong ring, which makes it impossible, in drawing nails, for the handle to give way, draw out, or become loose. The face of the patent hammer will thus always remain true, it being kept at the same angle with the handle. Six different sizes are now made, weighing from half a pound to one and a half pounds.

2243.

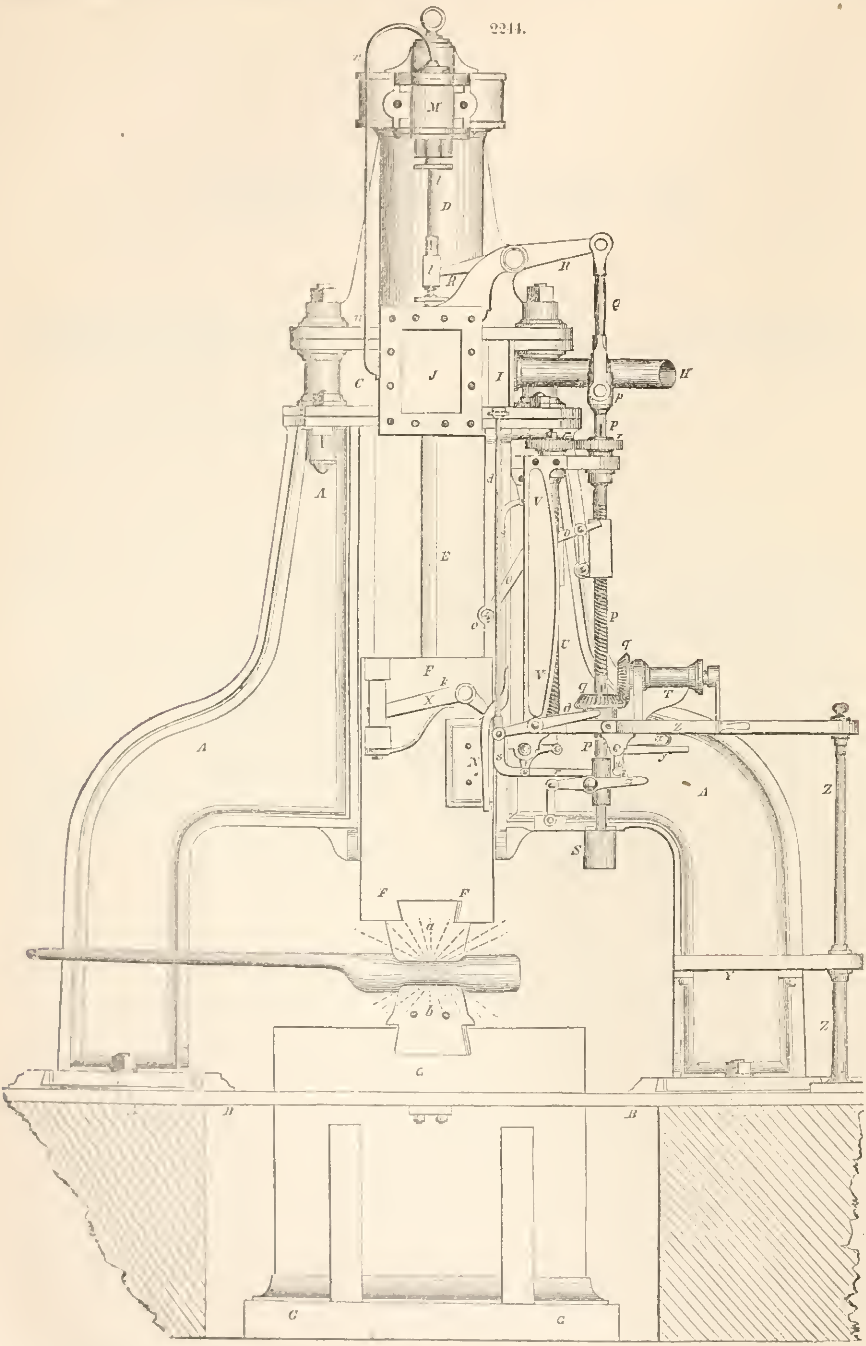


HAMMER, *steam.* James Nasmyth's patent steam-hammer. Before proceeding to describe the principle, mode of action, and constructive details of the direct-action steam-hammer, it may be proper to make a few remarks on the ordinary forge-hammers, so that the nature of the advantages possessed by the steam-hammer may be more clearly understood.

In all forge-hammers previously in use, the force necessary to set them into operation had to be transmitted in a very indirect manner,—for whether a water-wheel or steam-engine were the moving power, the requisite lifting and falling action of the hammer had to be produced by the employment of rotatory motion, thus rendering necessary the use of wheels, shafts, cams, and other cumbrous details, which, together with the apparatus requisite to connect the various parts of the machinery, and give due strength and solidity to the whole, not only caused great outlay and sacrifice of valuable space, but also occasioned much loss of power, by reason of the very circuitous manner in which the force of the prime moving agent had to travel ere it reached its final destination, and came forth in blows from the forge hammer. Great inconvenience, also, was found to result from having a considerable portion of the working machinery close to the hammer, as thereby a very serious impediment was offered to the free execution of the work. And when we add to this very limited range in the clear fall of an ordinary forge-hammer, (seldom, in any case, exceeding 18 inches,) causing the force of the blow to decrease in a very rapid ratio, with a moderate increase in the diameter or depth of the work; and when we take into consideration the fact that, in consequence of the helve of the hammer working on a centre or joint, its face is parallel to that of the anvil only at one particular distance; and finally, when to this list of inconveniences we add that in the ordinary forge-hammer we possess no power or control over the force of its blows, but are compelled to make the best use we can of them, whether they be adapted to our purpose at the time or otherwise, we find inherent in the very principle of such hammers, a combination of evils and inconveniences that only excite surprise that they should have been suffered to exist for so great a length of time.

This remark is most strikingly applicable in the case of those forge-hammers which receive their power from a steam engine, inasmuch as the power in question originates in the motion of the piston in the very state and condition in which, for the purpose of hammering, we desire it ultimately to be, namely, as a straight up and down motion; so that instead of causing this reciprocating action of the piston-rod to pass through all the complex media of beam, connecting rod, crank and cam shaft, for no other purpose than to cause it to act in the same manner as at first,—if we dispense with all this mass of intermediate machinery, and simply invert the steam cylinder so as to bring its piston-rod out at the bottom of the cylinder, and attach it *directly* to a block of iron working in guides right over the anvil

2244.



face, we shall then have obtained all the grand essentials of a forge-hammer in its simplest and most obvious, and, at the same time, as experience has demonstrated, in its most perfect and efficient form. Such is the Direct-Action Steam-Hammer, and such considerations as the preceding led to the invention of this machine.

Some idea of its efficiency in shingling puddled balls may be formed from the fact, that one of 3C cwt., which has been for nearly two years in constant operation at the Gartness Works of the Monkland Iron Company, in the West of Scotland, works off with perfect ease the constant produce of from 18 to 20 puddling furnaces. For this duty the steam-hammer is found to be peculiarly adapted, as it can be made to act for the first few strokes as a *squeezer*, to bring the puddled ball to a neat cubical form; after which it may be made to deal out upon it such energetic blows as secures the entire expulsion of all cinder and other non-metallic impurities, the absence of which, to a greater or less extent, mainly determines the quality of wrought-iron. In short, in every process where either blows of the most enormous energy, or slight taps of the utmost gentleness are required, either continuously or in all grades of variation from the one extreme to the other, the steam-hammer offers facilities which have never hitherto been obtained from any mechanical contrivance for such purposes.

Fig. 2244 represents a side elevation of the steam-hammer, exhibited in full operation, the hammer block, valve-geer, and other working parts being disposed in the positions which they occupy at the termination of a stroke. Fig. 2245 is a general plan corresponding to the above.

Fig. 2246 is an end elevation, and Fig. 2247 a vertical transverse section of the machine.

Fig. 2248 is a sectional elevation of a portion of the machine, showing the positions of the hammer-block, valve-geer, and other working parts when the hammer is raised for a fresh stroke.

The framing of the steam-hammer consists of two strong cast-iron standards A A, bolted and further secured by keys to a broad base-plate B B, embedded in the solid masonry forming part of the floor of the forge. The standards are surmounted, and their upper extremities united by a species of entablature C, in which the steam-passages and valve-face are formed, and to the upper surface of which the steam cylinder D is bolted. The piston-rod E is fitted to work vertically through a stuffing-box in the centre of this entablature, and its lower extremity is directly attached to the mass of cast-iron F, forming the hammer-block, which is guided to a strictly vertical and rectilinear course by being made to work freely in planed guides formed on the interior surfaces of the standards A A. The hammer *a* itself is inserted into a dovetail recess in the bottom of the block F, where it is retained by wooden packing and iron wedges; while the anvil *b* is in a similar manner secured to the anvil-block G, which is a mass of cast-iron of such weight as effectually to oppose, by its inertia, the momentum of the hammer, and prevent the force of the blows from being dissipated.

Such are the main features of this machine; from which it will be at once understood that, if we can provide the means of rapidly raising the hammer-block to a sufficient elevation, and then as rapidly letting it fall down upon, and so give a blow to the work placed upon the anvil, we have all that is requisite to produce a forge-hammer in its simplest, and, at the same time, its most powerful and perfect form.

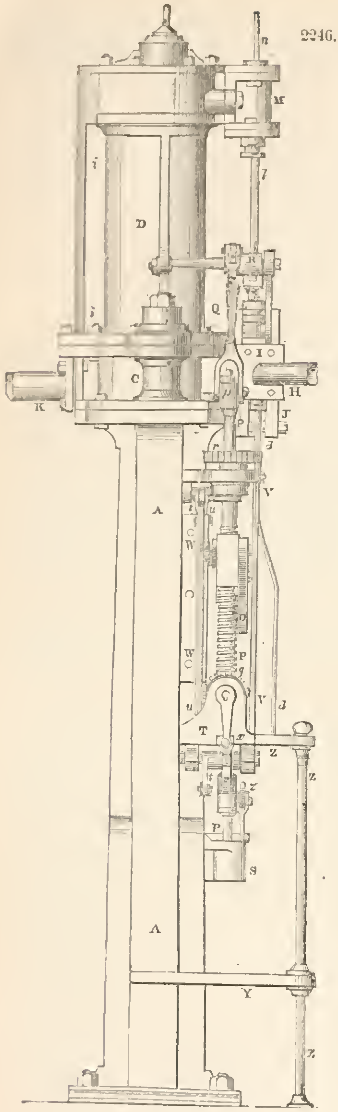
The duty above adverted to, of raising the hammer-block, is performed by the direct application of the elastic force of steam. For this purpose, the steam is led on to the machine by the steam-pipe H communicating with a neighboring high-pressure boiler; a throttle, or shut-off valve *c*, inclosed within the valve-box I, being situated close to its junction with the main steam-valve chest J, and brought within the control of the attendant workman by means of the rod and lever *d d*. The alternate admission of the steam into the cylinder by the port *f*, and its escape therefrom by the passage *g*, and waste steam-pipe K, are regulated by means of the slide-valve *e*, which may either be worked by hand, or, through the intervention of the self-acting mechanism to be hereafter specified, by the action of the machine itself. The piston L, which is strongly constructed of malleable iron, and fitted with a single packing ring, works steam-tight within the cylinder D; and being directly attached by the piston-rod E to the hammer-block F, it will be obvious that, on the admission of steam of sufficient elastic force beneath the piston, we are supplied with the means of raising the hammer-block to any required height within the range of the machine; while by opening the communication between the under side of the piston and the external atmosphere, the action of gravity will be unimpeded, and the hammer will descend upon the work placed on the anvil, and discharge a blow upon it, energetic in proportion to the weight of the hammer-block, and the height from which it has fallen.

And as, by these simple means, there is no practical inconvenience in supplying the power to raise a hammer-block of 5 or 6 tons weight to an elevation of 7 or 8 feet above the anvil, some idea may be formed of the vast energy of the blows given out by such a mass of iron falling rapidly through so great a space, and discharging *the whole* of its momentum upon the work placed below on the anvil to receive it. In the case of the old system of forge or helve hammers, about one-third only of the total weight of the hammer was effective, the other two-thirds resting on the pivot-standards; so that, in this point of view, the proportion between the blow of a steam-hammer and that of a helve-hammer is nearly 3 to 1 in favor of the former.

It will be seen, further, that the anvil-face and hammer-face are at all times parallel to each other, whatever be the height or distance between them. The practical value and importance of this property, which is inherent in the principle of the steam hammer, has been duly appreciated by all who have had experience of the working of this machine.

With a view to prevent any risk of the piston striking the cylinder-cover when working to the full, or very highest stroke of the hammer, a very simple but effective air or steam recoil spring is provided, by having the cylinder-cover screwed down quite air tight, so that as soon as the piston passes, in its upward motion, the holes *h h*, the air or steam remaining above is shut up in the upper chamber; and as it has no means of escape, it acts as a most perfect spring in arresting any further rise of the piston; and has, besides, the important advantage of converting into increased *downward* velocity of action the undue upward action, which might otherwise have proved not only useless, but destructive. The increase of energy in the blows which can be obtained by this simple means is a point of considerable importance. It is scarcely necessary to remark that, in the emergency above adverted to, the apertures *h h* act as safety valves for the issue of the main body of the steam, which escapes through the passage *i i*, into the exhaust or waste steam pipe K.

2246.



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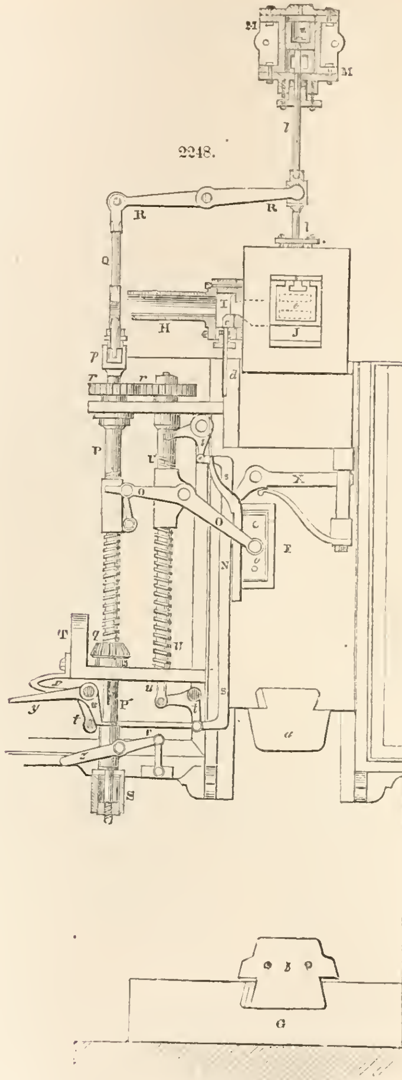

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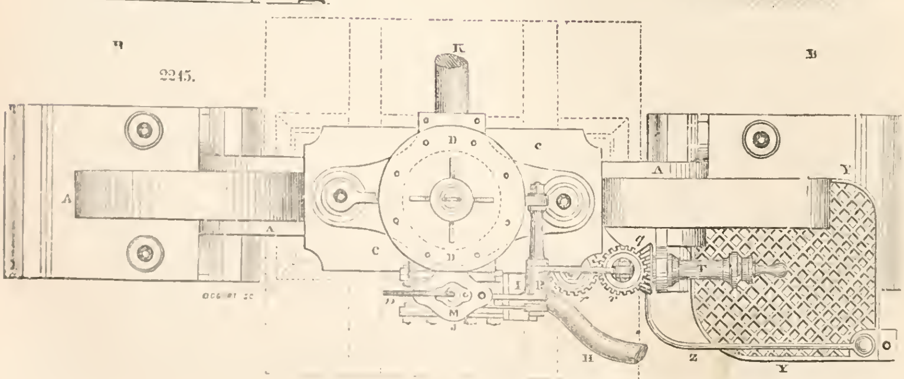
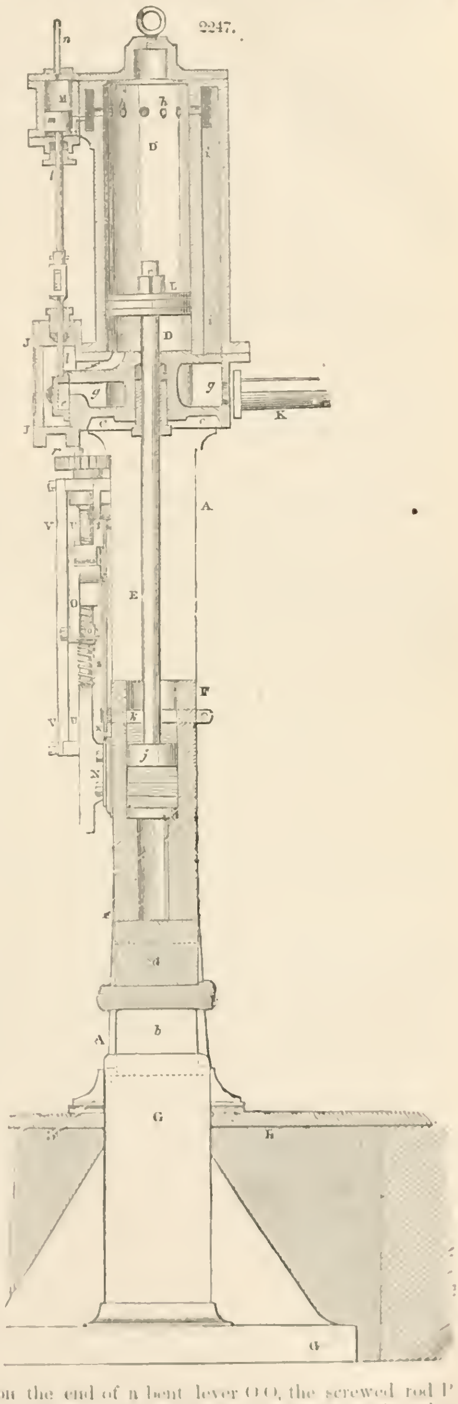


Plan of Fig. 2244 on preceding page.

Another point of constructive detail worthy of special notice is, the peculiar mode adopted for connecting the piston-rod to the hammer-block. This is one of the most important details in the entire invention, and without which no practical success would have attended it. Had the piston-rod been attached to the hammer in the ordinary mode of attaching pistons to the machinery of a steam-engine or such like, namely, by a cotter, or by screwing the rod into the hammer, or such other solid, unyielding mode, the effect of the blow or fall, at each stroke of the hammer, would have been that the piston-rod and piston (being composed of a considerable *mass* of materials) would have themselves acted *as a hammer*, and would have discharged their momentum upon the means of fastening, and this with such destructive effect as to break through all such *solid, unyielding means of resistance*, after a few blows.

2247.



This was foreseen from the first as an action to be prevented, and accordingly, in my original drawing, already adverted to, a remedy was provided, which experience has proved to be entirely effectual.

This contrivance consists in placing, in a cylindrical recess formed in the body of the hammer-block, and under the knob *i*, on the end of the piston-rod, a series of pieces of hard wood, or other *slightly* elastic material, as in Fig. 2246. The effect of this arrangement is to allow the momentum of the piston and piston-rod to deposit itself in such a comparatively gradual manner as to cause the concussion arising from the most severe and energetic blows of the hammer to have not the slightest evil effects on the piston and rod; it is, in fact, the very same expedient to which nature has had recourse for the purpose of obviating those unpleasant and destructive shocks and vibrations which we should experience at every step or stamp of the foot, had no cartilage been provided between the joints of our bones. It is surprising to observe by how small an amount of elasticity, from the employment of such compressible material, the evil effect of violent shocks may be removed. The connection of the piston-rod and hammer-block is secured by means of the two keys *k k*, driven very firmly *above* the knob or button *j*, a layer or two of the elastic material being interposed for the purpose of neutralizing any shock in the contrary direction.

We shall now proceed to describe the mechanism by which the height of the fall of the hammer, and consequent intensity of the blow, may be modified according to circumstances, and the machine made perfectly self-acting.

The requisite alternating motion of the steam-valve *e* is produced in the following manner:— The valve-spindle *l* is prolonged upwards and attached to a small solid piston *m*, working within a short cylinder M, bolted to the main steam cylinder D. A small portion of steam is supplied above the piston *m*, by a slender copper tube *n*, communicating with the steam valve-chest J; by this arrangement it will be seen that, unless counteracted by some superior force, the pressure of the steam upon the piston *m* will tend to keep the valve *e* constantly depressed, in which position the steam port *f* is full open. This counteracting force is supplied by the action of the hammer itself; for, by means of the tappet N, (which is bolted to the hammer block,) coming into sliding contact, when the latter is raised, with the small friction-roller *o*, mounted on the end of a bent lever O O, the screwed rod P which is jointed to the opposite end of that lever, is depressed, and that motion being communicated to the valve-spindle *l*, through the intervention of the connecting-rod Q and valve-lever R, the steam valve ϵ is raised, thus cutting off all further ingress of steam under the piston, and almost at the same instant permitting the escape of that which had served to raise the hammer. By this simple contrivance the upward motion of the hammer is made the agent for its own control in that respect. By comparing the relative positions of the parts referred to, as exhibited in Figs. 2244 and 2248, the nature of the motion above described will be at once most fully understood. To obviate the injurious effects of the shock of the tappet N against the lever O, a connection is provided at *p*, on a similar principle to that formerly described in reference to the connection of the piston-rod and the hammer-block; and in order to restrict the downward travel of the valve to the proper point, a check or *buffer-box* S is provided, consisting of a small cylinder bolted firmly to the framing of the machine, within which a circular nut, screwed on the lower end of the rod P, works as a piston, a few leather washers being interposed between the latter and the close or upper end of the cylinder.

It may be here remarked, that it is by no means necessary to continue the admission of steam under the piston until the termination of the upward stroke, or *lift* of the hammer, seeing that the velocity which the hammer-block has acquired in its upward motion makes it continue to ascend after the further ingress of the steam has been arrested. This circumstance is a source of considerable economy of steam, as we have by such action (as well as by that due to the expansive energy of the steam) an effect as to height of lift of the hammer, greater than that which is due to the actual expenditure of steam at its original pressure. It is worthy of remark, also, that as the *over-running* action above alluded to will necessarily increase in proportion to the velocity of ascent of the hammer-block, this circumstance will, to a considerable extent, compensate for the increased expenditure of steam due to that increased velocity.

From the above description it will be obvious, that the lift of the hammer, and consequent intensity of the blows, depends simply upon the position of the lever O, in relation to that of the hammer-block when at its lowest point. Therefore, if we can provide the means of altering the distance between these two points, we shall have it in our power to modify permanently the force of the blows to any required extent within the range of the machine. This condition is most completely satisfied by the arrangement of mechanism employed by me, and which is clearly represented in the figures.

The rod P which conveys the action of the lever O to the valve-lever R, is screwed throughout the greater part of its length, and is so adjusted in its bearings, as to be susceptible of rotatory as well as vertical motion. This motion of rotation is imparted to it by means of a handle fixed to a short axis, working in a bracket T bolted to the framing, and actuating a pair of small bevel-wheels *q q*. The nut through which the screw works forms the point of attachment between the rod P and the lever O, the connection being effected by means of a short intermediate rod for the sake of insuring parallelism of motion. A pair of small spur-wheels *r r*, (through the first of which the rod P works by means of a sunk feather,) serve to transmit the angular motion of the rod P to a similar screwed-rod U, situated parallel to and at a short distance from the former; the nut of the screw U forms the fulcrum or centre of motion of the lever O, and the pitch of the threads of both screws being equal, though formed in contrary directions to each other, it is obvious that, on turning the handle, the lever O and all its appendages will be simultaneously raised or depressed, and consequently the lift of the hammer regulated to any required extent, and its amount altered with the utmost ease and precision. The pin which forms the centre of motion of the lever O is protected and secured from lateral strains by the cast-iron guides V and W, seen most distinctly in the sectional plan, Fig. 2245.

A most essential part of the self-acting geer remains yet to be noticed. It is obvious that, were no provision made for the retention of the steam-valve in the position into which it is thrown by the upward motion of the hammer-block, the latter would not be permitted to have its due effect in the accomplishment of its work; for, as soon as it descended so far as to relieve the end of the lever O from contact with the tappet N, the valve would resume the position into which it is constantly solicited by the action of the *steam-spring* at M, and the descent of the blow would be impeded by the return of the steam into the cylinder, before the hammer had completed its fall. To obviate this inconvenience, a simple but most effectual contrivance has been applied. Towards the lower extremity of the valve-screw P a shoulder is formed, against which a short lever *w*, called the *trigger*, is constantly pressed by the spring *x*, so that when the rod P is depressed by the action of the lever O, it is arrested by the trigger and retained in that position until the blow has been struck. This delicate and most important part of the mechanism is very carefully constructed, the point of the trigger, and the shoulder against which it acts, being formed of steel, and hardened to resist wear.

To release the valve-screw from the trigger, and so permit the return of the valve into the position requisite for effecting a fresh stroke, the following mechanism has been adopted: on the front of the hammer-block, Figs. 2244 and 2248, a lever X, called the *latch-lever*, is fitted to work freely on a pin passing through the body of the hammer-block. That portion of the latch-lever which is most remote from the valve-geer is considerably heavier than the opposite end, and is constantly pressed upwards by means of a spring. The lighter end is brought into contact with a long bar *s s*, called the *parallel bar*, the extremities of which are suspended upon two small bell-cranks *t t*, whose other arms are connected by means of a slender rod *u*, Fig 2247, forming a species of parallel motion, for the purpose of adapting this geer to come into efficient operation, at whatever point in the range of the hammer its blow may be arrested. A small connecting-rod *v*, between the lower bell-crank and a short lever on the axis of the trigger *w*, completes this part of the mechanism.

The action of this geer is of a very peculiar nature, and is admirably adapted to fulfil the object intended. At the instant the hammer gives a blow to the work upon the anvil, the effect of the concussion is to cause the momentum of the heavy end of the lever X to overcome the upward pressure of the spring, and thereby to protrude its opposite end against the edge of the parallel bar *s*, which motion, though but slight in amount, is yet adequate, through the arrangements above described, to throw back the trigger from contact with the valve-screw, and leave the latter free to obey the impulse of the steam-spring in the readjustment of the valve into its original position.

These various movements, which have taken so long to describe, are all performed in less than half a second, and consequently the action of the hammer is proportionally rapid.

The construction of the self-acting geer is so arranged as to admit of advantage being taken, when circumstances render it desirable, of the very action to obviate which the trigger *w* is introduced. When it is desired to strike a gentle blow, such as is frequently required during particular stages in the progress of a piece of work, it is not requisite, for this purpose, to change the position of the valve-lever O. All that has to be done is to hold back the point of the trigger *w*, by its handle *y*; this permits the valve to reopen and let the steam in under the piston L, at the instant the tappet N has fallen away from contact with the lever O. The effect of this is, that a quantity of steam is admitted into the cylinder under the piston, which serves as a cushion, by which the violent fall of the hammer is arrested, and its momentum modified to any extent, or at the pleasure of the person in charge of the handles. The handle *z*, is for the purpose of placing the steam-valve also under his control, and, for his further convenience in the management of the hammer, a platform Y and hand-rail Z are erected against the framing of the machine.

A modification of the frame of this machine has been made at the Washington Navy Yard, one support only being used, by which means access is had to the anvil on all sides except that occupied by the support.

HAMMER, *Tilt or Trip*. See Tilting.

HARVESTER. An agricultural machine for reaping and gathering in grain, much used in the western country. There are many forms of them, known in this part of the country as Reapers, which see.

HAT-MAKING embraces two distinct kinds of manufacture, felted and covered hats; the covering of the latter being sometimes silk, and at other times cotton.

Felted hats comprehend two classes, differing chiefly in the materials used in making, the process being nearly identical. The lower class is marked by inferior ingredients, unmixed with beaver, and embraces *wool*, *plated*, and *short-nap* hats.

Wool hats are made entirely of coarse native wool and hair stiffened with glue. *Plates* have a *nap* or pile rather finer than their body, and are sometimes *water-proof* stiffened. *Short naps* are distinguished from plates by additional kinds of wool, viz. hare's back, seal, neuter, musquash, (Muscovy cat,) and are all water-proof stiffened.

The second class may be said to comprehend two orders, called stuff and beaver hats. The first includes mottled and stuff bodies. The latter term is not used generally, as all *stuffs* are understood to be of this sort when *mottled* is not expressed. *Mottled bodies* are made chiefly of fine wool, and inferior rabbit down or coney wool. *Stuff bodies* consist of the best hare, Saxony, and red wools, mixed with Cashmere hair and silk. *Stuff hats* are *napped*, that is, covered with pile of mixed seal, neuter, hare-back, inferior beaver, and musquash. *Beaver hats* are, or ought to be, napped with beaver only; the lower priced qualities with *brown wooms* taken from the back; the more valuable kinds with *cheek* and *white wooms*, being the finest parts of the fur found on the belly and cheeks of the beaver.

The apparatus and terms used in making felted hats, which it is necessary to describe briefly, are the bow, basket, hurdle, battery, and planks.

The *bow* is about six feet long, usually made of ash, thick enough not to be elastic. The handle is called the *stang*. The *bow-string* is a strong catgut cord tensely fastened.

The *hurdle* is a fixed bench, with three enclosing sides, to prevent the stuff being flittered off in bowing.

The *basket* is of light wicker-work, about twenty by twenty-two inches in size.

The *battery* consists of the kettle and the planks, which are inclined planes, usually eight in number, one only being appropriated to each workman. The half of each plank next the kettle is lead, the upper half is mahogany.

The first process in hat-making is *bowing* the stuff or furs, which are weighed out to a proportionate scale, and laid on the hurdle, immediately under the bow, which is suspended by a pulley. The bow is held firmly with the left hand, rather towards the *breech-end*, not edgewise, but on its side, with the string in contact with the stuff, the clotted and adherent portions of which are separated into single fibres, and attain a loose, flocky, mixed condition by the continued vibration of the bow-string, caused by a very rapid succession of touches with the bow-stick. It is then divided as nearly as possible, and one-half laid aside, whilst the other is again bowed. In this second operation, partly by the bowing, but chiefly by the *gathering*, or patting use of the basket, the stuff is loosely matted into a conical figure, about fifty by thirty-six inches, called a *bat*. In this formation care is taken to work about two-thirds of the wools down towards what is intended for the brim, which being effected, greater density is induced by gentle pressure with the basket. It is then covered with a wettish linen cloth, upon which is laid the *hardening skin*, a piece of dry half tanned horse-hide. On this the workman presses or bakes for seven or eight minutes, until the stuff shall have adhered closely to the damp cloth, in which it is then doubled up, freely pressed with the hand, and laid aside. By this process, called basoning, (from a metal plate or *bason*, used for like purposes in making *wool* hats,) the bat has become compactly felted and thinned towards the sides and point. The other half of the flocked stuff is next subjected to precisely the same proceedings, after which, a cone-shaped slip of stiff paper is laid on its surface, and the sides of the bat folded over its edges to its form and size. It is then laid paper side downward upon the first bat, which is now replaced on the hurdle, and its edges transversely doubled over the introverted side lays of the second bat, thus giving equal thickness to the whole *body*. In this condition it is reintroduced between folds of damp linen cloth, and again hardened, so as to unite both halves, the knitting together of which is quickly effected. The paper is now withdrawn, and the body being folded into three plies, is removed to the plank or battery-room.

In the battery the *liquor* is scalding heat, composed of pure soft water, with about half a gill of oil of vitriol as an astringent. Herein the body is imbrued, and withdrawn to the plank to partly cool and drain, when it is unfolded, rolled gently with a pin tapering towards the ends like a liquor horse, turned, and worked with in every direction, to toughen, shrink, and at the same time prevent adhesion of its sides. *Stopping* or thickening the thin spots which now appear on looking through the body, is carefully performed, by additional stuff daubed on by successive supplies of the hot liquor from a brush frequently dipped into the kettle, until the body be shrunk sufficiently, (about one-half,) and thoroughly equalized. When quite dried, *stiffening* is performed with a brush dipped into a glutinous pulpy composition, and rubbed into the body; the surface intended for the inside having much more imposed than the outer, while the brim is made to absorb many times the quantity applied to any other part. This viscous matter contains *proofing*, or those ingredients which render the hat waterproof.

On being again dried, the body is ready to be *covered*, and is once more taken to the battery. The first cover of beaver or napping, which has been previously *bowed*, is equally strewed on the body, and patted upon with the brush charged with the hot liquor, until incorporated; the *cut* ends only being the points which naturally intrude. Here the body is put into a coarse hair-cloth dipped and rolled in the hot liquor, until the beaver is quite worked in. This is called *rolling off*, or ruffing. A stripe for the brim round the edge of the inside, is treated in like manner, and is thus prepared for the second cover, which is applied and inworked in like manner; the rolling, &c., being continued until the whole has become incorporated, and a clean, regular, close, and well-felted *hood* is the result. The dry hood, after having the nap beat up and freed, is clipped to the length which may be thought best, by means of common shears. A clipping machine, invented nearly four years ago in Scotland, is now very generally preferred, and doubtless will soon everywhere supersede the ordinary process; much greater regularity, speed, and certainty being secured by it. When the nap is thus disposed of, the hood is soaked in the battery kettle, and then *drawn down* on a block to the size and shape wanted, firmly tied at the bottom with a cord, around which the brim is left in a frilled condition.

Dyeing is the next step. A *suit*, or six dozen, are put into the dye-kettle at a time, all on the crown-blocks already mentioned, and allowed to remain three-quarters of an hour in the liquor, which is kept as near as possible one degree below the boiling point. These being taken out and set in the yard to cool, another suit is introduced for a like period, and the various suits are so treated at least twelve times in successive order. Each of the first four introgressions of every suit is accompanied by about seven pounds of copperas, and two pounds of verdigris. The body is then washed and brushed out in changes of hot water, until no coloring can be recognized in it. When thus thoroughly cleansed, it is steamed on a block shaped as the hat is wished to be when complete; and in the finishing shop by heavy (21-pound) heated irons and moisture, the frilled brim is shrunk until rendered quite level, the nap gently raised all over with a fine wire card, and brushed and ironed smooth in the uniform directions. The tip, a thin lath-sheet, is then fitted and stuck to the inside of the crown, and *robbined* or secured all round the edges by stripes of prepared paper. When thus *got down*, it is sent to the *picker*, who, with tweezers, extracts the *kemps*, or "gray hairs," which are a few of those thick fibres peculiar to the fur of amphibious animals, that have escaped the search of the machine used in blowing the beaver, so as to separate them from its fine parts. This being carefully accomplished, it is transferred to the finisher, who, with a plush cushion, a brush, and hot iron, imparts to it that bright sleeky lustre. The *shaper* then rounds the brim with a knife and notched segment to the breadth wanted; and shapes it in varied styles by means of a hot iron and damp, with about a foot length of rope, over which the *curl* is laid. The *trimming* is next done, when the *tipper-off* corrects the twists, smooths the ruffled nap caused by trimming, and *papers* it up with tissue and cartridge, which completes it for the retailer.

Silk hats are made upon bodies of wool, stuff, willow, straw, and Leghorn plait, and cambric and woollen cloth, although chiefly on felted wool bodies, which are dipped in glue size, wrung out, blocked, and dried. The *tip* is then fitted and robbined, when a flour-box, charged with powdered shell-lac and rosin in like quantities, is used to strew equally its grainy mixture on the external surface of the *shell*, so called from being the frame-work. This is burned in by hot irons, first on the top, which passes through to the lath-tip within; then on the upper brim, the sides, and, finally, the under brim. When this is hardened it is coated with thick ordinary flour-paste, which is dried, and the shell again blocked and smoothed; then once more glue-sized outside, dried, and varnished, which prepares it for *covering*. The shag for the sides is cut across the web, in a ratio of obliquity increased by inferiority. This cross part is sown to a circular piece for the crown, whilst the brims are singly patched together. These preparations being completed, the *top-side* or upper brim is first stuck, then the crown, next the sides, and, finally, the under brim. *Sticking* is effected simply by the heat of the iron passing through the covering and melting the varnished surface. In the finish of this manufacture, the most particular part is the *side-seam*, which is disposed of thus: The selvidge end is cut perpendicularly from top to brim, by a sharpened pallet-knife, the nap having been previously brushed clear off its edge. The other selvidge end is then stuck and cut with the utmost nicety, in close parallel with the other. It is then finished very much in the same manner as a beaver hat.

The above-mentioned method of making hat-bodies is now mostly superseded in this part of the country by the adoption of machinery, the manual labor being confined to the getting up the hat, and is a distinct business; the hatter for the most part purchasing his hat-bodies far cheaper than he can make them.

The machinery is very simple. The fur or hair of which the felt is to be made, after being cleaned and lightly beat up, by passing through a kind of winnowing machine, is delivered to a boy, who spreads the fur very lightly and in small quantities on an endless web before him, which, passing between rollers, carries the fur into the body of the machine, where it encounters a cylindrical brush in rapid motion, which separates the hair or fur completely, throwing it towards a contracted opening in the sides of the cylinder case. This opening, about an inch wide at top and nearly three inches at bottom, is in height equal to the cone of the hat-body. Immediately in front, and close to this opening is placed a perforated copper cone, the perforations so small, and in such number, as almost to render the surface of the cone, from base to apex, a wire-gauze surface. This cone is open at the bottom and placed on an opening equal to its base, which opening is in communication with a fan or blast, so arranged as to exhaust the interior, or "suck," so to speak, the air through the meshes of the copper cone. The hair or fur in its divided state, thrown towards this opening in the cylinder case, is brought under the influence of the powerful draught towards and through the cone; the latter at the same time slowly revolving on its axis, exposes all its sides to the opening, and the hair is driven against it with such force as to adhere for the time, and receive and retain on all sides, as it revolves, the fine particles of hair as they are drawn from the cone. In the space of half a minute a dry hat-body is formed on the copper cone; this is immediately enveloped by a wetted felt, and the whole immediately removed, and its place supplied by a fresh copper while the first is being stripped of its now wet felt. The whole operation is performed with wonderful dispatch, the hat-body resulting from it being exceedingly light and uniform in texture, and requires but little labor before it is in condition to be transferred to the hands of the hatter for working up. In this manner any form of felt may be made. The opening in the cylinder case being of flexible metal, admits of adjustment to the wants of the particular form of the felt to be constructed. The application of this principle is universal in the manufacture of felt.

HEART-WHEEL. A cam for converting a uniform circular into a uniform rectilinear motion.

HEAT. Heat in the ordinary application of the word, implies the sensation experienced upon touching a body hotter or of a higher temperature. *Caloric*, the principle or cause of the sensation of heat. On touching a hot body, caloric passes from it, and excites the feeling of warmth: when we touch a body having a lower temperature than our hand, caloric passes from the hand to it, and thus arises the sensation of cold.

Caloric is usually treated of as if it were a material substance; but, like light and electricity, its true nature has yet to be determined.

Caloric passes through different bodies with different degrees of velocity. This has led to the division of bodies into *conductors* and *non-conductors* of caloric: the former includes such bodies as metals which allow caloric to pass freely through their substance, and the latter comprises those that do not give an easy passage to it, such as stones, glass, wood, charcoal, &c.

Table of the relative Conducting Power of different Bodies.

Gold	1000	Platinum	981
Silver	973	Copper	898
Iron	374	Zinc	363
Tin	304	Lead	180
Marble	24	Porcelain	12·2
Fire-brick	11	Fire-clay	11·4

With Water as the Standard.

Water	10	Elm	32
Pine	39	Ash	31
Lime	39	Apple	28
Oak	33	Ebony	22

Relative Conducting Power of different Substances compared with each other.

Hares' fur	1·315	Cotton	1·046
Eider-down	1·305	Lint	1·032
Beavers' fur	1·296	Charcoal	·937
Raw silk	1·284	Ashes (wood)	·927
Wool	1·118	Sewing-silk	·917
Lamp-black	1·117	Air	·576

Relative Conducting Power of Fluids.

Mercury	1·000	Proof spirit	·312
Water	·357	Alcohol (pure)	·232

Radiation of caloric.—When heated bodies are exposed to the air, they lose portions of their heat, by projection in right lines into space, from all parts of their surface.

Bodies which radiate heat best, absorb it best.

Radiation is affected by the nature of the surface of the body; thus, black and rough surfaces radiate and absorb more heat than light and polished surfaces.

Table of the Radiating Power of different Bodies.

Water	100	Blackened tin	100
Lamp-black	100	Clean "	12
Writing-paper	100	Scraped "	16
Glass	90	Ice	85
India-ink	88	Mercury	20
Bright lead	19	Polished iron	15
Silver	12	Copper	12

Reflection of caloric differs from radiation, as the caloric is in this case reflected from the surface without entering the substance of the body: hence the body which radiates, and consequently absorbs most caloric, reflects the least, and *vice versâ*.

Latent caloric is that which is insensible to the touch, or incapable of being detected by the thermometer. The quantity of heat necessary to enable ice to assume the fluid state is equal to that which would raise the temperature of the same weight of water 140°; and an equal quantity of heat is set free from water when it assumes the solid form.

If 5½ lbs. of water, at the temperature of 32°, be placed in a vessel communicating with another one (in which water is kept constantly boiling at the temperature of 212°,) until the former reaches this temperature of the latter quantity, then let it be weighed, and it will be found to weigh 6½ lbs., showing that 1 lb. of water has been received in the form of steam through the communication, and reconverted into water by the lower temperature in the vessel.

Now this pound of water, received in the form of steam, had, when in that form, a temperature of 212°. It is now converted into the liquid form, and still retains the same temperature of 212°, but it has caused 5½ lbs. of water to rise from the temperature of 32° to 212°, and this without losing any temperature of itself. It follows, then, that in returning to the liquid state, it has parted with 5½ times the number of degrees of temperature between 32° and 212°, which are equal 180°, and 180° × 5½ = 990°. Now this heat was combined with the steam; but as it was then not sensible to a thermometer, it was called *Latent.*

It is manifest, then, that a pound of water, in passing from a liquid at 212° to steam at 212°, receives as much heat as would be sufficient to raise it through 990 thermometric degrees, if that heat, instead of becoming latent, had been *sensible.*

The sum of the sensible and latent heat of steam is always the same at any one temperature; thus, 990° + 212° = 1202°.

If to a pound of newly fallen snow were added a pound of water at 172°, the snow would be melted, and 32° will be the resulting temperature, 138° of heat becoming latent in the melted snow.

Latent Heat of various Substances.

Fluids.		Vapors.	
Ice	140°	Steam	990°
Sulphur	144	Vinegar	875
Lead	162	Ammonia	860
Beeswax	175	Alcohol	442
Zinc	493	Ether	302

Sensible caloric is free and uncombined, passing from one substance to another, affecting the senses in its passage, determining the height of the thermometer, and giving rise to all the results which are attributed to this active principle. See Steam.

It is frequently desirable to convert the degrees of heat, as indicated by one thermometer, into its equivalent as denoted by another. The following rules will serve this purpose for the thermometers in general use:—

To reduce the degrees of a Fahrenheit thermometer to those of Reaumur and of the centigrade; the zero of the Reaumur scale being at the freezing point, and 80° at the boiling point, whilst the zero of the centigrade is at the freezing point, and 100° at the boiling. See Thermometer.

Fahrenheit to Reaumur.—Rule.—Multiply the number of degrees above or below the freezing point by 4, and divide by 9.

Thus, 212° — 32 = 180 × 4 = 720 ÷ 9 = 80, *Ans.*
+ 24° — 32 = 8 × 4 = 32 ÷ 9 = 3·5, *Ans.*

or 3·5 below zero.

Fahrenheit to centigrade.—Rule.—Multiply the number of degrees above or below the freezing point by 5, and divide by 9.

Thus, 212° — 32 = 180 × 5 = 900 ÷ 9 = 100, *Ans.*

Or multiply the degrees of Fahrenheit by ·444 for reducing them to Reaumur, and by ·555 for reducing them to centigrade.

Medium heat of the globe is placed at 50°; at the torrid zone, 75°; at moderate climates, 50°; near the polar regions, 36°.

The extremes of *natural heat* are from 70° to 120°; of *artificial heat,* from 91° to 36,000°.

Evaporation produces cold, because caloric must be absorbed in the formation of vapor, a large quantity of it passing from a sensible to a latent state, the capacity for heat of the vapor formed being greater than that of the fluid from which it proceeds.

Evaporation proceeds only from the surface of the fluids, and therefore, *other things equal,* must depend upon the extent of surface exposed.

When a liquid is covered by a stratum of dry air, evaporation is rapid, even when the temperature is low.

Table of Effects upon Bodies by Heat.

	Fahrenheit.		Fahrenheit.
Cast-iron, thoroughly smelted	2754°	Lead, melts	594°
Fine gold, melts	1983	Bismuth, melts	476
Fine silver, melts	1850	Tin, melts	421
Copper, melts	2160	Tin and bismuth, equal parts, melt	283
Brass, melts	1900	Tin 3 parts, bismuth 5, and lead 2, melt	212
Red heat, visible by day	1077	Alcohol, boils	174
Iron, red-hot in twilight	884	Ether, boils	98
Common fire	790	Human blood (heat of)	98
Iron, bright-red in the dark	752	Strong wines, freeze	20
Zinc, melts	740	Brandy, freezes	7
Quicksilver, boils	630	Mercury, melts	— 39
Linseed oil boils	600		

Wedgewood's zero is 1077° of Fahrenheit, and each of his degrees is equal to 130° of Fahrenheit.

Expansion of Solids.

At 212°, the length of the bar at 32° considered as 1·0000000.

Glass	·0008545	Gold	·0014950
Platina	·0009542	Copper	·0017450
Cast-iron	·0011112	Brass	·0019062
Steel	·0011899	Silver	·0020100
Marble	·0011041	Fire brick	·0004928
Forged iron	·0012575	Lead	·0028436
Granite	·0007894	Zinc	·0029420

To find the expansion in surface or in volume, it must be remembered that each dimension of a solid experiences a similar proportional expansion.

Table of the Expansion of Air by Heat.—By Mr. Dalton.

Fahrenheit.		Fahrenheit.		Fahrenheit.	
32°	1000	50°	1043	80°	1110
33	1002	55	1055	85	1121
34	1004	60	1066	90	1132
35	1107	65	1077	100	1152
40	1021	70	1089	200	1354
45	1032	75	1099	212	1376

Melting Point of Alloys.

Lead 2 parts,	tin 3 parts,	bismuth 5 parts,		melts at 212°
" 1 "	" 4 "	" 5 "		melts at 246
	" 1 "	" 1 "		melts at 286
	" 2 "	" 1 "		melts at 336
" 2 "	" 3 "			melts at 334
	" 8 "	" 1 "		melts at 392
" 2 "	" 1 "		common solder,	melts at 475
" 1 "	" 2 "		soft solder,	melts at 360

Boiling points.—The boiling point of water, from 27 to 31 inches of the mercurial column, varies 1·65° for every inch, being at 30 inches 212°; and on this variation is founded the apparatus for determining altitudes.

Comparative Heat from various Fuels.

1 lb. of tolerably good coal will raise the temperature of 60 lbs. of water from 32° to 212°.
1 lb. of kiln or perfectly dried wood will effect the same on 35 lbs.
1 lb. of wood simply dried in the air " " 26 lbs.
1 lb. charcoal " " 79 lbs.

Turf of good quality yields as much heat for equal weights as wood, and the heat it gives out by radiation whilst burning has been considered even greater than that of wood.

For the various methods of applying heat to the warming of buildings, see article Warming.

HEDDLES, *Machine for making Weavers'.* This machine is the invention of Mr. Kassimir Vogel, of Lowell, Massachusetts.

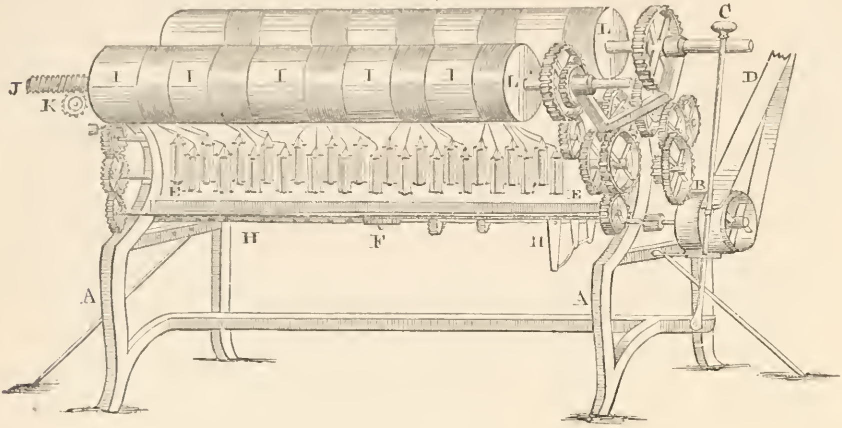
The object of the machine is to make weavers' heddles from the thread, casting the loop by braiding instead of knotting, and performing triple the amount of work, and better than can be done by hand. A patent is also secured for the peculiar eye of the heddle, so that both machine and its results are protected.

Description.—Fig. 2251 is a perspective view, and shows gangs of different heddles winding on the beams. A A is the iron framing. B are the driving and slack pulleys. C is the lever to geer and ungeer. E E are the bobbins, with the thread to make the heddles. There is a small shaft under the bed of E, which, by small cog-wheels on the same, operate and revolve the bobbins by geering into F. H are the heddles after the eye is formed, winding up on the beams L L. The gang of wheels at the left are for the purpose of connecting the shafts of the beams to be driven by the main shaft below. The number of eyes to the foot in the heddles can be increased or diminished by the geering of these small wheels. K is a small bearing for the shaft of L, and J is the shaft with a screw cut on part of it. This is for winding the heddle gradually along the beam, and as K is a grooved and wormed faced pulley driven slowly by the small gang of wheels at the right, the shaft J is wormed slowly through its bearings, carrying the beam to let the heddles wind one after another on the same. The heddles are formed of a double cord, which is twisted by the bobbins revolving, and the eyes or loops are formed by the bobbins being interlocked, braiding the two strands at the two points which form the eye of the heddles. The section views will explain the operations better in detail.

As the same letters indicate like parts on all the following engravings, we shall describe them collectively. Fig. 2252 is a side elevation. Fig. 2253 is a top view of the revolving tables and spindles. Fig. 2254 is an end elevation. Fig. 2255 is a view of the under side of the machine, showing the geering by which the tables that carry the spindles are made to revolve.

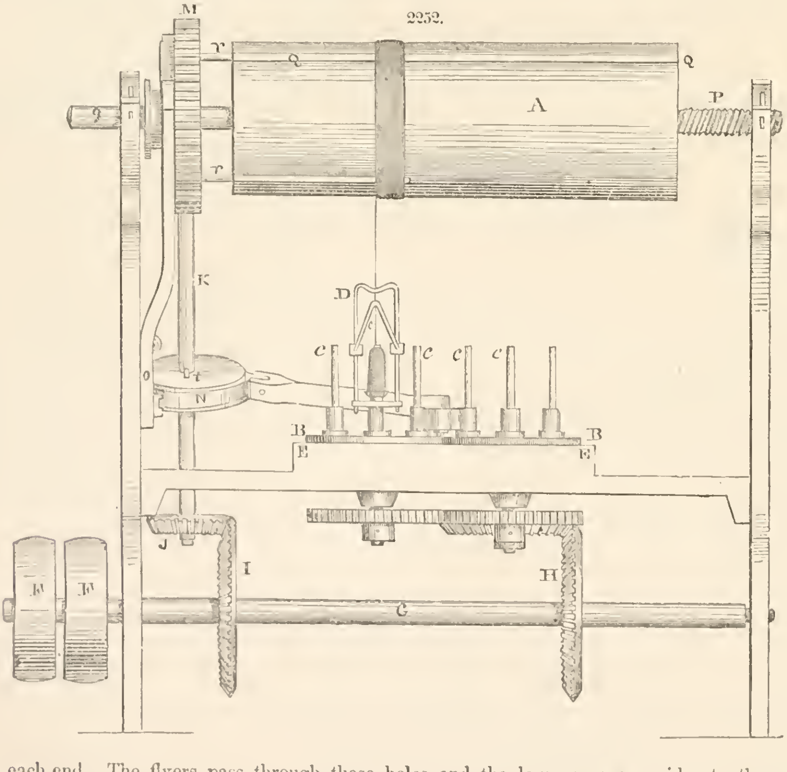
A is the heddle-beam. B B B B are revolving spool-frames or tables. C represents the spool-spindles. *a* are slots in the spool-tables. Each table has six slots or spindle recesses, but only three are occupied at once with the spindles. As the tables revolve, three slots are occupied with spindles and three are empty alternately, and an occupied slot in one is brought opposite to an empty recess in its

2251.



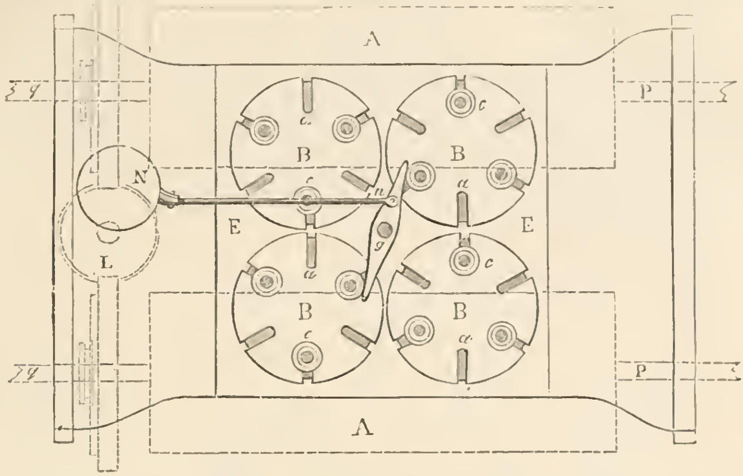
fellow-table, as seen in Fig. 2253. The tables B B constitute one pair, and the tables B 2, B 3, another, forming two distinct harness, one on each side on two beams, but driven by the same geering. The yarn is put on the spindles C, and passes through a hole in the top of the flyers D, or over a depression, Fig. 2252, to hold it in its place, and then passes under *c*, a recurved wire, that has a perforated weight

2252.



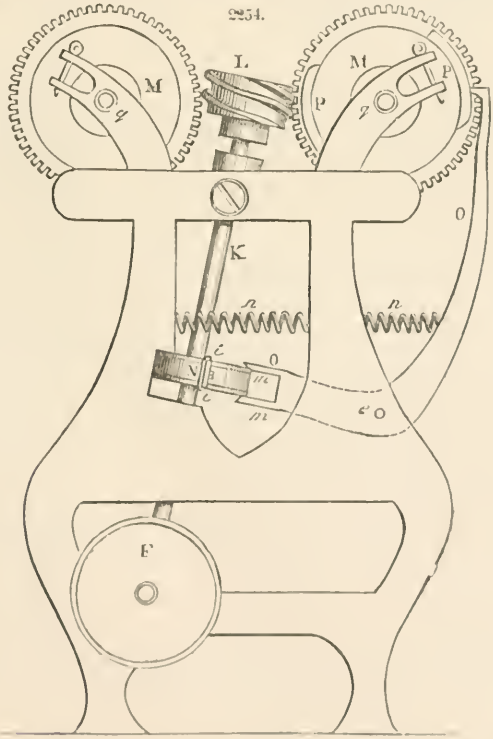
a at each end. The flyers pass through these holes, and the legs serve as guides to the weights. This is to take up the slack of the yarn. The spindles have each a groove in their lower parts, adapted to slide into the recesses of the tables when the recesses coincide. The platform E E has circular cavities for the lower ends of the spindles. F F, Fig. 2252, are fast and loose pulleys to drive the shaft G. A bevel-wheel H, on G, gives motion to the revolving spool-tables by toothed wheels, as seen at Fig. 2255. The bevel-wheel I, Fig. 2252, gives motion to the heddle-beams by geering into J, on the shaft K. This shaft carries a worm-wheel, which geers into M to drive A. N is an eccentric on K

2253.



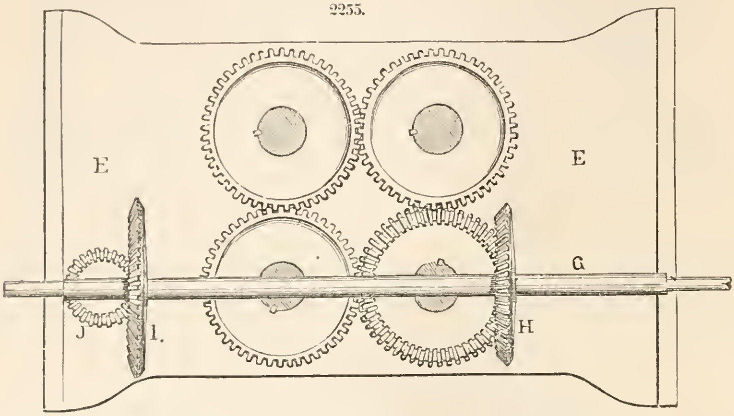
to vibrate *g*, a shipper, which shifts the spindles from one table to another; the opposite ends of *g* operate on two pairs of tables. A connecting-rod with N vibrates the shippers. N is connected with K, and turns with it by clutch-pins, and when these are not engaged the shafts turn without N. *i i*, Fig. 2254, is a pin that passes through N, projecting out above and below, nearly in contact with K. There

2254.



are two clutch-pins on K, either of which may be brought in contact with *i*, as the eccentric wheel is made to slide up and down on the shaft. O, Figs. 2252 and 2254, is a forked lever with its fulcrum at *c*. Its fork ends *m m* embrace N, the eccentric, and raise and lower it at proper times. *n n* is a spiral spring attached to the forked lever, serving to draw it inwards to depress the eccentric and make it clutch with the lever clutch-pin. On the wheel M are cams or lifting pieces *p p*, which, when they come in contact with the end of O, force it out and raise N, the eccentric, so as to engage with the upper clutch-pin at the required time, as will be understood by Fig. 2254. The axis of A is P, a screw Fig. 2252, tapped into the frame of the machine and moves A endwise as it revolves, to wind the heddles, as they are made spirally on the beams. *q* is the smooth axis of A, on which the beam slides, moved by the screw on the guide-rods *r r*. Q Q are rods that may be inserted in grooves in A. The semi-diameter of A must be of the length of the heddles. After the number of heddles for a harness have been made, grooved pieces may be slipped over Q and glued upon them to embrace the twisted strands, or any other mode may be adopted. The shipper connecting-rod *h*, (which looks like an *n*,) Figs. 2252 and 2253, has a hinge-joint *t*, to allow it to be lifted from the shipper *g*. The small bevel-wheel J, on the shaft K, is one-third of the diameter of the driving-wheels, when there are three spindles on the table, and therefore makes the changes of the spindles in the recesses in one revolution of the revolving spool-tables. If there were four spindles in the table, the wheel J would be one-fourth the diameter of the driving-wheel, &c.

2255.



To explain its operation, Fig. 2251 exhibits a different arrangement of mechanical parts from the section views, but they are just the mechanical equivalents to accomplish the same thing. Heddle or harness making is the formation of *eyes* by two *cords* being knotted together. These eyes must be formed at regular distances on the harness. This machine forms two cords by B B, revolving and twisting the yarn on the three spindles, one by each table revolving, the cord winding at the same time as it is twisted on the beam A. Now to form four eyes on the heddles every revolution of the beam, look at Fig. 2253. If the strands that make the two cords were interlocked at certain periods, eight times during the revolution of A, that four eyes would be formed by the strands of the two cords being thus at certain points braided into one another. This is the way this machine does its work, and this can be done by the forked lever in Fig. 2254 shifting the shipper, or by cams on the inside of the upper geer-wheel of Fig. 2251. To make the spindles in *c* interlock to braid the eyes. The cams or clutch operate the shipper *g*, so that instead of vibrating from side to side, as now seen in Fig. 2253, touching the spindles outside, it is (the shipper) stopped by the resting of the eccentric one-sixth of the revolution of the tables, and then it will be easily perceived that the shipper will take into the inside of the spindle *e* and throw it into the empty recess *a* of the other table, which coincides, thus interlocking the threads and braiding the two cords together into one, forming an eye of the heddle by braiding instead of knotting. It will be observed, too, that the clutch can be changed by cams, to operate the shipper, to make as large or as many eyes in a foot as may be desired; but the changing or passing of the spindles from one table to another must be performed by the shipper twice for one eye, according to the length of the eye, and they are not shifted again until A has revolved the distance wanted to form the base of a new eye for the harness.

HELIOTROPE *Reflecting Lantern*, used by Major J. D. Graham as meridian marks for great distances, in 1841, while tracing the due north line from the monument at the source of the river St. Croix.

The lantern was constructed by Messrs. Henry N. Hooper & Co. of Boston, under Maj. G.'s directions. It was similar in form to the Parabolic Reflector Lantern, sometimes used in light-houses, but much smaller, so as to be portable.

The burner was of the argand character, with a cylindrical wick, whose transverse section was half an inch in diameter, supplied with oil in the ordinary manner. This was placed in the focus of a parabolic reflector, or paraboloid, of sheet-copper, lined inside with silver about 1-20th of an inch in thickness, polished very smooth and bright. The dimensions were as follows:

	Inches.
Diameter of the base of frustrum of reflector	16·
Distance of vertex from base	3·75
Distance of focus from vertex	2·25
Diameter of cylindrical burner	·50
Diameter of a larger burner which was never used, but which, by an adapting piece, could be easily substituted	1·25

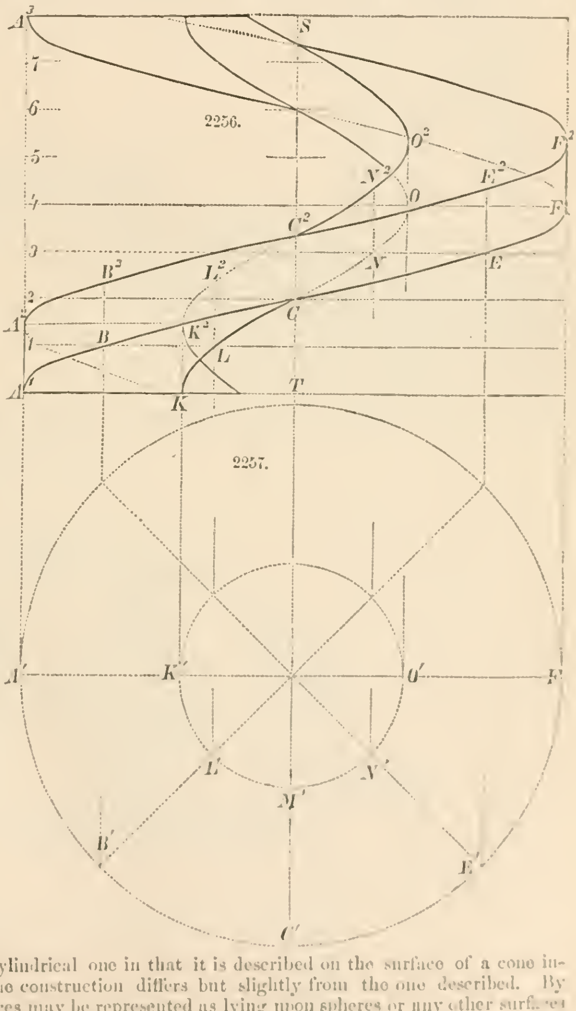
The instrument answered the purpose for which it was intended admirably well, and was of great use in tracing the due north line. While it occupied the station at Park's Hill, 15 feet above the surface of the ground, or 828 feet above the sea, in the latter part of September and early part of October, 1841, the light from it was distinctly seen with the naked eye at night, when the weather was clear from Blue Hill, whose summit, where crossed by the meridian line, is 1071 feet above the sea, the intervening country averaging about 500 feet above the sea, and the stations being 36 miles apart. The light appeared to the naked eye, at that distance, as bright, and of about the same magnitude, as the planet Venus.

The wick employed by Major G. was considerably smaller than that usually made, even for parlor lamps; and to this cause is attributed, in a great measure, the perfection with which the parallel rays were transmitted from the reflecting parabolic surface, so as to make them visible at so great a distance. Though a greater quantity of light is generated by a larger wick, the portion of rays reflected in a direction parallel to the axis, and which alone come to the eye, is the smaller as the flame transcends the focal limit. The size of wick most advantageous for use may easily be determined by experiment. The smaller is its transvere section, provided it is only large enough to escape being choked up by the charred particles, even one-third, or perhaps less, the further the light would be visible.

The heliotrope, which is employed in the day time, was made by order of Mr. Hassler, at the instrument shop of the coast survey office. It was a rectangular parallelogram of good German plate-glass, 1 4-5ths by 1 1-5th inch in size, giving an area of reflecting surface of $2\frac{16}{100}$ square inches. This also was seen at the distance of 36 miles.

HELIX. A spiral curve. The cylindrical or screw helix is the curve described upon the surface of a cylinder by a point revolving round it, and at the same time moving parallel to its axis by a certain invariable distance during each revolution.

Figs. 2256 and 2257, to construct the helical curve described by the point A upon a cylinder projected horizontally in the circle A′ C′ F′, the pitch being represented by the line A′ A³. Divide the pitch A′ A³ into any number of equal parts, say eight; and through each point of division, 1, 2, 3, &c., draw straight lines parallel to the ground line. Then divide the circumference A′ C′ F′ into the same number of parts; the points of division B′, C′, E′, F′, &c., will be the horizontal projections of the different positions of the given point during its motion round the cylinder. Thus, when the point is at B′ in the plan, its vertical projection will be the point of intersection B of the perpendicular drawn through B′ and the horizontal drawn through the first point of division. Also when the point arrives at C′ in the plan, its vertical projection is the point C, where the perpendicular drawn from C′ cuts the horizontal passing through the second point of division, and so on for all the remaining points. The curve A B C F A³ drawn through all the points thus obtained, is the helix required.



A helical surface is generated by the revolution of a straight line round the axis of a cylinder; its outer end moving in a helix, and the line itself forming with the axis a constant and invariable angle.

The conical helix differs from the cylindrical one in that it is described on the surface of a cone instead of on that of a cylinder; but the construction differs but slightly from the one described. By following out the same principles, helices may be represented as lying upon spheres or any other surfaces of revolution. In the arts are to be found numerous practical applications of the helical curve, as wood and machine screws, geers and staircases.

HEPTAGON. A figure having seven equal angles and sides.

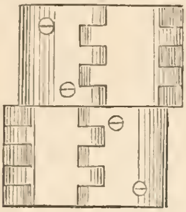
HEXAEDRON, *the Cube*. One of the five regular or Platonic bodies, and so called from its having six faces. The square of the side or edge of a hexaedron is one-third of the square of the diameter of the circumscribing sphere; and hence the diameter of a sphere is to the side of its inscribed hexaedron as $\sqrt{3}$ to 1.

HEXAGON. A figure of six sides and angles. Angle at the centre = 60°; angle at the circumference = 120°; area to side, 1 = 2·5980762; area to any side, (S) = $3^2 \times 2·5980762$.

HIGH-PRESSURE ENGINE. The simplest form of the steam engine is the non-condensing, or high-pressure engine. In this engine the condensing apparatus is dispensed with, and steam being admitted into the cylinder, at a high temperature, and consequently high pressure, and having acted on the piston, is allowed to escape into the open air. A part of the force of the steam is of course expended in overcoming the pressure of the atmosphere, and it is only that portion of the steam's elastic force that exceeds 15 pounds to the square inch that is effective in moving the engine. The surplus pressure is usually from 30 to 40 pounds on the circular inch. See STATIONARY ENGINES, AND ENGINES VARIETIES OF.

HINGE, TAFT'S *double-jointed hinge and door-spring*, Figs. 2260 and 2261. This hinge is so constructed that it admits of the opening of the door, or gate, in either direction, and in combination with it is a spring connected by a chain with the casing, whereby the door is held close to it as well as made to close itself. Each hinge employed in this improvement may consist of four or more pieces, two of which are

2260.



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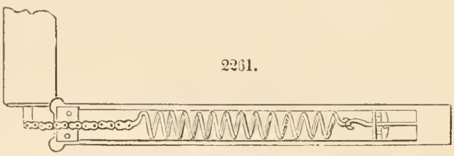


side plates with knuckles attached thereto. The connecting plates with their knuckles are connected by pivots to those of the plates, and each connects the plate to the other, so that when the hinge is opened in the opposite direction the connecting plate changes sides and folds upon the plate, so that the hinge presents the same appearance in either position.

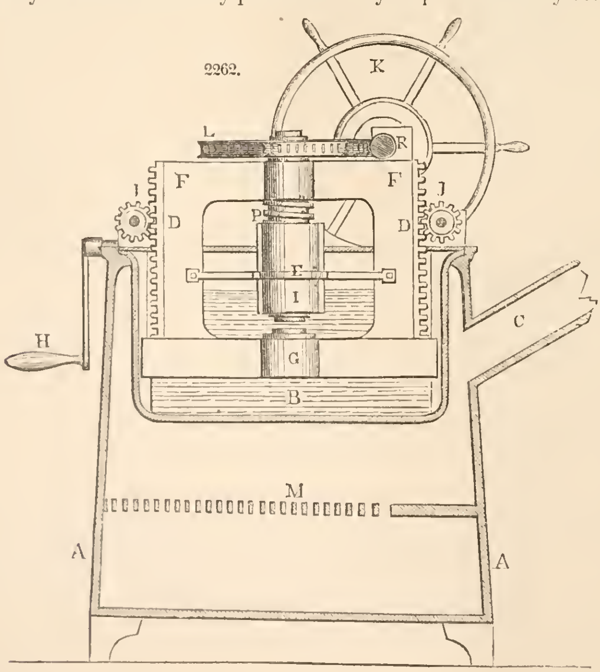
HINGES. The joints on which doors, gates, &c., turn.

HIP. The external angle formed by the meeting of the sloping sides of roofs which have their wall-plates running in different directions.

HORN. See ANIMAL MATTER USED IN THE ARTS.

HORN, *machine for pressing*. Horn, tortoise-shell, and many other animal substances, are capable of being softened by heat and moulded by pressure into any shape and with any design in the sharpest

2262.



and most delicate relief. A screw press has usually been employed for this purpose, but the one represented by Fig. 2262, which is a section through its centre, is far superior.

A A is a box of cast-iron. B is a copper to contain the hot water, and M is a grate for the fire to heat the same. C is the smoke-pipe. F F G is the press, made of strong cast-iron, and capable of being drawn up and let down in the water at pleasure, by means of racks D D, at each side, actuated by pinions J J. The axles of these pinions cross the machine and have each a wheel at the end, moved by two arms, or screws cut upon the axis and turned by the handle H. The press is guided in the ascent or descent by grooves in the side of the boiler. When raised up out of the water, the moulds, with the horn or tortoise-shell between them, are put beneath the presser, and a severe pressure is produced by turning the wheel K. This wheel has an endless screw R upon its axis, which works the teeth of a large wheel L, fixed on the top of the screw P. The screw is received into an interior screw formed within the box or presser I, which is guided and prevented turning round by the cross-bar E, through which the presser is fitted; by this means, when the screw P is turned round by the wheel L and endless screw, the horn or tortoise-shell is pressed between the moulds; the press is then lowered again into the water of the boiler, in order to be still further softened by the boiling; but when the press is down in the boiler, the screw can be screwed tighter by turning the wheel K until the desired impression is obtained. By turning the handle H, the press is then raised up out of the boiler, and by turning back the wheel K the pressure is released and the moulds can be removed.

HORSE. *The power of a horse* when applied to draw loads, as well as when made the standard of comparison for determining the value of other powers, has been variously stated.

The relative strength of men and horses depends, of course, upon the manner in which their strength is applied. Thus, the worst way of applying the strength of a horse is to make him carry a weight up a steep hill, while the organization of the man fits him very well for that kind of labor. And three men, climbing up a steep hill, with each 100 lbs. on his shoulders, will proceed faster than most horses with 300 lbs.

It is highly useful to load the back of a drawing horse to a certain extent; though this, on a slight consideration, might be thought to augment unnecessarily the fatigue of the animal: but it must be recollected that the mass with which the horse is charged vertically is added in part to the effort which he makes in the direction of traction, and thus dispenses with the necessity of his inclining so much forward as he must otherwise do: and may, therefore, under this point of view, relieve the draught more than to compensate for the additional fatigue occasioned by the vertical pressure. Carmen, and wagoners in general, are well aware of this, and are commonly very careful to dispose of the load in such a manner that the shafts shall throw a due proportion of the weight on the back of the shaft horse.

The best disposition of the traces during the time a horse is drawing is to be perpendicular to the position of the collar upon his breast and shoulders: when the horse stands at ease, this position of the traces is rather inclined upwards from the direction of the road; but when he leans forward to draw the load, the traces should then become nearly parallel to the plane over which the carriage is to be drawn; or, if he be employed in drawing a sledge, or any thing without wheels, the inclination of the traces to the road should be about $18\frac{1}{2}°$, when the friction is one-third of the pressure.

When a horse is made to move in a circular path, as is often practised in mills and other machines moved by horses, it will be necessary to give the circles which the animal has to walk round the greatest diameter that will comport with the local and other conditions to which the motion must be subjected. It is obvious, indeed, that, since a rectilinear motion is the most easy for the horse, the less the line in which he moves is curved, with the greater facility he will walk over it, and the less he need recline from a vertical position: and besides this, with equal velocity the centrifugal force will be less in the greatest circle, which will proportionally diminish the friction of the cylindrical part of the trunnions, and the labor of moving the machine. And, further, the greater the diameter of the horse-walk, the nearer the chord of the circle in which the horse draws is to coincidence with the tangent, which is the most advantageous position of the line of traction. On these accounts it is that, although a horse *may* draw in a circular walk of 18 feet diameter, yet in general it is advisable that the diameter of such a walk should not be less than 25 or 30 feet; and in many instances 40 feet would be preferable to either.

It has been stated by Desaguliers and some others, that a horse employed daily in drawing nearly horizontally can move, during eight hours in the day, about 200 lbs. at the rate of $2\frac{1}{2}$ miles per hour, or $3\frac{2}{3}$ feet per second. If the weight be augmented to about 240 or 250 lbs., the horse cannot work more than six hours a day, and that with a less velocity. And, in both cases, if he carry some weight, he will draw better than if he carried none. M. Sauveur estimates the mean effort of a horse at 175 French, or 189 avoird. pounds, with a velocity of rather more than three feet per second. But all these are probably too high to be continued for eight hours, day after day. In another place Desaguliers states the mean work of a horse as equivalent to the raising a hogshead full of water (or 550 lbs.) 50 feet high in a minute. But Mr. Smeaton, to whose authority much is due, asserts, from a number of experiments, that the greatest effect is the raising 550 lbs. forty feet high in a minute. And, from some experiments made by the Society for the Encouragement of Arts, it was concluded, that a horse moving at the rate of three miles an hour can exert a force of 80 lbs. The proper estimate would be that which measures the weight that a horse would draw up out of a well; the animal acting by a horizontal line of traction turned into the vertical direction by a simple pulley, or roller, whose friction should be reduced as much as possible.

Tredgold has directed his attention to the subject of "*horse-power.*" His expression for the power of a horse is $250\,v\left(1-\frac{v}{\mathrm{v}}\right)$; and $\frac{250\,d\,v\left(1-\frac{v}{\mathrm{v}}\right)}{1+n}$ for the day's work in lbs. raised one mile; d being the hours which the horse works in a day, and the weight of the carriage to that of the load as n . 1 He also gives $\frac{14\cdot7}{\sqrt{d}}$, for the greatest speed in miles per hour, when the horse is unloaded.

He gives the following table of the comparison of duration of a horse's daily labor and maximum velocity unloaded:—

Duration of labor. Hours.	Maximum velocity unloaded in miles per hour.	Duration of labor. Hours.	Maximum velocity unloaded in miles per hour.
1	14·7	6	6·
2	10·4	7	5·5
3	8·5	8	5·2
4	7·3	9	4·9
5	6·6	10	4·6

Taking the hours of labor at 6 per diem, the utmost he would recommend, the maximum of useful effect he assigns at 125 lbs., moving at the rate of three miles per hour; and regarding the expense of carriage in that case as unity, then,

Miles per hour.	Proportional expense.	Moving force or traction.
2	1·125	166 lbs.
3	1·	125 "
3½	1·0285	104 "
4	1·125	83 "
4½	1·333	62½ "
5	1·8	41 "
5⅓	2·	36½ "

That is, the expense of carrying goods at 3 miles per hour being 1, the expense at 4½ miles per hour will be 1⅓; the expense being doubled when the speed is 5⅓ miles per hour.

Various estimates have been made of a horse's power by Desaguliers, Smeaton, and others; but the estimate now generally adopted as a standard for measuring the power of steam-engines, is that of Mr. Watt, whose computation is about the average of those given by the other writers. The measure of a horse's power, according to Mr. Watt, is, that he can raise a weight of 33,000 pounds to the height of one foot in a minute.

Horse-power, as the measure of the force of steam-engines.—It is by this nominal power that engines are usually bought and sold and always spoken of, unless when the contrary is expressly stated.

The following is Boulton and Watt's rule for determining the nominal horses' power.

Let D = the diameter of the cylinder in inches.

V = half the velocity of the piston in feet per minute.

Then $\frac{(D^2 - 4\,D)\,V}{2650}$ = the number of nominal horses' power.

But in order to determine V before the engine has been made, Boulton and Watt fixed upon an empirical velocity for each different length of stroke. The several velocities are as follow:

Stroke. ft.	in.	Velocity. ft.	Stroke. ft.	in.	Velocity. ft.
2	0	160	4	0	200
2	6	170	4	6	210
3	0	180	5	0	220
3	6	190			

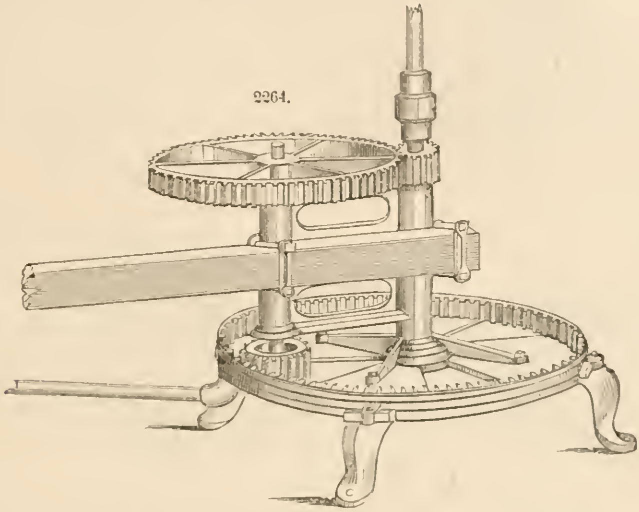
And so on, with 10 feet of additional velocity for every 6 inches of additional stroke. The original engines of the Thames and Shannon, constructed by Boulton and Watt, were rated at 80 horse-power, the cylinders being 47½ inches in diameter, and the length of stroke 4 feet 6 inches, $(47·5)^2 - 4\,(47·5) = 2066·25 \times 105 = 217930 \div 2650 = 83$ horse-power nearly, instead of 80. Land engines of 43½ inches diameter of cylinder and 8 feet stroke, making 16 double strokes in a minute, were rated by Boulton and Watt at 80 horse-power. The average effective pressure on the piston is rated at barely 7 lbs. per square inch, and the power may be thus computed, $(43\tfrac{1}{2})^2 \times ·7854 = 1486·2 \times$ by 7 and 266, and $\div$ by 33,000 = about 80 horse-power. In marine engines a greater area of piston is allowed to represent a horse-power than in land engines, because the motion of the piston is supposed to be slower, but the effective force is calculated a little higher, or at 7·3 per square inch.

HORSE-POWER, Bogardus's. This improvement in the horse-power for driving machinery is based on the principle of the well-known sun and planet motion, and consists of a base-frame having cogs in the inner periphery of the rim into which mash the cogs of a pinion on the lower end of the arbor of the planet-wheel, the cogs of which drive a pinion on a central shaft that carries the driving-pulley, the arbor of the planet-wheel being adapted to turn in a sleeve, in a travelling wing to which the horse-beam is secured; and the said wing having another and parallel sleeve that turns on a central hollow standard of the frame through which the shaft of the central pinion and driving-pulley passes, and in which it turns.

The base-frame is cast in one piece, consisting of the central hub, and the outer ring connected by radial arms, and standing on legs. The central hub is cast with a hollow standard properly turned with a slight taper, to which is fitted a sleeve that turns thereon freely but accurately, and resting on the upper surface of the hub; and likewise with this sleeve, and making part thereof, is cast a wing, to which is secured by bolts the horse-beam or lever, by which the whole is operated. The other end of the wing is also provided with another sleeve cast therewith, and parallel to the other, to which is fitted accurately (but yet to admit of turning freely) the arbor of the planet-wheel and planet-wheel pinion, the former being at the top and the latter at the bottom. One of these, either the wheel or the pinion, can be permanently attached to the arbor, and the other keyed on after it has been inserted in the sleeve. The cogs of the pinion of the planet-wheel take into the cogs formed in the inner periphery of the rim of the base-frame, and which may be called the master-wheel; and the cogs of the planet-wheel take into the cogs of and drive the central pinion on the upper end of a vertical shaft that passes through and turns freely but accurately in the central hollow standard, which is adapted to it, the driving-pulley being keyed on the lower end and below the hub.

A band from the driving-pulley can be carried under the frame and between the legs, to any place required in the usual manner to drive any piece of machinery; but if desired, the driving-pulley can be attached to the central shaft above the central pinion, Fig. 2264. The arbor of the planet-wheel is oiled through a hole in the wheel which delivers it at the junction of the sleeve and arbor; and in like manner the central shaft and the sleeve that turns on the central standard are oiled by pouring the oil through a hole in the central pinion, which delivers it on the upper end of the hollow standard, and which is grooved to direct the oil to its inner and outer periphery.

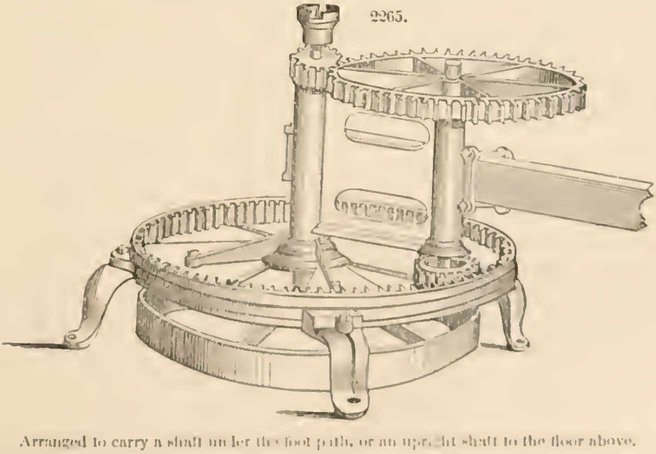
2264.



Arranged to carry the belt from the horizontal pulley under the foot-path on which the horse walks.

The whole apparatus is made light and portable, rests on the case-frame, and turns on the central standard, which makes part of the base-frame, without supports or bearings at the top. The whole can be taken apart for transportation, and can be again put together with ease. The whole strain comes on and is supported by the hollow standard, which being cast with the base-frame will resist any strain that can be applied to it by the horses employed to drive the machine. The sleeves of the wing and the inside of the central standard are or may be laid with soft metal.

2265.



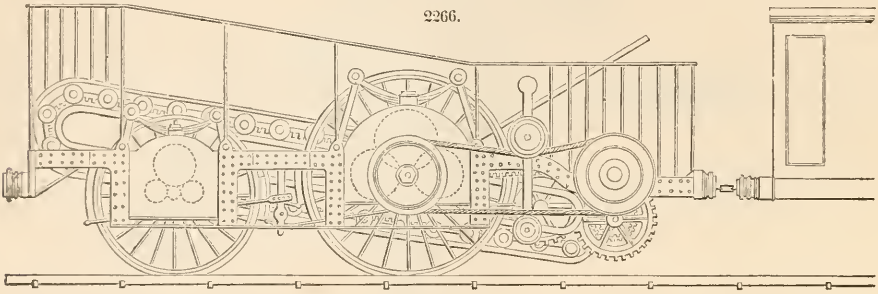
Arranged to carry a shaft under the foot path, or an upright shaft to the floor above.

In some ferry-boats and machines, horses are placed on a revolving platform, which passes backward under the feet whenever the horse exerts his strength in drawing against a fixed resistance so that the horse propels the machinery without moving from his place. A horse may act within still narrower limits, if he is made to stand on the circumference of a large vertical wheel, or upon a bridge supported by endless chains which pass round two drums, and are otherwise supported by friction-wheels. Various other methods have been practised for applying the force of animals, but most of them are attended with great loss of power, either from friction, or from the unfavorable position of the animal.

For agricultural purposes, the movable-platform horse-power is probably the best, and is coming very much into use. It consists of an inclined platform, or endless chain, provided with slats of wood upon which the horse treads, giving motion to a horizontal shaft by means of teeth in the chain or rack, working into a pinion on the shaft. It has very lately been patented in Italy under the name of *impulsoria*. and is in experimental use on the Southwestern Railway in England, and is thus described in a late number of the *London News*:—

The patent impulsoria, for railways, consists in introducing the animals into a kind of coach, called impulsoria, by which they transmit their acting power to the leading wheels. This transmission is conveyed by a very simple means, rendering useful both the driving power of the animals and their own weight. The horse being thus introduced into the impulsoria, is placed upon a perfect rectilinear, artificial ground, or platform, turning so easily that the animal, which is yoked to the shafts, when it walks, does not itself advance, but, what amounts to the same thing, the platform itself is pushed backward, as shown in Fig. 2266. By this artificial ground platform, called by the patentee *pedivella*, is moved an axle, armed with a pulley, from which, by means of a rope, the motion is conveyed to the axletree of the leading wheels. The varying proportions between the diameters of the pulleys give different degrees of speed. The horses are to be worked always at their usual pace, whilst the new locomotive will be able to run at any requisite speed, without ever altering the usual walking pace of the horses, which are inside the impulsoria, as on the floor of a room, sheltered from the weather.

2266.



The importance of introducing the horses into the carriage in order to get more speed from the surplus of the acting power, had been long thought of, and the principle has been several times attempted in England, France, and Italy, but hitherto without success.

The new machine (whose inventor is Signor Clemente Masserano, from Pignerol, Piedmont) has been brought from Italy to England, and deposited at the Nine-elms terminus of the Southwestern Railway, where it may be seen working on the line. It has been made for two horses only, and they work it very well on the *pedivella*. More than thirty wagons have been already experimentally drawn by it up the very inclined line of the station. For working it up and down the station, a wagon is fastened to it when it attains a speed of seven miles an hour. In the experiment to be made on the great line, it is expected to gain a speed of from fifteen to twenty miles an hour. The impulsoria runs either way, like the steam-engine; but the driving horses do not change direction or movement. They can instantly be stopped, without stopping the machine; and the machine can likewise be stopped while the horses continue to walk on the *pedivella*, without transmitting motion to the leading wheels.

By the simple manner in which the horses exercise their moving power on the new machine, they can work easily the usual time, commonly about eight hours a day.

Such economy is of the utmost importance to the numerous interests engaged in the railways subject to enormous working expenses. The principal advantage of the new machine will be to afford very cheap locomotion on all branch lines, thus extending the advantage of the railway to localities hitherto impracticable from the expensive moving power.

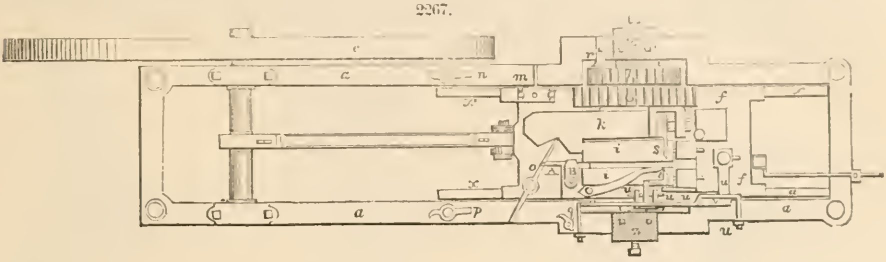
The directors of the Southwestern Railway were the first to receive the impulsoria on their line where they have granted every facility to its ingenious inventor.

HORSE-SHOE, Burden's Patent Machine for making. From the specifications of the patents we extract the following description of the machine and its operation.

Fig. 2267, section and plan of the machine for rolling, drawing, and shaping horse-shoes; *a a a a* stationary or outside frame; *b b b b* feet which support the same; *c* the fly-wheel; *d* the connecting-rod *e e* the crank; *f f* the moving-frame; *g* the rack, having cogs in it, which is bolted into the moving-frame, and which mashes or fits into the segment *h*, having long cogs, as seen at *h*, the lower or under segment which is fastened into the roller *i*, as seen at *i*. Fig. 2269, K the moving-jaw; *l l* the side steels or iron, between which the piece of iron is confined and the sides, while it is drawn or rolled by the swedges D D having steels or swedges E E the exact thickness of the shoe intended.

It will be observed that one of these side steels or irons is fastened into the moving-jaw *k* or K, by means of screw-bolts, while the other is similarly fastened into the moving-frame *f f*. *m* a button, or cam, which, when the moving-frame *f f* is moved or drawn backwards and forwards by the crank *e*, through the connecting-rod *d*, it strikes against the pin or stop *n*, which permits the button or cam *o* to push back or open the moving-jaw *k*, when it strikes against the pin or stop *p* on the other side of the stationary frame, by which means the piece of iron which may be between the side steels or irons, and which is drawn or rolled to the shape desired, is permitted to drop out. *q*, a pin or stop, which, when the cam *o* strikes against it on the moving-frame's return motion, permits the cam *m*, when it strikes against the pin or stop *r*, to close the moving-jaw *k*. It will be observed that when the moving-frame *f f* has performed its forward motion, then the cam *m* strikes against the stop *n*, which permits the cam *o* to open the moving-jaw *k* by striking against the stop *p*, which allows the piece of iron, which may have been rolled or shaped to a horse-shoe, to drop from between the side steels or irons *l l*. *s*, a chisel fastened by screw-bolts on the top of the side steel or iron *l*; *t*, a chisel fastened by screw-bolts in the chisel box *u u u*.

2267.



It will be observed that the box *u u u* turns on a pin in the moving-frame, which, when the crank pushes back the moving-frame, the head or box part strikes against the pin or piece of iron *w*, and presses up the chisel *t* against the chisel *s*, and cuts off the piece of iron to the length intended for a horse-shoe. *v*, a piece of iron intended to draw back the chisel-box *u u u*, as seen at Fig. 2268; *x x x x*, brasses on which the moving-frame slides backwards and forwards; *y*, a piece of iron to lay the bar on as a guide while in the act of feeding into the machine. Z Z end view and section of the posts through which the rollers *i i* are fastened and revolve; A, piece of iron or stop which graduates the length of shoe; B, piece of iron having a hole in it, through which the iron or stop A passes, which graduates the length of shoe; C, the piece of iron which prevents the shoe from being drawn back by the chisel on the side steel *l*, previous to the swedges pressing it between them.

2268.

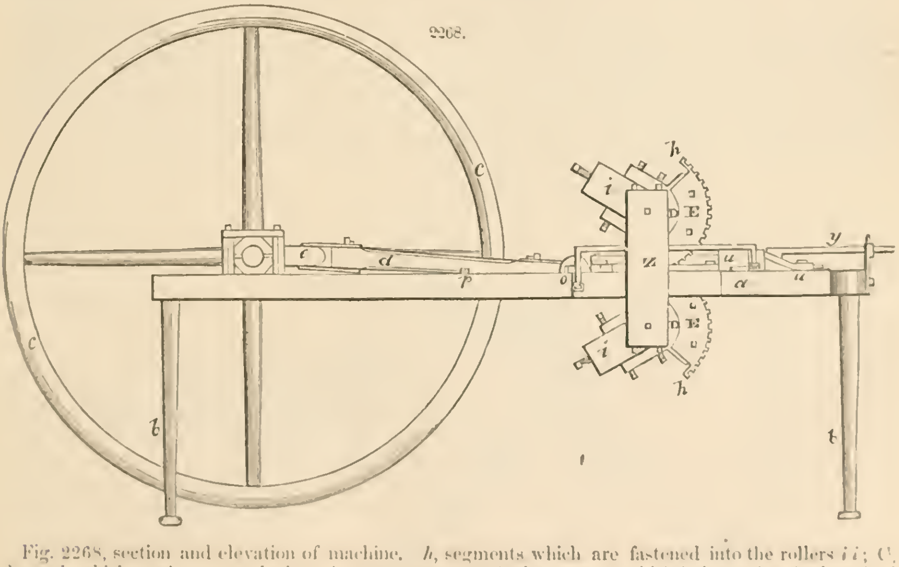
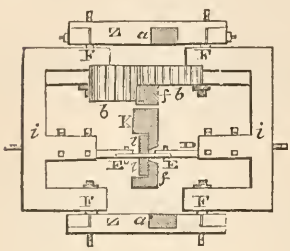


Fig. 2268, section and elevation of machine. *h*, segments which are fastened into the rollers *i i*; C, the rack which mashes or works into the upper segment *h*, the cogs of which being twice the length of the under segment *h* permits the rack to operate into it, which, when pushed backwards and forwards by the moving frame *f f*, the whole is put in motion. *i i*, the rollers into which the segments, with cogs *h h* and swedges D D, with pieces or swedges E E, are fastened. *k* the moving-jaw; *l l* the side steels or irons between which the piece of iron is held, while it is rolled or drawn by the vertical swedges D D and the steels or swedges E E to the desired shape of shoe. It will be perceived that the rollers *i i* revolve on gudgeons. Z Z, posts or stationary frame, into which the rollers *i i* are fastened and revolve.

Fig. 2271, sectional elevation of part of the machine. *i i*, the rollers in which the swedges with the pieces of steel or swedges E E are fastened. *l l*, one of the side steels or irons. H represents a piece of iron as being formed into a horse-shoe. It will readily be perceived that by grinding the steels or swedges E E, any shape or taper required can be given to the piece of iron or shoe marked H. It will be observed that the four views or figures, as above described, represents the part or parts of machinery for cutting off, rolling, or drawing the iron into the shape required for horse-shoes, and that Fig. 2267 is a section, having the upper roller *i* removed for the purpose of showing more distinctly the interior arrangements of the machine.

Fig. 2270, sectional elevation of part of the machine. *i i* the rollers. D D the swedges: the under one, which is cast-iron, or may be fitted with steel swedge similar to those used for rolling or shaping the shoe, as seen at D D, E E, the edge of which being similar to the flat side of a horse-shoe. The upper one is also of cast-iron, so constructed as to fasten in two pieces of steel under the covers or caps *i i*. These pieces of steel are so shaped at their edges as to groove and punch the holes at one operation. They are graduated as to depth by the four screws which pass through the *flanch* above *l l*, one of the side steels. H represents a horse-shoe in the act of being grooved and punched.

2269.



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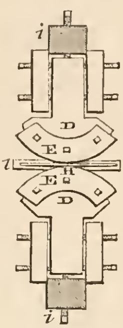
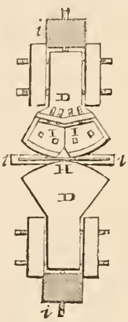


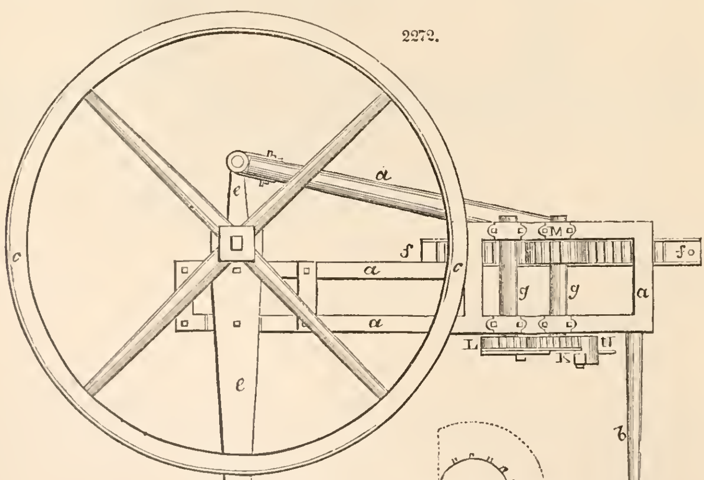
2271.



The machine for grooving and punching is precisely as the one for rolling or drawing the shoe to the required shape, with the exception of the upper swedge, as described above.

Fig. 2272, elevation of machine for bending horse-shoes. *a a a* the frame. *b b* the feet which support the same. *c c* the fly-wheel. *d* the connecting-rod. E the crank-shaft. *f f* the rack. *g g* the two shafts. K the piece of iron round which the shoe is bent, having cogs on its edges shaped so as to fit and mash into the piece K, while they revolve round on their respective shafts *g g*. M the wheel which mashes and fits into the rack *f f*, and which communicates motion to the shafts *g g* and pieces of iron K and L. N a button or nipper which takes hold at the end of the horse-shoe, in consequence of its coming in contact with the piece of iron L, and holds it fast while it is in the act of bending; and when bent, said button or nipper strikes against the other side of piece L, which opens and lets the shoe drop. It will be observed that the shafts *g g* and pieces of iron K and L do not make a full revolution

2272.



2273.

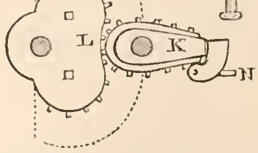
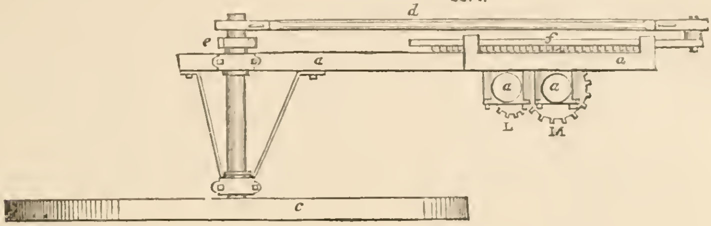


Fig. 2274, plan of machine for bending horse-shoes. *a a* the frame. *c* the fly-wheel. *e* the crank-shaft. *d* the connecting-rod. *f* a rack. M a wheel, whose cog mashes or fits into the cogs of the rack *f*. L the eccentric piece of iron which fits into the piece K, on which the shoe is formed, as seen at Figs

2272 and 2273. O, cap which confines the piece of iron while in the act of bending around the piece K, as represented by the dotted lines at Fig. 2273.

Fig. 2273, section of the irons K and L. These two pieces, K and L, are fastened on the shaft *g g* with their reversed sides up from what they appear in the drawing. The dotted lines represent a cap, which is fastened on the piece of iron L with screw-bolts. This cap is about one inch thick, and serves the purpose of keeping the iron close up while in the operation of bending around the piece of iron K.

2274.



The nature of the operation is as follows:—

Firstly: Fig. 2267 represents a section of the machine, having the upper roller *i* removed, so as to show more distinctly the interior arrangement of the machine. Supposing a pulley of about four feet diameter were bolted to the arms of the fly-wheel *c*, (which is omitted in the drawing,) and to which motion were communicated by a leather strap or belt from a corresponding pulley on a shaft connected with a water-wheel or other power; it is evident that every revolution of the fly-wheel *c* would move the carriage or moving-frame *f f* backwards and forwards, giving motion to the different parts of the machine, as described and shown above.

And supposing the crank *e e*, by the connecting-rod *d*, had pulled or drawn the moving-frame *f f* forward so as to cause the button or cam *m* to strike against the stop *n*, the cam *o* would also strike against the stop *p*, and consequently push back or open the moving-jaw *k*, which turns on a pivot at the other end. And supposing the moving-frame *f f* were pushed back on the brasses *x x*, and towards the last part of the motion a hot piece of iron (previously rolled to the desired size) were introduced between the side steels or irons *l l*, it is evident that the cutter-box *u u u* would strike against the stop *w* and press up the chisel *t* against the chisel *s*, cutting off the necessary length of iron to make the shoe; and should the moving-frame be drawn forward by the crank *e*, the piece of iron, being confined by the side steels or irons *l l* on the sides, would be rolled or shaped by the vertical steels or swedges E E, when the cam *m* would strike against the stop *n* and permit *o* to open the jaw *k* and let the piece drop; the appearance and shape of which may be seen as represented by H, are so ground or shaped as to roll or taper the piece H at each end intended for the heels of the shoe; but it is found by experiment that by using the iron square, and so grinding the steel or swedges E E as to flatten or roll down the middle of the piece, leaving the ends square for the heels of the shoe, makes the best shoe.

Secondly: Having explained the process of cutting the bar or rod into suitable lengths, and rolling or shaping the same suitable for horse-shoes, it remains to describe the method of punching and grooving them. And having already stated that the machine for grooving and punching is precisely the same as the one above described for rolling or shaping the shoe, with the exception of the upper swedge, which is substituted for the swedge represented in Fig. 2271: supposing in a machine every way similar to the one for rolling or shaping the shoe, as described under the first head, (with the exception of the upper swedge, in lieu of which the one represented by Fig. 2270 was substituted,) the piece of iron which came from the first machine were introduced between the side steels or irons *l l*, and the machine set in motion, it is evident it would be grooved and punched and drop out of the machine on the moving-jaw K being opened in the same manner as the piece dropped out from the first machine, as described under the first head.

Thirdly: Having described the manner in which the piece is grooved and punched, it remains to show how it is bent, which is the last operation. The piece of iron being now rolled or shaped as may be desired for a horse-shoe, as also grooved and punched, is introduced into the machine, as shown and described in Figs. 2272 to 2274.

We here copy Mr. Burden's claim:

"First: I claim the machine for rolling, drawing, or shaping horse-shoes, as described and represented by Figs. 2267 to 2272, *as a whole as there arranged;* namely, those parts called side steels or irons *l l*, which confine the piece of iron intended for a horse-shoe, on the sides, while it is rolled or shaped by the vertical swedges E E. I also claim the vibrating or reciprocating motion of moving frame *f f*, which gives motion to all the other parts of the machine, which enables the operator to feed up the iron intended for horse-shoes to the stop A, cutting it off accurately, and rolling and shaping them at the same time.

And I claim the above named reciprocating motion, whether it be by side steels or swedges, as above named, or whether it be merely a pair of common grooved rollers, the one having a groove or channel turned or cut the shape of the shoe, the other having a tongue so shaped as to fit the groove exactly, the periphery of said tongue being so shaped as to roll the shoe thinner at some parts than at others, as may be desired.

It will be observed that if *two* rollers, as aboved named, were connected together at the end by two pinions, and on the other end of one were fastened a wheel similar to the wheel M on one of the shafts *z* of the bending machine, having a rack operating into said wheel, connected to a crank in every respect similar to the bending machine, it is evident that said rollers would move backwards and forwards, making such part of a revolution as the length of the crank might give them. I therefore claim said reciprocating motion when applied to rolling or shaping horse-shoes by rollers. I do not claim the use of *solid rollers* in rolling horse-shoes; for I believe this has been done, or, rather, *attempted to be done*, and has universally proved a failure, in consequence of not having reciprocating motion to enable the operator to feed up the iron to a stop so as to insure the piece of iron intended for a horse-shoe being always in the proper place to receive the impression from the roller.

Another reason why rolling horse-shoes by solid rollers has failed, is, that the tongue of the one and socket of the other are liable to wear, and consequently have to be laid aside. Whereas, my method of having the tongue or swedges, as also the socket, divided into sections, allows the whole being ground, repaired, and moved at pleasure by screws, so as to insure the sides of the socket fitting close to the tongue, as also having one side of the socket movable, to allow the shoes being discharged. I also claim the method of having those parts of the machine which confine the iron on the sides, represented as side steels, marked *l l*, movable, so as to permit their being ground, when worn, at the same time moving them close up to the swedges E E by screws. I also claim the plan of making the rollers *i i*, with an open mortise, so as to permit the swedges D D being moved. In fine, I claim the method of dividing the working parts which roll or shape the shoe into such sections as enables me to grind, replace, and remove them at pleasure; in lieu of solid rollers, which, when worn, have to be laid aside altogether. I wish it to be particularly understood that I do not confine myself to the precise method of operating the machine for rolling or shaping horse-shoes, as represented by the drawing hereunto annexed; as, in lieu of the frame *f f* being moved, it may be made stationary, and the rollers *i i* moved backwards and forwards in slides, with corresponding movements given to the other parts, which would give analogous results.

Secondly: I claim the machine for grooving and punching horse-shoes, as represented by the figures and descriptions thereof. That is to say, I claim the manner of confining the piece of iron intended for a horse-shoe, between the side steels *l l*, while in the act of grooving and punching, by the upper swedge D having the pieces of steel fastened under the caps *i i*. I also claim the vibrating or reciprocating motion of the machine in grooving and punching, for the same reasons as set forth in my claim to the machine for rolling or shaping. I claim the manner of so shaping the edge of the steels as to leave projections for the heads of the nails, as in all cases, even when made by hand, the groove is first made, then the holes; but by my plan I make both at once, which serves the double purpose of adding strength to the punches, by being formed and composing part of the steel which forms the groove or channel, as also performing both operations at once. I also claim the method of fastening the two pieces of steel which groove and punch the shoe under the caps *i i*, which permits their being screwed down by four screws, when necessary, in consequence of their becoming short by filing or other causes. And as I deem the discovery of forming the projections or punches on the same piece of steel which grooves or channels the shoe of great importance, I shall describe the manner in which it is done. Take a piece of cast or other steel, previously rolled or hammered to about one-fourth of an inch in thickness, about four inches wide, and as long as necessary, to form the groove on one side of the shoe. Then grind or reduce the edge by a file to the proper shape to form the groove: then mark the projections or punches, filing down the spaces between the projections so as to give them sufficient length to form the holes, which adds great strength to the punches, compared with the method of inserting small pieces or steel into a roller to form punches.

Thirdly: I claim the machine for bending horse-shoes, as represented and described by the drawings thereof, in *every particular as there arranged*. And in addition to which, I claim any other method or bending horse-shoes, so long as the piece is taken hold of by one end, while the other is bent round the mould, no matter whether the mould revolve round or is stationary, and the piece of iron is pulled or bent round it.

I also claim, in a particular manner, the placing of the face of the mould downwards, so as to permit the shoe to drop or discharge itself. I also claim the using of a piece of flat iron, as represented by the dotted lines in Fig. 2273, for the purpose of keeping the shoe close up to the mould while in the act of bending. I also claim the *nipper* or *button*, which closes and holds fast the end of the horse-shoe by striking against the piece L while in the act of bending round the shoe shape K, and which opens in consequence of its coming in contact with the other side of the piece L, and lets the shoe drop.

I also claim the manner of making the geering or wheels connected with the pieces of iron K and L eccentric, or so shaped as to have the pitched line describe the same circle as the shoe.

HYDRAULIC RAM. See Ram.

HYDRODYNAMICS, is that branch of general mechanics which treats of the equilibrium and motion of fluids. The terms *hydrostatics* and *hydrodynamics* have corresponding signification to the *statics* and *dynamics* in the mechanics of solid bodies; viz., hydrostatics is that division of the science which treats of the equilibrium of fluids, and hydrodynamics that which relates to their forces and motion. It is, however, very usual to include the whole doctrine of the mechanics of fluids under the general term of hydrodynamics, and to denote the divisions relative to their equilibrium and motion by the terms HYDROSTATICS and HYDRAULICS. We adopt the latter division, and shall confine ourselves to a few of the most usually received theoretical deductions, and state those rules which have been the result of a judicious application of theory to experiment, as the subject itself is the one the least advanced of any branch of mechanics, and we are as yet far from being in possession of the requisite data for a rigorous solution of the problems which arise. Very many excellent treatises have been written, to which we refer the scientific reader; but the extent of the subject forbids the introduction of any of them into this work, further than to select the best practical rules for the use of the mechanic.

Hydrostatics comprises the doctrine of the pressure and the equilibrium of non-elastic fluids, as water mercury, &c., and that of the weight and pressure of solids immersed in them.

1. Fluids press *equally in all directions*, upwards, downwards, aslant or laterally

This constitutes one essential difference between fluids and solids, solids pressing only *downwards* or in the direction of gravity.

2. The upper surface of a gravitating fluid at rest is horizontal.

3. The pressure of a fluid on every particle of the vessel containing it, or of any other surface, real or imaginary, in contact with it, is equal to the weight of a column of the fluid, whose base is equal to that particle, and whose height is equal to its depth below the upper surface of the fluid.

4. If, therefore, any portion of the upper part of a fluid be replaced by a part of the vessel, the pressure against this from below will be the same which before supported the weight of the fluid removed, and every part remaining in equilibrium, the pressure on the bottom will be the same as it would if the vessel were a prism or a cylinder.

5. Hence, the smallest given quantity of a fluid may be made to produce a pressure capable of sustaining any proposed weight, either by diminishing the diameter of the column and increasing its height, or by increasing the surface which supports the weight. It is upon this principle that the hydrostatic press is made to operate. See Hydrostatic Press.

6. The pressure of a fluid on any surface, whether vertical, oblique, or horizontal, is equal to the weight of a column of the fluid whose base is equal to the surface pressed, and height equal to the distance of the centre of gravity of that surface below the upper horizontal surface of the fluid.

7. Fluids of different specific gravities that do not mix, will counterbalance each other in a bent tube when their heights above the surface of junction are inversely as their specific gravities.

A portion of fluid will be quiescent in a bent tube, when the upper surface in both branches of the tube is in the same horizontal plane, or is equidistant from the earth's centre. And water poured down one branch of such a tube, (whether it be of uniform bore throughout or not,) will rise to its own level in the other branch.

Thus, water may be conveyed by pipes from a spring on the side of a hill, to a reservoir of equal height on another hill.

8. The ascent of a body in a fluid of greater specific gravity than itself, arises from the pressure of the fluid upwards against the under surface of the body.

The *centre of pressure* is that point of a surface against which any fluid presses, to which if a force equal to the whole pressure were applied, it would keep the surface at rest, or balance its tendency to turn or move in any direction.

The centre of pressure of a parallelogram, whose upper side is in the plane of the horizontal level of the liquid, is at $\frac{2}{3}$ of the line (measuring downwards) that joins the middles of the two horizontal sides of the parallelogram.

If the base of a triangular plane coincides with the upper surface of the water, then *the centre of pressure is at the middle of the line drawn from the middle of the base to the vertex of the triangle.* But, if the vertex of the triangle be in the upper surface of the water, while its base is horizontal, the *centre of pressure is at $\frac{3}{4}$ of the line drawn from the vertex to bisect the base.*

If b the breadth and d the depth of a rectangular gate, or other surface, exposed to the pressure of water from top to bottom, then the entire pressure is equal to the weight of a prism of water whose content is $\frac{1}{2} b\, d^2$. Or, if b and d be in feet, then the whole pressure $= 31\frac{1}{4}\, b\, d^2$, in pounds.

If the gate be in form of a trapezoid, widest at top, then, if B and b be the breadths at the top and bottom respectively, and d the depth,

$$\text{Whole pressure in pounds} = 31\tfrac{1}{4}\,[\tfrac{1}{3}\,(B - b) + b]\,d^2.$$

Floating bodies.—If any body float on a fluid, it displaces a quantity of the fluid equal to itself in weight. Also, the centres of gravity of the body and of the fluid displaced, must, when the body is at rest, be in the same vertical line.

If a vessel contain two fluids that will not mix, (as water and mercury,) and a solid of some intermediate specific gravity be immersed under the surface of the lighter fluid and float on the heavier, the part of the solid immersed in the heavier fluid, is to the whole solid as the difference between the specific gravities of the solid and the lighter fluid is to the difference between the specific gravities of the two fluids.

The buoyancy of casks, or the load which they will carry without sinking, may be estimated by reckoning 10 pounds avoirdupois to the ale gallon.

The buoyancy of *pontoons* may be estimated at about *half a hundred weight* for each cubic foot.

Thus a pontoon which contained 96 cubic feet, would sustain a load of 48 cwt. before it would sink. This is an approximation, in which the difference between $\frac{6}{11}$ and $\frac{1}{2}$, that is, $\frac{1}{22}$ of the whole weight, is allowed for that of the pontoon itself.

This property has been successfully employed in pulling up piles in a river where the tide ebbs and flows. A barge of considerable dimensions is brought over a pile as the water begins to rise; a strong chain which has been previously fixed to the pile by a ring, &c., is made to gird the barge, and is then fastened. As the tide rises the vessel rises too, and by means of its buoyant force draws up the pile with it.

In an actual case, a barge 50 feet long, 12 feet wide, 6 deep, and drawing 2 feet of water, was employed. Here, $50 \times 12 \times (6 - 2) \times \frac{4}{7} = \frac{50 \times 12 \times 16}{7} = 192 \times 7\frac{1}{7} = 1344 + 27\frac{3}{7} = 1371\frac{3}{7}$ cwt = 86½ tons, nearly, the measure of the force with which the barge acted upon the pile.

Specific gravities.—If a body float on a fluid, the part immersed is to the whole body as the specific gravity of the body to the specific gravity of the fluid. (See Gravity and Specific Gravity.)

Hydraulics is that part of mechanical science which relates to the motion of non-elastic fluids, and the forces with which they act upon bodies.

Motion and effluence of liquids.—1. A jet of water, issuing from an orifice of a proper form, and directed upwards, rises, under favorable circumstances, nearly to the height of the head of water in the reservoir; and since the particles of such a stream are but little influenced by the neighboring ones, they may be considered as independent bodies, moving initially with the velocity which would be acquired in falling from the height of the reservoir. And the velocity of the jet will be the same whatever may be its direction.

2. Hence, if a jet issue horizontally from any part of the side of a vessel standing on a horizontal plane, and a circle be described having the whole height of the fluid for its diameter, the fluid will reach the plane at a distance from the vessel, equal to that chord of the circle in which the jet initially moves.

3. When a cylindrical or prismatic vessel empties itself by a small orifice, the velocity at the surface is uniformly retarded; and in the time of emptying itself, twice the quantity would be discharged if it were kept full by a new supply.

4. But the quantity discharged is by no means equal to what would fill the whole orifice, with this velocity. If the aperture is made simply in a thin plate, the lateral motion of the particles towards it tends to obstruct the direct motion, and to contract the stream which has left the orifice, nearly in the ratio of two to three. So that in order to find the quantity discharged, the section of the orifice must be supposed to be diminished from 100 to 62 for a simple aperture, to 82 for a pipe of which the length is twice the diameter, and in other ratios according to circumstances.

5. When a siphon, or bent tube, is filled with a fluid, and its orifices immersed in the fluids of different vessels, if both surfaces of the fluids are in the same level, the whole remains at rest; but if otherwise, the longer column of fluid in the siphon preponderates, and the pressure of the atmosphere forces up the fluid from the higher vessel, until the equilibrium is restored; and the motion is the more rapid as the difference of levels is greater: provided that the greatest height of the tube above the upper surface be not more than a counterpoise to the pressure of the atmosphere.

6. If a notch or sluice in form of a rectangle be cut in the vertical side of a vessel full of water, or any other fluid, the quantity flowing through it will be $\frac{2}{3}$ of the quantity which would flow through an equal orifice placed horizontally at the whole depth, in the same time, the vessel being kept constantly full.

7. If a short pipe, elevated in any direction from an aperture in a conduit, throw the water in a parabolic curve to the distance or range R, on a horizontal plane passing through the orifice, and the greatest height of the spouting fluid above that plane be H, then the height of the *head* of water above that conduit pipe may be found, *nearly:* viz., by taking, first, $2 \cot E = \frac{R}{2H}$; and, secondly, the altitude of the head $A = \frac{1}{2} R \times \operatorname{cosec} 2E$.

Ex. Suppose that $R = 40$ feet, and $H = 18$ feet. Then $\frac{R}{2H} = \frac{40}{36} = 1{\cdot}1111111 = 2 \cot 60^\circ\ 57'$: and $A = \frac{1}{2} R \times \operatorname{cosec} 2E = 20 \times \operatorname{cosec} 121^\circ\ 54' = 20 \times 1{\cdot}177896 = 23{\cdot}55792$ feet, height required.

Note. This result of theory will usually be found about 4-5ths of that which is furnished by experiment.

Motion of water in conduit pipes and open canals, over weirs, &c.—1. When the water from a reservoir is conveyed in long horizontal pipes of the same aperture, the discharges made in equal times are nearly in the inverse ratio of the square roots of the lengths.

It is supposed that the lengths of the pipes to which this rule is applied are not very unequal. It is an approximation not deduced from principle, but derived immediately from experiment.

2. Water running in open canals, or in rivers, is accelerated in consequence of its depth, and of the declivity on which it runs, till the resistance increasing with the velocity, becomes equal to the acceleration, when the motion of the stream becomes uniform.

It is evident that the amount of the resisting forces can hardly be determined by principles already known, and therefore nothing remains but to ascertain, by experiment, the velocity corresponding to different declivities, and different depths of water, and to try, by multiplying and extending these experiments, to find out the law which is common to them all.

The Chevalier Du Buat has given a formula for computing the velocity of running water, whether in close pipes, open canals, or rivers, which, though it may be called *empirical,* is extremely useful in practice.

Let V be the velocity of the stream, measured by the inches it moves over in a second; R a constant quantity, viz., the quotient obtained by dividing the area of the transverse section of the stream, expressed in square inches, by the boundary or perimeter of that section, *minus* the superficial breadth of the stream expressed in linear inches.

The mean velocity is that with which, if all the particles were to move, the discharge would be the same with the actual discharge.

The line R is called by Du Buat the *radius,* and by Dr. Robison the *hydraulic mean depth.* As its affinity to the radius of a circle seems greater than to the depth of a river, we shall call it, with the former, the *radius of the section.*

Lastly, let S be the denominator of a fraction which expresses the slope, the numerator being unity, that is, let it be the quotient obtained by dividing the length of the stream, supposing it extended in a straight line, by the difference of level of its two extremities; or, which is nearly the same, let it be the co-tangent of the inclination or slope.

The above denominations being understood, and the section, as well as the velocity, being supposed uniform, V in English feet,

$$= \frac{307 \sqrt{(R - \frac{1}{10})}}{S^{\frac{1}{2}} - \frac{1}{2} \log.(S + \frac{16}{10})} - \frac{3}{10} \sqrt{(R - \frac{1}{10})}:$$

$$\text{or } v = \sqrt{R - \tfrac{1}{10}}\left(\frac{307}{s^{\frac{1}{2}} - \frac{1}{2}\log.\left(s + \frac{16}{10}\right)} - \frac{3}{10}\right)$$

When R and s are very great,

$$v = R^{\frac{1}{2}}\left(\frac{307}{s^{\frac{1}{2}} - \frac{1}{2}\log.\, s} - \frac{3}{10}\right) \text{ nearly.}$$

The logarithms understood here are the hyperbolic, and are found by multiplying the common logarithms by 2·3025851.

The slope remaining the same, the velocities are as $\sqrt{R - \frac{1}{10}}$.

The velocities of two rivers that have the same declivity, are as the square roots of the radii of their sections.

If R is so small, that $\sqrt{R - \frac{1}{10}} = 0$, or $R = \frac{1}{10}$, the velocity will be nothing, which is agreeable to experience; for in a cylindric tube $R = \frac{1}{2}$ the radius; the radius, therefore, equal two-tenths; so that the tube is nearly capillary, and the fluid will not flow through it.

The velocity may also become nothing by the declivity becoming so small, that

$$\frac{307}{s^{\frac{1}{2}} - \frac{1}{2}\log.\left(s + \frac{16}{10}\right)} - \frac{3}{10} = 0;\ \text{but}$$

ıf $\frac{1}{s}$ is less than $\frac{1}{500000}$, or than $\frac{1}{10}$ of an inch to an English mile, the water will have sensible motion.

In a river, the greatest velocity is at the surface, and in the middle of the stream, from which it diminishes towards the bottom and the sides, where it is least. It has been found by experiment, that, if from the square root of the velocity in the middle of the stream, expressed in inches per second, unity be subtracted, the square of the remainder is the velocity at the bottom.

Hence, if the former velocity be $= v$, the velocity at the bottom $= v - 2\sqrt{v} + 1$. (A.)

The mean velocity, or that with which, were the whole stream to move, the discharge would be the same with the real discharge, is equal to half the sum of the greatest and least velocities, as computed in the last proposition.

The mean velocity is, therefore, $= v - \sqrt{v} + \frac{1}{2}$. (B.)

This is also proved by the experiments of Du Buat.

When the water in a river receives a permanent increase, the depth and the velocity, as in the example above, are the first things that are augmented. The increase of the velocity increases the action on the sides and bottom, in consequence of which the width is augmented, and sometimes also, but more rarely, the depth. The velocity is thus diminished, till the tenacity of the soil, or the hardness of the rock, afford a sufficient resistance to the force of the water. The bed of the river then changes only by insensible degrees, and, in the ordinary language of hydraulics, is said to be permanent, though in strictness this epithet is not applicable to the course of any river.

When the sections of a river vary, the quantity of water remaining the same, the mean velocities are inversely as the areas of the sections.

This must happen, in order to preserve the same quantity of discharge.

The following table, abridged from Du Buat, serves at once to compare the surface, bottom, and mean velocities in rivers, according to the formulæ (A) and (B).

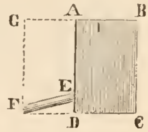
VELOCITY IN INCHES.			VELOCITY IN INCHES.		
Surface.	Bottom.	Mean.	Surface.	Bottom.	Mean.
4	1·	2·5	56	42·016	49·008
8	3·312	5·67	60	45·509	52·754
12	6·071	9·036	64	49·	56·5
16	9·	12·5	68	52·505	60·252
20	12·055	16·027	72	56·025	64·012
24	15·194	19·597	76	59·568	67·784
28	18·421	23·210	80	63·107	71·553
32	21·678	26·839	84	66·651	75·325
36	25·	30·5	88	70·224	79·112
40	28·345	34·172	92	73·788	82·894
44	31·742	37·871	96	77·370	86·685
48	35·151	41·570	100	81·	90·5
52	38·564	45·282			

The knowledge of the velocity at the bottom is of the greatest use for enabling us to judge of the action of the stream on its bed.

Every kind of soil has a certain velocity consistent with the stability of the channel. A greater velocity would enable the waters to tear it up, and a smaller velocity would permit the deposition of more movable materials from above. It is not enough, then, for the stability of a river, that the accel erating forces are so adjusted to the size and figure of its channel that the current may be in train: it must also be in equilibrio with the tenacity of the channel.

We learn from the observations of Du Buat, and others, that a velocity of three inches per second at the bottom will just begin to work upon the fine clay fit for pottery, and however firm and compact it may be, it will tear it up. Yet no beds are more stable than clay, when the velocities do not exceed this; for the water soon takes away the impalpable particles of the superficial clay, leaving the particles of sand sticking by their lower half in the rest of the clay, which they now protect, making a very permanent bottom, if the stream does not bring down gravel or coarse sand, which will rub off this very thin crust, and allow another layer to be worn off. A velocity of six inches will lift fine sand; eight inches will lift sand as coarse as linseed; twelve inches will sweep along fine gravel; twenty-four inches will roll along rounded pebbles an inch diameter; and it requires three feet per second at the bottom to sweep along angular stones of the size of an egg. (*Robison on Rivers.*)

Eytelwein, a German mathematician, has devoted much time to inquiries in hydrodynamics. His formulæ apply to the motion of water; 1st, in a cylindric tube; 2d, in an open canal.



Let d be the diameter of the cylindric tube E F, h the total height F G of the head of water in the reservoir above the middle of the orifice F, and l the length E F of the tube, all in inches; then the velocity in inches with which the fluid will issue from the orifice F will be

$$v = 23\tfrac{1}{3}\sqrt{\frac{57\, h d}{l + 57\, d}}:$$

this multiplied into the area of the orifice will give the quantity per second.

Let d = diameter of the pipe in inches, Q = the quantity of water in cubic feet discharged through the pipe per minute, l = the length of the pipe in feet, and h = the difference of level between the surface of the water in the reservoir and at the end of the pipe or the head; then, any three of these quantities being given, the fourth may be determined from the following formulæ:—

$$d = \sqrt[5]{\frac{\cdot0448\, Q^2 (l + 4\cdot2\, d)}{h}}$$

$$Q = \sqrt{\frac{h d^2}{\cdot0448\, (l + 4\cdot2\, d)}}$$

$$l = \frac{h d^5}{\cdot0448\, Q^2} - 4\cdot2\, d \qquad h = \frac{\cdot0448\, Q^2 (l + 4\cdot2\, d)}{d^5}.$$

These formulæ are more convenient expressed logarithmically, thus—

$$\text{Log. } d = \tfrac{1}{5}\left\{2 \text{ log. } Q + \bar{2}\cdot6515 + \text{log. } (l + 4\cdot2\, d) - \text{log. } h\right\}.$$

$$\text{Log. } Q = \tfrac{1}{2}\left\{\text{log. } h + 5 \text{ log. } d - \bar{2}\cdot6515 - \text{log. } (l + 4\cdot2\, d)\right\}.$$

$$\text{Log. } l = \text{log. } h + \text{log. } d - \bar{2}\cdot6515 - 2 \text{ log. } Q \text{ (neglecting } - 4\cdot2\, d).$$

$$\text{Log. } h = 2 \text{ log. } Q + \bar{2}\cdot6515 + \text{log. } (l + 4\cdot2\, d) - 5 \text{ log. } d.$$

When a pipe is bent in one or more places, then if the squares of the sines of the several changes of direction be added into one sum s, the velocity v will be found by the formula

$$v = \sqrt{\frac{548\, d h}{d + \frac{1}{45} l + \frac{1}{6} d s}}$$

l, h, d, and v, being all in inches.

Prony gives a very safe formula for calculating the velocity of water in pipes, and it is very convenient for use, and is reliable.

V = velocity in feet per second.
D = diameter of pipe in feet.
H = the head, from surface of water in reservoir to the surface of water above the mouth of pipe.
L = the length of pipe.

$S = \frac{H}{L}$. Then $V = 48\cdot5254\sqrt{D S}$. The measures are all in feet.

For open canals.—Let v be the mean velocity of the current in feet, a area of the vertical section of the stream, p perimeter of the section, or sum of the bottom and two sides, l length of the bed of the canal corresponding to the fall h, all in feet: then

$$v = \sqrt{9582 \frac{a h}{p l} + 0\cdot0111} - 0\cdot109.$$

The experiments of M. Bidone, on the motion of water in canals, agree within the 80th part of the results of computations from the preceding formulæ.

We have used the following formula of Eytelwein, taken from the Edinburgh Encyclopedia, article *Hydrodynamics*, for ascertaining the velocity of water in an open canal, and the results have been satisfactory.

d = *hydraulic mean depth*, or *mean radius* in inches, called R in preceding formulæ of Du Buat.
f = fall in two mile of canal, in inches.
V = velocity in inches per second.

Then, $V = 0\cdot91\sqrt{f d}$.

For apertures in the sides or bottom of vessels.—If q equal the quantity of water discharged in cubic feet per minute, v the velocity of the affluent water in feet per second through the aperture, a the area of the aperture in square inches, and h the height from its centre to the surface of the water, we have

$$v = c\sqrt{h}\,; \text{ and } q = \cdot 4167\, a\, c\sqrt{h}\,;$$

in which c is a constant quantity, depending upon the nature of the aperture, and the value of which, for several different forms, is contained in the following table:—

Nature of the Orifices employed.	Ratio between the theoretical and real discharges.	Coefficients for finding the velocities in Eng. ft.
For the whole velocity due to the height	1 to 1·00	8·04
For wide openings whose bottom is on a level with that of the reservoir	1 to 0·961	7·7
For sluices with walls in a line with the orifice	1 to 0·961	7·7
For bridges with pointed piers	1 to 0·961	7·7
For narrow openings whose bottom is on a level with that of the reservoir	1 to 0·861	6·9
For smaller openings in a sluice with side walls	1 to 0·861	6·9
For abrupt projections and square piers of bridges	1 to 0·861	6·9
For openings in sluices without side walls	1 to 0·635	5·1
For an orifice in a thin plate	1 to 0·621	5·0

The following table of Smeaton is mainly the result of experiments.

TABLE, *abridged from one by Mr. Smeaton, for showing the height of head necessary to overcome the friction of water in horizontal pipes.*

Velocities per second of water in the pipes.										Bore of the pipes.
Ft. in. 0 6	Ft. in. 1 0	Ft. in. 1 6	Ft. in. 2 0	Ft. in. 2 6	Ft. in. 3 0	Ft. in. 3 6	Ft. in. 4 0	Ft. in. 4 6	Ft. in. 5 0	
0 4·5	1 4·7	2 11·0	4 9·7	7 1·7	10 1·0	13 8·0	17 10·0	22 6·7	28 0·2	½ inch.
0 3·0	0 11·1	1 11·3	3 2·5	4 9·2	6 8·6	9 1·3	11 10·6	15 0·5	18 8·1	¾ "
0 2·2	0 8·4	1 5·5	2 4·9	3 6·9	5 0·5	6 10·0	8 11 0	11 3·4	14 0·0	1 "
0 1·8	0 6·7	1 2·0	1 11·1	2 10·3	4 0·4	5 5·6	7 1 6	9 0·3	11 2·5	1¼ "
0 1·5	0 5·6	0 11·7	1 7·2	2 4·6	3 4·3	4 6·7	5 11·3	7 6·2	9 4·1	1½ "
0 1·3	0 4·8	0 10·0	1 4·5	2 0·5	2 10·6	3 10·9	5 1·1	6 5·4	8 0·1	1¾ "
0 1·1	0 4·2	0 8·7	1 2·4	1 9 4	2 6·2	3 5·0	4 5·5	5 7·7	7 0·0	2 "
0 1·0	0 3·7	0 7·8	1 0·8	1 7·0	2 2·9	3 0·4	3 11·6	5 0·1	6 2·7	2¼ "
0 0·9	0 3·3	0 7·0	0 11·5	1 5·1	2 0·2	2 8·8	3 6·8	4 6·1	5 7·2	2½ "
0 0·7	0 2·8	0 5·0	0 9·6	1 2·3	1 8·2	2 3·3	2 11·7	3 9 1	4 8·0	3 "
0 0·6	0 2·4	0 5·0	0 8·2	1 0·2	1 5·3	1 11·4	2 6·6	3 2·7	4 0·0	3½ "
0 0·6	0 2·1	0 4·4	0 7·2	0 10·7	1 3·1	1 8·5	2 2·7	2 9·8	3 6·0	4 "
0 0·5	0 1·9	0 3·9	0 6·4	0 9·5	1 1·4	1 6·2	1 11·8	2 6·1	3 1·4	4½ "
0 0·4	0 1·7	0 3·5	0 5·8	0 8·6	1 0·1	1 4·4	1 9·4	2 3·1	2 9·6	5 "
0 0·4	0 1 4	0 2·9	0 4 8	0 7·1	0 10·1	1 1·7	1 5 8	1 10·6	2 4·0	6 "
0 0·3	0 1·2	0 2·5	0 4·1	0 6·1	0 8·6	0 11·7	1 3·3	1 7·3	2 0·0	7 "
0 0·3	0 1·0	0 2·2	0 3·6	0 5·4	0 7·6	0 10·2	1 1·4	1 4·9	1 9 0	8 "
0 0·25	0 0·9	0 1·9	0 3·2	0 4·8	0 6·7	0 9·1	0 11·9	1 3·0	1 6·7	9 "
0 0·2	0 0·8	0 1·7	0 2·9	0 4·3	0 6·0	0 8·2	0 10·7	1 1·5	1 4·8	10 "
0 0·2	0 0·8	0 1·6	0 2·6	0 3·9	0 5·5	0 7·5	0 9·7	1 0·3	1 3·3	11 "
0 0·19	0 0·7	0 1·5	0 2·4	0 3·6	0 5·0	0 6·8	0 8·9	0 11·3	1 2·0	12 "

Look for the velocity of water in the pipe in the upper row, and in the column below it, and opposite to the given diameter of the pipe standing in the last column, will be found the perpendicular height of a column or head, in feet, inches, and tenths, requisite to overcome the friction of such pipe for 100 feet in length, and obtain the given velocity.

From the present standard work, *Lowell Hydraulic Experiments*, by Jas. B. Francis, Esq., we extract the following on weirs:

The formula proposed for weirs of considerable length in proportion to the depth upon them, and having complete contraction, (as first suggested to the author by Mr. Boyden in 1846,) is

$$Q = C'(l - b\,n\,h)\,h^{a}\,;$$

in which

Q = the quantity discharged in cubic feet per second.
C' = a constant coefficient.
l = the total length of the weir in feet.
b = a constant coefficient.
n = the number of end contractions. In a single weir having complete contraction, n always equals 2, and when the length of the weir is equal to the width of the canal leading to it, $n = 0$.
h = the depth of water flowing over the weir, taken far enough upstream from the weir, to be unaffected by the curvature in the surface caused by the discharge.
a = a constant power.

By experiments the numerical values were determined as follows:

$$Q = 3.33\,(L - 0.1\,n\,H)\,H^{\frac{3}{2}}:$$

the English foot being the unit of measure.

This formula is only applicable to rectangular weirs, made in the side of a dam, which is vertical on the upstream side, the crest of the weir being horizontal, and the ends vertical; also, the edges of the orifice presented to the current must be sharp; for, if bevelled or rounded off in any perceptible degree, a material effect will be produced on the discharge; it is essential, moreover, that the stream should touch the orifice only at these edges, after passing which it should be discharged through the air, in the same manner as if the orifice was cut in a thin plate. The formula is not applicable to cases in which the depth on the weir exceeds one third of the length; nor to very small depths. There seems no reason why it should not be applied with safety to any depths between 6 inches and 24 inches.

The height of the surface of the water in the canal, above the crest of the weir, is to be taken for the depth upon the weir; this height should be taken at a point far enough from the weir to be unaffected by the curvature caused by the discharge; if more convenient, it may be taken by means of a pipe opening near the bottom of the canal near the upstream side of the weir, which pipe may be made to communicate with a box placed in any convenient situation; and if the box and pipe do not leak, the height may be observed in this manner, very correctly. However the depth may be observed, it may require to be corrected for the velocity of the water approaching the weir.

The end contraction must either be complete, or entirely suppressed; the necessary distance from the side of the canal or reservoir to the end of the weir, in order that the end contraction may be complete, is not definitely determined. In cases where there is end contraction, we may assume a distance from the side of the canal to the end of the weir equal to the depth on the weir, as the least admissible, in order that the proposed formula may apply.

As to the fall below the weir, requisite to give a free discharge to the water, it is not definitely determined; it appears that when the sheet, passing the weir, falls into water of considerable depth, the depth on the weir being about 0.85 feet, no difference is perceptible in the discharge, whether the water is 1.05 feet or 0.235 feet below the crest of the weir; it is very essential, however, in all cases, that the air under the sheet should have free communication with the external atmosphere. With this precaution it appears that, if the fall below the crest of the weir is not less than half the depth upon the weir, the discharge over the weir will not be perceptibly obstructed. If the sheet is of very great length, however, more fall will be necessary, unless some special arrangement is made to supply air to the space under the sheet at the places that would otherwise not have a free communication with the atmosphere.

In respect to the depth of the canal leading to the weir, experiments show that, with a depth as small as three times that on the weir, the proposed formula agrees with experiment, within less than one per cent.; this proportion may be taken as the least admissible, when an accurate gauging is required.

It not unfrequently happens that, in consequence of the particular form of the canal leading to the weir, or from other causes, the velocity of the water in the canal is not uniform in all parts of the section; this is a frequent cause of serious error, and is often entirely overlooked. If great irregularities exist, they should be removed by causing the water to pass through one or more gratings, presenting numerous small apertures equally distributed, or otherwise, as the case may require, through which the water may pass under a small head; these gratings should be placed as far from the weir as practicable.

If the canal leading to the weir has a suitable depth, it will be requisite only when great precision is required, to correct the depth upon the weir for the velocity of the water in the canal by the formula (D).

h being the head due to the velocity with which the water approaches the weir: —

$$H' = \left[(H+h)^{\frac{3}{2}} - h^{\frac{3}{2}}\right]^{\frac{2}{3}}$$

Substituting H' for H in the previous formula, we obtain the flow increased for the velocity with which the water approaches the weir.

Of gauging the flow of water in open canals of uniform rectangular section.—It has been frequently found convenient at Lowell, to gauge large streams of water by causing them to flow through short rectangular canals of uniform section, and a particular method of obtaining the mean velocity has been practised, which will now be described.

A convenient part of the feeding canal is selected and lined with timbers and planks, so as to make a smooth and uniform rectangular channel; this is called a flume. The mean velocity is obtained by means of tubes, loaded at one end, so that they may float in nearly a perpendicular position, the lower ends just clearing the bottom of the flume; these tubes are put in near the upper end of the flume, and from the observed paths and velocities that they assume through a defined portion of the length of the flume, a mean velocity is deduced. The times of the transits are observed by the same chronometer, the signals being made by an electric telegraph erected for the purpose. The telegraph used for this purpose is a very simple apparatus; the circuit is formed by an insulated copper wire, about $\frac{1}{30}$ of an inch in diameter, and the electric current is maintained by a small galvanic battery. Whenever the circuit is broken, a small electro-magnet becomes demagnetized, which causes a slight blow to be struck on a vertical glass plate, placed near the observer, who notes the times of the transits. The tubes are cylinders, made of tinned plate, about two inches in diameter, and of a length usually a little exceeding the depth of the water in the flume By a comparison of the results obtained by gauging, by the floats and by weir, the error in assuming the average velocity of the floats for that of the stream, was found to be correct within a trifling per centage.

Contrivances to measure the velocity of running waters.—For these purposes, various contrivances have been proposed, of which two or three may be here described.

Suppose it be the velocity of the water in a river that is required; or, indeed, both the velocity and the quantity which flows down it in a given time. Observe a place where the banks of the river are steep and nearly parallel, so as to make a kind of trough for the water to run through, and by taking the depth at various places in crossing make a true section of the river. Stretch a string at right angles over it, and at a small distance another parallel to the first. Then take an apple, an orange, or other small ball, just so much lighter than water as to swim in it, or a pint or quart bottle partly filled with water, and throw it into the water above the strings. Observe when it comes under the first string, by means of a quarter second pendulum, a stop-watch, or any other proper instrument; and observe likewise when it arrives at the second string. By this means the velocity of the upper surface will be obtained. And the section of the river at the second string must be ascertained by taking various depths, as before. If this section be the same as the former, it may be taken for the mean section: if not, add both together, and take half the sum for the mean section. Then the area of the mean section in square feet being multiplied by the distance between the strings in feet, will give the contents of the water in solid feet, which passed from one string to the other during the time of observation; and this by the rule of three may be adapted to any other portion of time. The operation may often be greatly abridged by taking notice of the arrival of the floating body opposite two stations on the shore, especially when it is not convenient to stretch a string across.

M. Pitot invented a stream measurer of a simple construction, by means of which the velocity of any part of a stream may readily be found. This instrument is composed of two long tubes of glass open at both ends: one of these tubes is cylindrical throughout; the other has one of its extremities bent into nearly a right angle, and gradually enlarges like a funnel, or the mouth of a trumpet: these tubes are both fixed in grooves in a triangular prism of wood; so that their lower extremities are both on the same level, standing thus one by the side of the other, and tolerably well preserved from accidents. The frame in which these tubes stand is graduated, close by the side of them, into divisions of inches and lines.

To use this instrument, plunge it perpendicularly into the water, in such manner that the opening of the funnel at the bottom of one of the tubes shall be completely opposed to the direction of the current, and the water pass freely through the funnel up into the tube. Then observe to what height the water rises in each tube, and note the difference of the sides: for this difference will be the height due to the velocity of the stream. It is manifest, that the water in the cylindrical tube will be raised to the same height as the surface of the stream, by the hydrostatic pressure: while the water entering from the current by the funnel into the other tube, will be compelled to rise above that surface by a space at which it will be sustained by the impulse of the moving fluid: that is, the momentum of the stream will be in equilibrio with the column of water sustained in one tube above the surface of that in the other. In estimating the velocity by means of this instrument, we must have recourse to theory as corrected by experiments. Thus, if h, the height of the column sustained by the stream, or the difference of heights in the two tubes, be in feet, we shall have $v = 6·5 \sqrt{h}$, nearly, the velocity, per second, of the stream; if h be in inches, then $v = 22·47 \sqrt{h}$, nearly: or further experiments made with the instrument itself may a little modify these coefficients.

NOTE. In an example like this, it is a good approximation, *to multiply continually together, the area of the orifice, the number* 336, ($336 = 5·6 \times 66$,) *and the square root of the depth in feet of the middle of the orifice.*

Thus, in the preceding example, it will be $\frac{1}{2} \times \frac{1}{2} \times 336 \times \sqrt{4·25} = \frac{1}{4} \times 336 \times 2·062 = 173·2$ cubic feet.

The less the height of the orifice compared with its depth under the water, the nearer will the result thus obtained approach to the truth. If the height of the orifice be such as to require consideration, the principle of Art. 6, page 17, may be blended with this rule.

Thus, applying this rule to *Ex.* 2, we shall have area $\times \sqrt{\text{depth}} \times 336 \times \frac{2}{3} = 9 \times 3 \times 224 = 6048$, for the cubic feet discharged. This is less than the former result by about its 900th part. It is, therefore, a good approximation, considering its simplicity: it may, in many cases, supersede the necessity of recurrence to tables.

HYDRO ELECTRICAL MACHINE. The production of electricity by the passage of steam through a small jet, was unknown till 1840. It is now generally concluded that it is the effect of the friction of globules of water against the sides of the opening, urged forward by the rapid passage of the steam; the effect of this is to render the steam or water positive, and the pipes from which it issues negative.

Fig. 2275 represents this machine, as manufactured by Benjamin Pike, Jr., of 294 Broadway, New York, in which A A, &c., are six green glass supports, three feet long; B is a cylindrical tubular boiler of rolled iron plate, [illegible] inch thick; its extreme length is seven feet six inches, one foot of which is occupied by the smoke-chamber, making the actual length of the boiler six and a half feet; its diameter three and a half feet. The furnace D and ash-hole C are contained within the boiler, and are furnished with a metal screen to be applied for the purpose of excluding the light during the progress of one class of experiments; F is the water-gage; E the feed valve; J J are two tubes leading from the valves K K to the two tubes H; A and I are forty-six bent iron tubes, terminating in jets, either half or the whole of which may be opened by means of the lever G G; L is a valve for liberating steam during the existence of the maximum pressure; M is the safety-valve; N is a cap covering a jet, that is employed for illustrating a certain mechanical action of a jet of steam; O is the first portion of the funnel, P the second portion, which slides into itself by a telescope joint, so that the boiler may be insulated when the experiments commence. The boiler is cased in wood.

Fig. 2276, which may be called the prime conductor, but which is not used for the purpose, is a zinc case, furnished with four rows of points. It is placed in front of the jets, in order to collect the elec tricity from the ejected vapor, and thus prevent its returning to restore the equilibrium of the boiler The maximum pressure at the commencement of the experiments is 80 pounds, which gradually gets reduced to 40 pounds, or lower. The portion of the apparatus which is peculiarly connected with the generation of the electricity, is a series of bent tubes with their attached jets. Each jet consists of a brass socket, containing a cylindrical piece of partridge-wood, with a circular hole or passage through it, $\frac{1}{8}$ of an inch in diameter, into which the steam is admitted through an aperture. The peculiar shape of this aperture appears to derive its efficacy from the tendency it gives the steam to spread out in the form of a cup, on entering the wooden pipe, and by that means to bring it and the particles of water of which it is the carrier, into very forcible collision with the rubbing surface of the wood.

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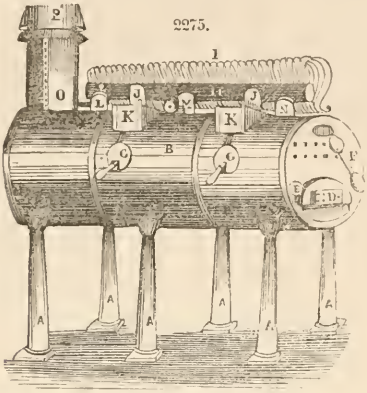

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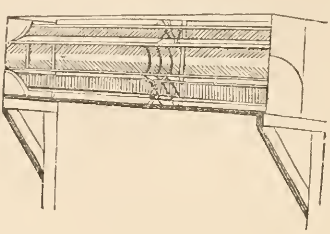

The electricity produced by this engine is not so remarkable for its high intensity, as for its enormous quantity. In no case, antecedent to this, has the electricity of tension taken so rapid a stride towards assimilating with galvanic electricity. Mr. Faraday's experiments on the identity of the electricities had shown how small was the quantity obtained from the best machines; and had given good reason to expect that chemical effects would be exalted when the quantity could be increased. And such is the case here; a very remarkable experiment in illustration of this is, that not only is gunpowder ignited by the passage of the spark, but even paper and wood shavings will be inflamed when placed in the course of the spark passing between two points—such an effect was never before produced with common electricity. In like manner, chemical decompositions are effected much more readily by means of the hydro-electric, than by that from the common machine.

HYDRO-EXTRACTOR. An apparatus for removing liquids or moisture from yarns or cloths in the process of manufacture. The main feature or principle of the machine is extremely simple, consisting merely of a circular open wire-basket, in which the wet cloths are placed as uniformly as possible, and which is then made to revolve with such rapidity that the moisture is thrown out by the centrifugal force through the interstices of the basket. As the vis inertiæ prevents the instant communication of a sufficient velocity to the basket loaded with heavy goods, various expedients have been resorted to to make communicated velocity progressive. The contrivances for this purpose, on the original English patent, are extremely complicated; but the arrangement shown in Fig. 2277, (which is an exterior view of the machine and the driving apparatus,) is much more simple, and perfectly effective. It is the invention of M. C. Bryant, of Lowell, Massachusetts. The whole machine rests on two square bed-stones; the outside of the case, or tub, is only shown in the figure, within which the wire-basket, open at the top for the reception of the goods, revolves on a vertical shaft; to this shaft motion is communicated from the horizontal shaft beneath the tub by means of bevel-geers. On the extremity of this horizontal shaft is fixed the driving-pulley, (as shown in the figure.) This pulley is of

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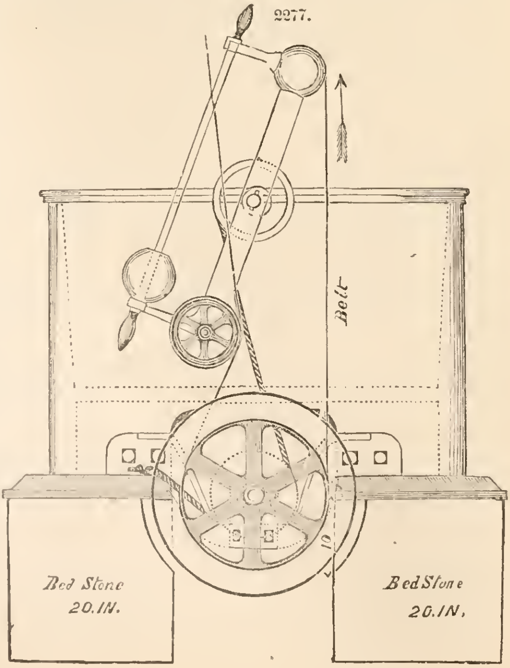


the form usually employed on small tilt or trip hammers; a belt passing round this pulley, and continually moving, communicates motion to the pulley whenever a binder brings the belt in close contact with its periphery. The binder is attached to an extremity of an oscillating frame, suspended from the top of the tub, as shown in the figure. The binder presses against the belt so as to communicate motion to the pulley. To stop the motion, the upper end of the oscillating binder-frame is pressed down by a handle; the binder relieves the belt, and a rope attached to the periphery of a small pulley on the binder-frame passing over a pulley fixed on the horizontal driving-shaft, and fastened at the other end to the bottom of the tub, acts as a friction-brake to retard the motion of the shaft, and consequently of the basket. To keep the binder-frame in extreme positions a movable weight is placed on the handle rod at the top of the frame, which slides from one end to the other of the rod, as the binder is raised or depressed.

The basket in this hydro-extractor is about three and a half feet in diameter; and in full action, should make about 800 revolutions per minute. The driving-belt is about eight inches wide; the driving-pulley eighteen inches diameter.

This machine is in operation at the Bay State Mills, in Lawrence, and at the carpet mill in Lowell; and machines similar in the main principle are employed in many of the mills in this country, and give complete satisfaction.

HYDROMETER. An instrument for determining the specific gravities of liquids, and thence the strength of spirituous liquors; these being inversely as their specific gravities. Various instruments of different forms have been proposed for ascertaining readily the specific gravities of fluids, but only two or three of them are deserving of description.

The hydrometer represented in Fig. 2278 consists of a hollow glass ball B, with a smaller ball C appended to it, and which, from its superior weight, serves to keep the instrument in a vertical position, to whatever depth it may be immersed in a liquid. From the large ball rises a cylindrical stem *a d*, on which are marked divisions into equal parts; and the depth to which the stem will sink in water, or any other liquid fixed on as a standard of specific gravity, being known, the depth to which it sinks in a liquid whose specific gravity is required, will indicate, by the scale, how much greater or less it is than that of the standard liquid.

Those most celebrated are the scales of Baumé, Cartier, Twaddell, and Guy Lussac. Most of these scales are arbitrary, and formed after the ideas of their projectors, but having no particular reference by which they may be understood.

The centesimal hydrometer, by Guy Lussac, is an exception, the extreme points being water and absolute alcohol; this space is divided into one hundred parts, thus showing in alcoholic mixtures the per centage of alcohol in the liquid. They are made of glass, brass, and silver, usually from six to ten inches long, of the form represented in the cut, the graduations being marked on the stem.

2278.

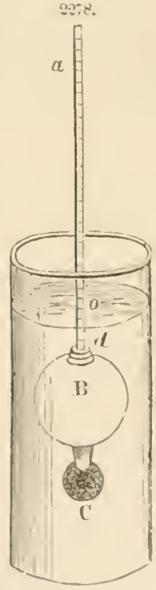


TABLE *showing the Comparative Scales of Guy Lussac and Baumé, with the Specific Gravities and Proof, at the Temperature of* 60°.

Guy Lussac's Scale. (Per centage of pure alcohol.)	Baumé's Scale.	Specific Gravity.	Proof.
100	45	796	100 (Per centage over proof.)
95	40	815	92
90	36	833	82
85	33	848	72
80	31	863	62
75	28	876	52
70	26	889	42
65	24	901	32
60	23	912	22 4th proof.
55	21	923	12
50	19	933	0 Proof.
45	18	942	8 (Under proof.)
40	17	951	18
35	16	958	29
30	15	964	35
25	14	970	48

Explanation of Baumé's scale.—Manufacturers who employ Baumé's hydrometer, or have occasion to know the value of the degrees on his scale, may find the following formula useful:—

Let B = Baumé's degrees, and 100 = water. Then

$$\text{Specific gravity} = \frac{144}{144 - B}.$$

That is to say, 144 divided by the difference between 144 and the given degree of Baumé, is the specific gravity in question, stated in reference to water assumed = 100. Thus, suppose Baumé = 66°. Then

$$\text{Specific gravity} = \frac{144}{144 - 66} \text{ or } \frac{144}{78} = 1{\cdot}846 = \text{specific gravity}.$$

Scale of Specific Gravities indicated by Twaddell's Scale.

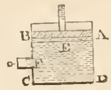
Twaddell.	Sp. Gr.	Twaddell.	Sp. Gr.	Twaddell.	Sp. Gr.	Twaddell.	Sp. Gr.
0	1000	50	1250	100	1500	150	1750
10	1050	60	1300	110	1550	160	1800
20	1100	70	1350	120	1600	170	1850
30	1150	80	1400	130	1650	180	1900
40	1200	90	1450	140	1700	190	1950

Hydrometer with weights.—There is a variety of kinds of hydrometers, with weights; the principal ones are Dica's and Sikes's. They are used for ascertaining the strength of spirituous liquors.

Another easy method of determining the densities of different liquids, frequently practised, is by means of a set of glass beads previously adjusted and numbered. Thrown into any liquid, the heavier balls sink and the lighter float at the surface; but one of them approaching the density of the liquid will be in a state of indifference as to buoyancy, or will float under the surface. The number on this ball indicates, in thousandth parts, the specific density of the liquid.

HYDROSTATIC PRESS. If there be any number of pistons of different magnitudes, any how applied to apertures in a cylindrical vessel filled with an incompressible and non-elastic fluid, the forces acting on the pistons to maintain an equilibrium, will be to one another as the areas of the respective apertures, or the squares of the diameters of the pistons.

Let A B C D represent a section passing along the axis of a cylindrical vessel filled with an incompressible and non-elastic fluid, and let E F be two pistons of different magnitudes, connected with the cylinder and closely fitted to their respective apertures or orifices; the piston F being applied to the aperture in the side of the vessel, and the piston E occupying an entire section of the cylinder or vessel, by which the fluid is contained.



Then, because by the nature of fluidity, the pressures on every part of the pistons E and F, are mutually transmitted to each other through the medium of the intervening fluid; it follows that these pressures will be in a state of equilibrium when they are equal among themselves.

Now, it is manifest, that the sum of the pressures propagated by the piston E, is proportional to the area of a transverse section of the cylinder; and in like manner the sum of the pressures propagated by the piston F is proportional to the area of the aperture which it occupies; consequently, an equilibrium must obtain between these pressures when the forces on the pistons are to one another, respectively, as the areas of the apertures or spaces which they occupy.

Hence it appears, that by taking the areas of the pistons E and F, in a proper ratio to one another, we can, by means of an incompressible fluid, produce an enormous compression, and that too by the application of a very small force.

Put $P =$ the force or pressure on the piston E,
$A =$ the area of the orifice which it occupies,
$p =$ the pressure on the piston F, and
$a =$ the area of the orifice or space to which it is fitted:

then, according to the principle announced in the foregoing proposition and demonstrated above, we shall obtain

$$a : A :: p : P.$$

But because, by the principles of mensuration, the areas of different circles are to one another as the squares of their diameters; if, therefore, we substitute d^2 and D^2 respectively for a and A in the above analogy, we shall have

$$d^2 : D^2 :: p : P;$$

and from this, by making the product of the mean terms equal to the product of the extremes, we get the general equation,

$$p\,D^2 = P\,d^2 \ldots\ldots\ldots\ldots (A)$$

This is the principle upon which depends the construction and use of that very powerful instrument, the *Hydrostatic Press*, first brought into notice about the year 1796, by Joseph Bramah, Esq., of London.

The improvement introduced by Mr. Bramah, consisted in the application of the common forcing-pump to the injection of water, or some other incompressible and non-elastic fluid, into a strong metallic cylinder, truly bored and furnished with a movable piston, made perfectly water-tight by means of leather collars or packing, neatly fitted into the cylinder.

The proportion which subsists between the diameter of this piston, and that of the plunger in the forcing-pump, constitutes the principal element by which the power of the instrument is calculated; for, by reason of the equal distribution of pressure in the fluid, in proportion as the area of the transverse section of the one exceeds the area of a similar section of the other, so must the pressure sustained by the one exceed that sustained by the other.

Therefore, if the piston F, in the preceding diagram, be assimilated to the plunger in the barrel of a forcing-pump, and the piston E to that in the cylinder of the hydrostatic press; then, the equation (A) involves every particular respecting the power and effects of the engine.

Example. If the diameter of the cylinder is 5 inches, and that of the forcing-pump one inch; what is the pressure on the piston in the cylinder, supposing the force applied on the plunger or smaller piston to be equivalent to 750 lbs.?

Here we have given $D = 5$ inches, $d = 1$ inch, and $p = 750$ lbs.; therefore, by substitution, equation (A) becomes

$$5^2 \times 750 = P \times 1^2; \text{ that is, } P = \frac{pD^2}{d^2} = 18{,}750 \text{ lbs.}$$

Rule.—Multiply the square of the diameter of the cylinder by the pressure on the piston, of the forcing pump, and divide the product by the square of its diameter, and the quotient will express the intensity of the pressure on the piston of the cylinder.

$$p = \frac{P\,d^2}{D^2}:$$ or, in words:—

Rule.—Multiply the given pressure on the piston of the cylinder by the square of the diameter of the forcing pump, and divide the product by the square of the diameter of the cylinder for the power required.

$$D = \sqrt{\frac{P\,d^2}{p}}.$$

Rule.—Multiply the pressure on the piston of the cylinder by the square of the diameter of the forcing pump, and divide the product by the force with which the plunger descends; then the square root of the quotient will be the diameter of the cylinder sought.

$$d = \sqrt{\frac{p\,D^2}{P}}.$$

Rule.—Multiply the force with which the plunger descends by the square of the diameter of the cylinder and divide the product by the entire pressure on the piston; then extract the square root of the quotient for the diameter of the forcing pump.

The Hydrostatic press is generally furnished with an *indicator* or *safety-valve* for measuring the intensity of pressure, which may be easily estimated by considering the diameter of the valve, and the pressure upon it as the plunger of the forcing pump, and using previous rules.

To determine the thickness of metal in the cylinder to withstand the required pressure.—The amount of force which tends to rupture the cylinder along the curved side, that is to divide the cylinder in halves lengthways, is equal to the pressure per square inch on each lineal unit of the diameter multiplied by the length of the cylinder.

Thus, let the piston of a hydraulic press be 10 inches in diameter, and the pressure 300 tons *net*: then the pressure per square inch of piston will be 300 tons divided by the number of square inches in the piston, or $\frac{600.000}{78.54} = 7.639$ lbs. The pressure per inch in length of the cylinder tending to split or tear it apart, is equal to the diameter multiplied by the pressure per square inch, or in this case, $10 \times 7639 =$ 76,390 lbs., of which, of course, each side sustains one half.

The cohesive strength of cast iron varies from 13,000 to 20,000 lbs. per square inch; of wrought iron, from 50 to 60,000 lbs.; 8,000 lbs. may be taken as the safe limit for cast iron, 20,000 for wrought iron: hence, to withstand a force equal $\frac{76390}{2}$ or 38,195 lbs. on each side; the thickness, if cast iron, should be about 5 inches; if wrought iron, 2 inches.

Presses made to withstand but little pressure, that is per square inch, are mostly made with cylinders of cast iron. Some of the cylinders of large presses are made of cast iron, bound with wrought iron hoops, as fig. 2289, but the best material to withstand great pressure, is wrought iron. Of this material R. Hoe & Co., of New York, make their presses, and of this are the jacks of R. Dudgeon constructed.

An English rule for the construction of cast iron cylinders, is to make the thickness of metal equal to the interior radius of the cylinder, and to determine the entire pressure in tons. When the diameter of the cylinder is given, the following simple rule is used:

Rule.—Multiply the square of the diameter in inches by the constant number, 2·9186, and the product will be the pressure in tons.

And again, when the pressure in tons is given, the diameter of the cylinder may be determined by reversing the process, or by the following rule:

Rule.—Divide the given pressure in tons by the constant number 2·9186, and extract the square root of the quotient for the diameter of the cylinder in inches.

Example.—The diameter of the cylinder in a hydrostatic press, is 10 inches; what is its power, or what pressure does it transmit?

Here, by the first rule above, we have, $P = 10^2 \times 2{\cdot}9186 = 291{\cdot}86$ tons.

Example.—What is the diameter, and what the thickness of metal, in a press of 300 tons power?

By the second rule above, we have, $D^2 = 300 \div 2{\cdot}9186 = 102{\cdot}81$ nearly;

therefore by extracting the square root, we obtain, $D = \sqrt{102{\cdot}81} = 10{\cdot}13$ inches; consequently, the thickness of metal is, $t = 10{\cdot}13 \div 2 = 5{\cdot}065$ inches.

The hydrostatic press is one of the most convenient and simplest of all machines for transmitting great force; it is used for punching, pressing, lifting and pulling. It was used for raising the immense tubes of the CONWAY TUBULAR BRIDGE, and is in general use for the baling and pressing of materials and goods. At the United States Navy Yard, Washington, it is used as a PROVING MACHINE for proving chain cables; as a JACK it is made portable, and is applicable to all the purposes for which such machines are intended.

Figs. 2280, 2283 represent the front and side elevation of a small hydraulic press with a hand forcing pump: F is a strong metallic cylinder of cast-iron, or some other material of sufficient density to prevent the fluid from issuing through its pores, and of sufficient strength to preclude the possibility of rupture, by reason of the immense pressure which it is destined to withstand.

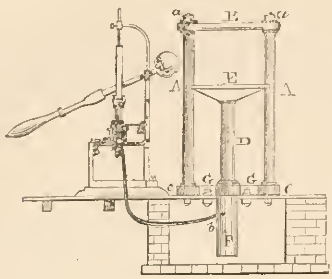
The cylinder F is bored and polished with the most scrupulous precision, and fitted with the movable piston D, which is rendered perfectly water-tight, by means of leather collars constructed for the purpose, and fixed in the cylinder by a simple but ingenious contrivance to be described hereafter.

Into the side or base of the cylinder F, the end of a small tube *b b b* is inserted, and by this tube the water is conveyed or forced into the cylinder; the other end of the tube is attached to the forcing-pump as represented in Fig. 2280; but this will be more particularly explained in another place.

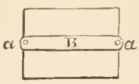
A A are two very strong upright bars, generally made of wrought-iron, and of any form whatever corresponding to the notches in the sides of the flat table E, which is fixed upon the end of the piston D and by workmen is usually denominated the "*follower*" or "*pressing-table*."

B is the top of the frame into which the upright bars A A are fixed, and *c c* is the bottom thereof both of which are made of cast, in preference to wrought-iron, being both cheaper and more easily moulded into the intended form.

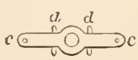
2280.



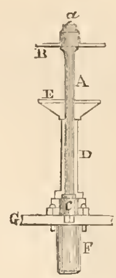
2281.



2282.



2283.



The bottom of the frame *c c* is furnished with four projections or lobes, with circular perforations, for the purpose of fastening it by iron bolts to the massive blocks of wood, whose transverse sections are indicated by the lighter shades at G G. The top B has two similar perforations, through which are passed the upper extremities of the vertical bars A A, and there made fast, by screwing down the *cup-nuts* represented at *a* and *a*.

Fig. 2281 represents the plan of the top, or, as it is more frequently termed, the head of the frame; the lower side or surface of which is made perfectly smooth, in order to correspond with, and apply to the upper surface of the pressing-table E, in Fig. 2280; this correspondence of surfaces becomes necessary on certain occasions such as the copying of prints, taking fac-similes of letters, and the like; in all such cases, it is manifest, that smooth and coincident surfaces are indispensable for the purpose of obtaining true impressions.

Fig. 2281 represents the upper side of the block, in which the middle part B (through whose rounded extremities *a* and *a*, the circular perforations are made for receiving the upright bars or rods A A, Fig. 2280, is considerably thicker than the parts on each side of it; this augmentation of thickness is necessary to resist the immense strain that comes upon it in that part; for although the pressure may be equally distributed throughout the entire surface, yet it is obvious that the mechanical resistance to fracture must principally arise from that part which is subjected to the reaction of the upright bars.

Fig. 2282 represents the plan of the base or bottom of the frame; it is generally made of uniform thickness, and of sufficient strength to withstand the pressure; for be it understood, that all the parts of the machine are subjected to the same quantity of strain, although it is exerted in different ways. The upright bars, cylinders, and connecting-tubes resist by tension, the pistons by compression, and the pressing-table, together with the top and bottom of the frame, resist transversely.

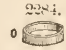
The circular perforations *c c* correspond to *a a* in the top of the frame, and receive the upright bars in the same manner; the perforations *d d d d* receive the screw-bolts which fix the frame to the beams of timber represented at G G, Fig. 2280; the large perforation F receives the cylinder, the upper extremity of which is furnished with a flanch, for the purpose of fitting the circular swell around the perforation, and preventing it from moving backwards during the operation of the instrument.

A side view of the engine, as thus completed, is represented in Fig. 2283, where, as is usual in all such descriptions, the same letters of the alphabet refer to the same parts of the structure.

F is the cylinder into which the fluid is injected; D the piston, on whose summit is the pressing-table E; A one of the upright rods or bars of malleable iron; B the head of the press, fixed to the upright bar A by means of the *cup-nut a*; *c* the bottom, in which the upright bar is similarly fixed; and G a beam of timber supporting the frame with all its appendages.

But the *hydrostatic press*, as here described and constructed, must not be considered as fit for immediate action; for it is manifestly impossible to bore the interior of the cylinder so truly, and to turn the piston with so much precision, as to prevent the escape of water between their surfaces, without increasing the friction to such a degree, that it would require a very great force to counterbalance it.

2284.

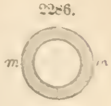


In order, therefore, to render the piston water-tight, and to prevent as much as possible the increase of friction, recourse must be had to other principles, which we now proceed to explain.

2285.

The piston D is surrounded by a collar of pump leather *o o*, represented in Fig. 2284, which collar being doubled up, so as in some measure to resemble a lesser cup placed within a greater, it is fitted into a cell made for its reception in the interior of the cylinder; and when there, the two parts are prevented from coming together by means of the copper ring *p p*, represented in Fig. 2285, being inserted between the folds, and retained in its place, by a lodgment made for that purpose on the interior of the cylinder.

2286.



The leather collar is kept down by means of a brass or bell-metal ring *m m*, Fig. 2286, which ring is received into a recess formed round the interior of the cylinder, and the circular aperture is fitted to admit the piston D to pass through it, without materially increasing the effects of friction, which ought to be avoided as much as possible.

The leather is thus confined in a cell, with the edge of the inner fold applied to the piston D, while the edge of the outer fold is in contact with the cylinder all around its interior circumference; in this situation, the pressure of the water acting between the folds of the leather, forces the edges into close contact with both the cylinder and piston, and renders the whole water-tight; for if the leather be properly constructed and rightly fitted into its place, it is almost impossible that any of the fluid can escape; for the greater the pressure, the closer will the leather be applied to both the piston and the cylinder.

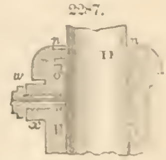
The metal ring *m m* is truly turned in a lathe, and the cavity in which it is placed is formed with the same geometrical accuracy; but in order to fix it in its cell, it is cut into five pieces by a very fine saw, as represented by the lines in Fig. 2286, which are drawn across the surface of the ring. The four segments which radiate to the centre are put in first, then the segment formed by the parallel kerfs, (the copper ring *p p* and the leather collar *o o* being previously introduced,) and lastly, the piston which carries the pressing-table.

That part of the cylinder above the ring *m m*, where the inner surface is not in contact with the piston, is filled with tow, or some other soft material of a similar nature; the material thus inserted has a twofold use: in the first place, when saturated with sweet oil, it diminishes the friction that necessarily arises, when the piston is forced through the ring *m m*; and in the second place, it prevents the admission of any extraneous substance, which might increase the friction or injure the surface of the piston, and otherwise lessen the effects of the machine.

The packing here alluded to, is confined by a thin metallic annulus, neatly fitted and fixed on the top of the cylinder, the circular orifice being of sufficient diameter to admit of a free and easy motion to the piston.

If a cylinder thus furnished with its several appendages be placed in the frame, and the whole firmly screwed together and connected with the forcing-pump, as represented in Fig. 2280, the press is completed and ready for immediate use; but in order to render the construction still more explicit and intelligible, and to show the method of connecting the press to the forcing-pump, let Fig. 2287 represent a section of the cylinder with all its furniture, and a small portion of the tube immediately adjoining, by which the connection is effected.

2287.



Then is F F the cylinder; D the piston; the unshaded parts *o o* the leather collar, in the folds of which is placed the copper ring *p p*, distinctly seen, but not marked in the figure; *m m* is the metal ring by which the leather collar is retained in its place; *n n* the thin plate of copper or other metal fitted to the top of the cylinder, between which and the plate *m m* is seen the soft packing of tow, which we have described above, as performing the double capacity of oiling the piston and preventing its derangement.

The combination at *w x* represents the method of connecting the injecting-tube to the cylinder: it may be readily understood by inspecting the figure; but in order to remove all causes of obscurity, it may be explained in the following manner.

The end of the pipe or tube, which is generally made of copper, has a projecting piece or socket-flanch soldered or screwed upon it, which fits into a perforation in the side or base of the cylinder, according to the fancy of the projector, but in this figure the perforation is in the side.

The tube thus furnished is forcibly pressed into its seat by a hollow screw *w*, called a union screw, which fits into another screw of equal thread made in the cavity of the cylinder; the joint is made water-tight, by means of a collar of leather, interposed between the end of the tube and the bottom of the cavity.

A similar mode of connection is employed in fastening the tube to the forcing-pump, the description of which, although it constitutes an important portion of the apparatus, does not properly belong to this place; the principles of its construction and mode of action must therefore be supposed as known, until we come to treat of the construction and operation of pumps in general.

Admitting, therefore, that the action of the forcing-pump is understood, it only now remains to explain the nature of its operation in connection with the *hydrostatic press*, the construction of which we have so copiously exemplified.

In order to understand the operation of the press, we must conceive the piston D, Fig. 2280, as being at its lowest possible position in the cylinder, and the body or substance to be pressed, placed upon the crown or pressing-table E; then it is manifest, that if water be forced along the tube *b b b* by means of the forcing-pump, it will enter the chamber of the cylinder F immediately beneath the piston D, and cause it to rise a distance proportioned to the quantity of fluid that has been injected, and with a force determinable by the ratio between the square of the diameter of the cylinder and that of the forcing pump. The piston thus ascending, carries its crown, and consequently, the load along with it, and by repeating the operation, more water is injected, and the piston continues to ascend, till the body comes into contact with the head of the frame B, when the pressure begins; thus it is manifest, that by continuing the process, the pressure may be carried to any extent at pleasure; but we have already stated, in developing the theory, that there are limits, beyond which, with a given bore and a given thickness of metal, it would be unsafe to continue the strain.

When the press has performed its office, and it becomes necessary to relieve the action, the discharging valve, placed in the furniture of the forcing pump, must be opened, which will admit the water to escape out of the cylinder and return to the cistern, while the table and piston by means of their own weight, return to their original position.

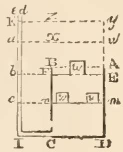
Theory of construction and description of the hydrostatic weighing machine.—If into the side of an open cylindrical or other vessel a bent tube be inserted, and if on the surface of the fluid a movable cover exactly fitting the vessel be placed with a weight upon it, and the tube graduated:—

Then, any additional weight placed upon the cover, may be determined by knowing the height to which the fluid rises in the tube; and conversely:—If the additional weight be known, the height to which the fluid rises in the tube may be found.

Let A B C D represent a vertical section of a cylindrical vessel, or of any other vessel, whose sides are perpendicular to the horizon; and let K I C be the corresponding section of the equilibrating tube.

Let both the vessel and the communicating tube be open at the upper parts A B and $d e$, and conceive the vessel to be filled with fluid to the line E F or altitude D E; then, on the surface of the fluid at E F, let there be placed a movable cover exactly fitting the vessel, so that the whole may be water-tight.

2288.



Produce E F to b, then is the point b at the same level in the tube I K, as the surface of the fluid in the vessel whose level is E F: upon the cover E F let the weight w be placed, and suppose a to be the point in the tube, to which the fluid will rise by the action of the cover, together with the weight w which is placed upon it; in this case, the machine is in a state of equilibrium.

If some additional weight w' be placed upon the cover, then the original equilibrium will be destroyed, and can only be restored by the fluid ascending in the tube to a sufficient height to balance the additional weight.

Put D = A B or D C, the diameter of the cylindrical vessel, of which A B C D is a section,
$d = d e$, the diameter of the communicating tube K I C,
$h = b a$, the height of the original equilibrating column,
w = the weight supported by the column $b a$,
w' = the additional weight, whose quantity is required,
$h' = a$ K, the increased altitude of the supporting column,
δ = E m, the descent of the cover occasioned by the additional load w', and
s = the specific gravity of the fluid.

Then it is manifest, that when the equilibrium originally obtains; that is, when the surface of the fluid in the tube is at a, and that in the vessel at E F, the pressure of the fluid in the tube exerted at b, is

$$p = \cdot 7854\ d^2 h s,$$

where the symbol p denotes the pressure at b; omitting the steps of the algebraic calculation, we obtain

$$w' = 7854\ h' s\ (D^2 + d^2).$$

If the fluid be water, whose specific gravity is represented by unity, the equation becomes somewhat simpler; for in that case, we have

$$w' = \cdot 7854\ h'\ (D^2 + d^2).$$

From this equation the magnitude of the additional weight, or the measure by which it is expressed, can very easily be ascertained; and the practical rule by which it is discovered is as follows:

Rule.—Multiply the sum of the squares of the diameters by ·7854 times the rise of the fluid in the tube, or the elevation above the first level, and the product will express the magnitude of the additional weight.

Example.—The diameter of a cylindrical vessel is 16 inches, and that of the communicating tube one inch; now, supposing the machine in the first instance to be in a state of equilibrium, and that by the addition of a certain weight on the movable cover, the water in the tube rises 6 inches above the original equilibrating level; how much weight has been added?

By proceeding, according to the rule, we have $D^2 + d^2 = 16^2 + 1^2 = 256 + 1 = 257$,
and by multiplication, we obtain $w' = \cdot 7854 \times 6 \times 257 = 1211 \cdot 0868$ avoirdupois lbs.

If the additional weight by which the water is made to rise in the tube be given, the distance above the first level to which it will rise, can easily be found; for let both sides of the equation $w' = \cdot 7854\ h'$ $(D^2 + d^2)$ be divided by the quantity $\cdot 7854\ (D^2 + d^2)$, and we shall obtain

$$h' = \frac{w'}{\cdot 7854\ (D^2 + d^2)}.$$

And from this equation, we deduce the following rule:—

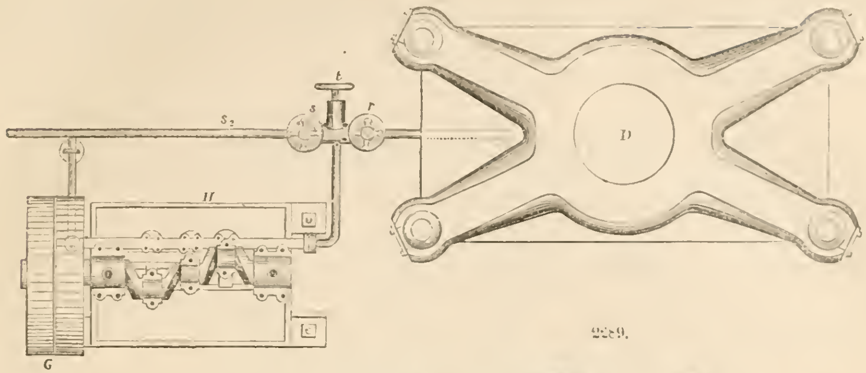
Rule.—Divide the additional weight by the sum of the areas of the movable cover and the cross section of the communicating tube, and the quotient will give the height to which the fluid will rise above the first level.

Example.—The diameter of the movable cover is 16 inches, and that of the communicating tube one inch; then, supposing that the machine in the first instance is brought to a state of equilibrium, and that a load of 1211 lbs. is applied on the cover, in addition to that which produces the equipoise; to what height above the first level will the water ascend in the communicating tube?

Proceeding, according to the rule, we obtain $\cdot 7854\ (D^2 + d^2) = \cdot 7854\ (16^2 + 1^2) = 201 \cdot 8478$ divisor;

consequently, by division it is $h' = \frac{1211}{201 \cdot 8478} = 6$ inches nearly.

And exactly after the manner of these two examples, may any other case be calculated; but in applying the principles to the determination of weights, mercury ought to be employed in preference to water, as it exerts an equal influence in less space, and besides, it is not subject to a change of density by putrefaction and the like.



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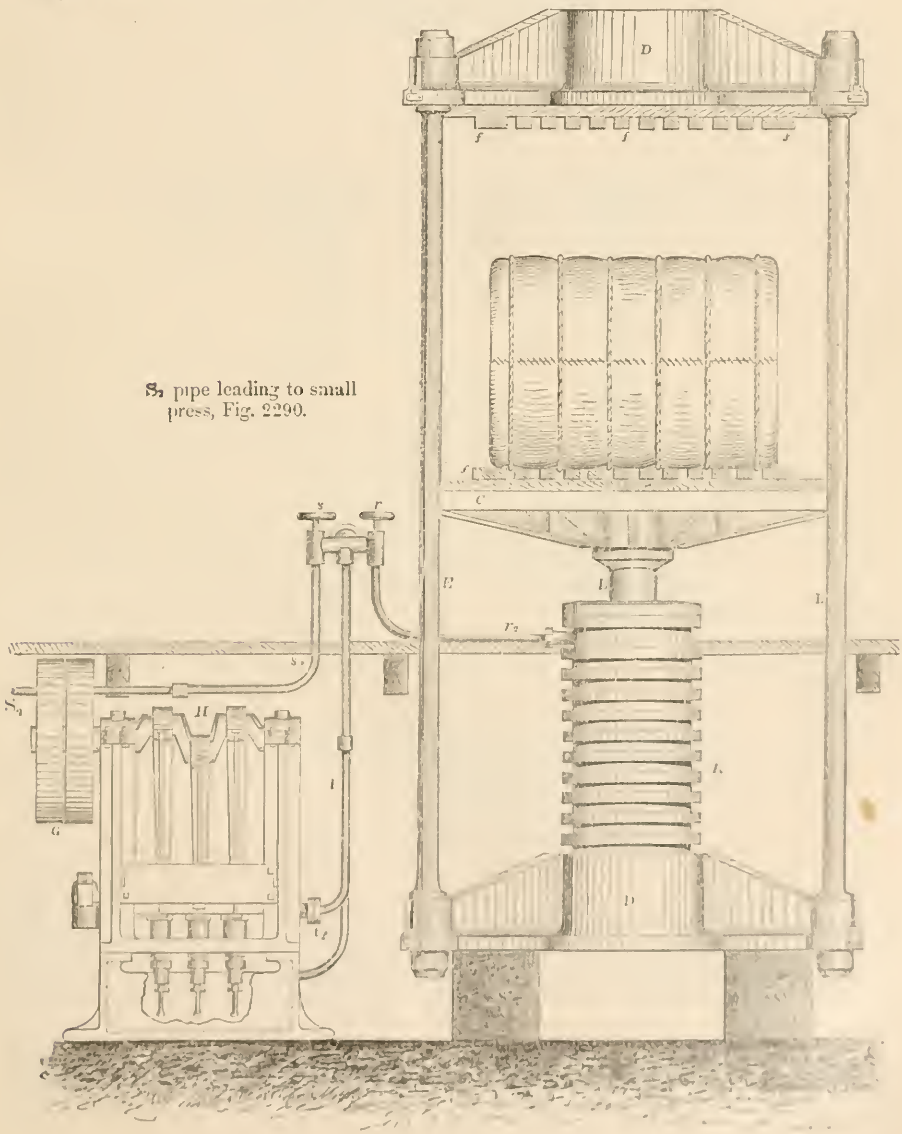
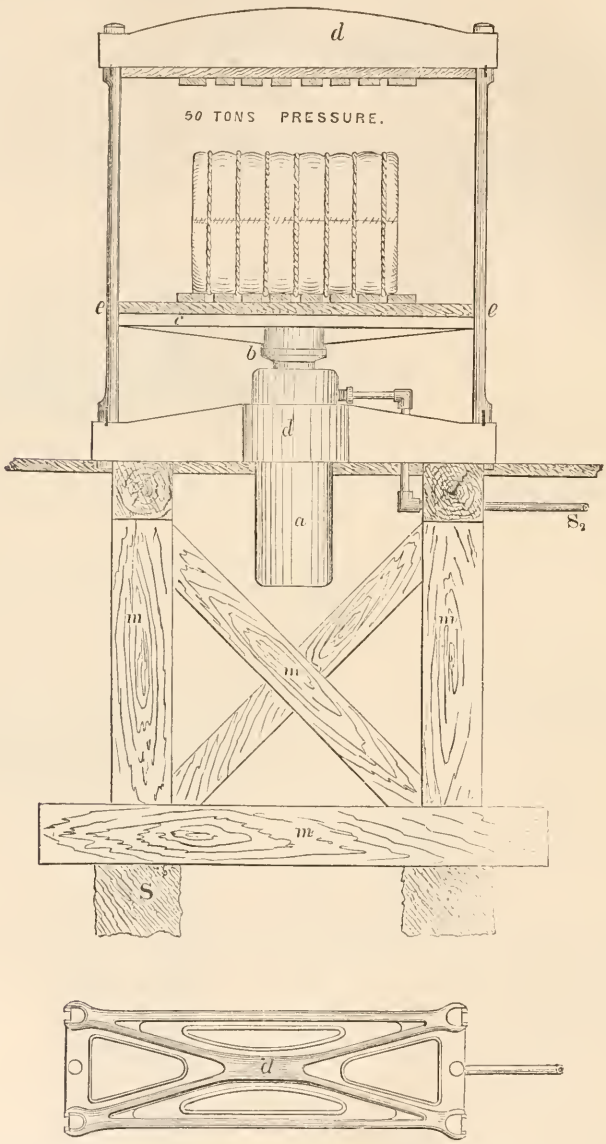


S_2 pipe leading to small press, Fig. 2290.

Figs. 2280 and 2290 show the elevation and plan of a press capable of giving a pressure equal to 200 tons weight; also of a press which is suitable for a pressure of 50 tons weight. By the arrangement shown, one set of pumps is sufficient to operate both presses.

2290.



The hand-wheels *s* and *r* operate valves which can be opened or shut as is wanted, so as to connect or shut off either press from the pumps. *w* is a hand-wheel moving a valve which allows either of the press cylinders to be drawn off, and returns the water into the tank under the pump through the pipe t^2. *t* is a pipe through which the water is pumped on its passage to the presses until it reaches the valves *s* and *r*, where it passes through the pipes r^2 or s^2 to either or both presses, as is wanted. The pumps have three pistons, which are operated by the three-throw crank H, and are driven by means of the pulleys G.

s s s s are foundation blocks, of stone, on which the presses are placed. *m m m m* is a wooden frame under the small press to raise it to a convenient height. A and *a*, are the chambers or cylinders of the presses. B and *b*, are the pistons. D D and *d d*, are the top and bottom pieces, and E E, *e c*, are the columns to the frames. C and *c*, are the platens or followers which are moved up by the pistons B and *b*. These presses are from the Lowell Machine Shop.

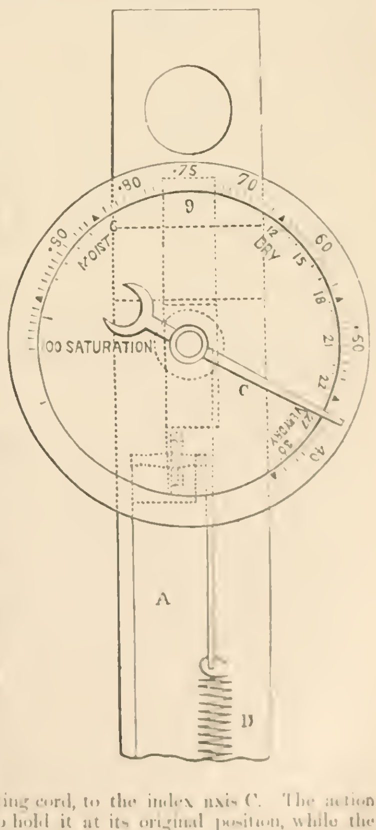
HYGROMETER, an instrument for measuring the degrees of moisture or dryness of the atmosphere

Variations in the state of the atmosphere, with respect to moisture and dryness, are manifested by a great variety of phenomena, and, accordingly, numerous contrivances have been proposed for ascertaining the amounts of those variations by referring them to some conventional scale. All such contrivances are called *hygrometers;* but though the variety of form that may be given to them, or of substances that may be employed, is endless, they may all be referred to two classes; namely, 1st, those which act on the principle of *absorption;* and, 2d, those which act on the principle of *condensation.*

1. *Hygrometers on the principle of absorption.*—Many substances in each of the three kingdoms of nature absorb moisture from the atmosphere with greater or less avidity, and thereby suffer some change in their dimensions, or weight, or some of their physical properties. Animal fibre is softened and relaxed, and consequently elongated, by the absorption of moisture. Cords composed of twisted vegetable substances are swollen, and thereby shortened, when penetrated by humidity; and the alternate expansion and shrinking of most kinds of wood, especially when used in cabinet-work, and after the natural sap has been evaporated, is a phenomenon with which every one is familiar. Many mineral substances absorb moisture rapidly, and thereby obtain an increase of weight. Now it is evident that any of these changes, either of dimension or of weight, may be regarded as the measure of the quantity of moisture absorbed, from which the quantity of water existing in the atmosphere in the state of vapor is inferred; but many of them are so small in amount, or take place so slowly, that they afford no certain indication of the actual state of the atmosphere at any particular moment.

Saussure's hygrometer consists of a human hair, prepared by boiling it in a caustic ley. One extremity of the hair is fastened to a hook, or held by pincers; the other has a small weight attached to it, by which it is kept stretched. The hair is passed over a grooved wheel or pulley, the axis of which carries an index which moves over a graduated arch. Such is the essential part of the instrument, and it is easy to conceive how it acts. When the surrounding air becomes more humid, the hair absorbs an additional quantity of moisture, and is elongated; the counterpoise consequently descends, and turns the pulley, whereby the index is moved towards the one hand or the other. On the contrary, when the air becomes drier the hair loses a part of its humidity, and is shortened. The counterpoise is consequently drawn up, and the index moves in the opposite direction. The accuracy of the indications of this instrument depends on the assumed principle that the expansion and contraction of the hair are due to moisture alone, and are not affected by temperature, or other changes in the condition of the atmosphere. Experiment shows that the influence of temperature is not very great; but after all precautions have been taken in preparing the instrument, it is found to be exceedingly irregular in its movements, and subject to great uncertainties. Besides, the substance is soon deteriorated, and will scarcely maintain its properties unimpaired during a single year.

2291.



The hygrometer of De Luc consists of a very thin slip of whalebone, cut transversely or across the fibres, and stretched, by means of a spring, between two points. One end is fixed to a bar, while the other acts on the shorter arm of the index of a graduated scale. When the whalebone absorbs moisture it swells, and its length is increased; as it becomes dry it contracts; and the space over which the index moves by the one or the other of these effects, gives the measure of the expansion or contraction, and the corresponding change in the hygrometric state of the atmosphere. The action of this hygrometer appears to be more uncertain than that of Saussure.

The hygrometers which have been proposed on the principle of a change of weight arising from the absorption of moisture, are liable to still greater objections. Changes of weight may indeed be measured with greater accuracy by the common or torsion balance: but in the present case they are so small, that the particles of dust which are at all times floating in the atmosphere may produce a great alteration in the results.

Hygrometer, portable.—This hygrometer is of very simple construction, and is so arranged as to show the humidity of the atmosphere in decimal parts of the saturation, as well as to afford a means of ascertaining the dew-point. Fig. 2291 represents a front elevation of the instrument, with the details dotted. A is the back or main supporting piece, of metal or glass, to which is attached, at the lower extremity, a long thin strip of wood, the grain of which runs in a direction transverse to the length of the strip. The upper end of this strip is attached to the axis of the index C, which points out the degrees of saturation of the atmosphere. A helical spring D is fastened at its lower end to a bracket projecting from the front of the back piece A, its contrary extremity being fastened, by means of a connecting cord, to the index axis C. The action of the spring upon the index is such as to tend constantly to hold it at its original position, while the expansion and contraction of the wood slip, due to the greater or less amount of moisture in the atmosphere, moves the index round accordingly, and thus indicates upon the graduated dial the ratio o moisture existing at the time being.

The dew-point is readily found by first ascertaining the exact temperature at the time of observation, and from this subtracting the number indicated on the dial by the hand C, the remainder being the temperature corresponding to the amount of moisture in the atmosphere, or, as it is technically termed, the dew-point.

2. *Hygrometers on the principle of condensation.*—The instruments of this class are of a more refined nature than those which we have been describing. In order to give an idea of the general principle on which they depend, let us conceive a glass jar, having its sides perfectly clean and transparent, to be filled with water, and placed on a table in a room where the temperature is, for example, 60°, the temperature of the water being the same as that of the room. Let us next suppose pieces of ice, or a freezing mixture, to be thrown into the water, whereby the water is gradually cooled down to 55, 50, 45, &c., degrees. As the process of cooling goes on, there is a certain instant at which the jar loses its transparency, or becomes dim; and on attentively examining the phenomenon, it is found to be caused by a very fine dew, or deposition of aqueous vapor, on the external surface of the vessel. The precise temperature of the water, and, consequently, of the vessel, at the instant when this deposition begins to be formed, is called the *dew-point*, and is capable of being noted with great precision. Now this temperature is evidently that to which, if the air were cooled down, under the same pressure, it would be completely saturated with moisture, and ready to deposit dew on any body in the least degree colder than itself. The difference, therefore, between the temperature of the air, and the temperature of the water in the vessel when the dew begins to be formed, will afford an indication of the dryness of the air, or of its remoteness from the state of complete saturation.

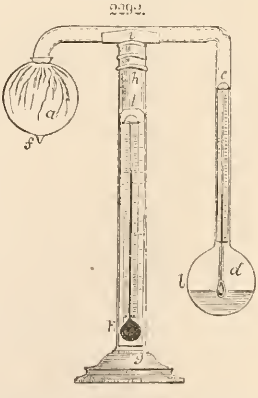
But the observation which has now been described is capable of affording far more interesting and precise results than a mere indication of the comparative dryness or moisture of the atmosphere. With the help of tables of the elastic force of aqueous vapor at different temperatures, it gives the means of determining the absolute weight of the aqueous vapor diffused through any given volume of air, the proportion of vapor existing in that volume to the quantity that would be required to saturate it, and of measuring the force and amount of evaporation.

The elastic force of aqueous vapor at the boiling point of water is evidently equal to the pressure of the atmosphere. This may be assumed as corresponding to a column of mercury 30 inches in height. Mr. Dalton, in the fifth volume of the *Manchester Memoirs*, has given the details of a most valuable and beautiful set of experiments, by which he ascertained the elastic force of vapor from water at every degree between its freezing and boiling points, in terms of the column of mercury which it is capable of supporting. As the same experiments have since been frequently repeated, and the different results present all the accordance which can be expected in so delicate an investigation, the tension of vapor at the different temperatures may be regarded as sufficiently well determined. Supposing, then, we have a table exhibiting the elasticity or tension corresponding to every degree of the thermometer, the weight of a given volume of vapor, for example, a cubic foot, may be determined as follows:—

Steam at 212°, and under a pressure of 30 inches of mercury, is 1700 times lighter than an equal bulk of water at its greatest density, or a temperature of about 40°, and a cubic foot of water at that temperature weighs 437,272 grains; the weight, therefore, of a cubic foot of steam at that temperature and pressure is, $437272 \div 1700 = 257{\cdot}218$ grains. Hence we may find the weight of an equal bulk of vapor of the same temperature under any other given pressure, suppose 0·56 of an inch; for the density being directly as the pressure, we have 30 in. : 0·56 in. : : 257·218 grs. : 4·801 grs., which is the weight required.

Having thus explained the principle of the condensation hygrometer, we will now describe one or two of the forms under which it has been most frequently constructed. Daniell's hygrometer is represented in Fig. 2292: *a* and *b* are two thin glass balls of 1¼ inch diameter, connected together by a tube having a bore about ⅛ of an inch. The tube is bent at right angles over the two balls, and the arm *b c* contains a small thermometer *d c*, whose bulb, which should be of a lengthened form, descends into the ball *b*. This ball having been about two-thirds filled with ether, is heated over a lamp till the fluid boils, and the vapor issues from the capillary tube *f* which terminates the ball *a*. The vapor having expelled the air from both balls, the capillary tube is hermetically closed by the flame of a lamp. The other ball *a* is now to be covered with a piece of muslin. The stand *g h* is of brass, and the transverse socket *i* is made to hold the glass tube in the manner of a spring, allowing it to turn and be taken out with little difficulty. A small thermometer *k l* is inserted into the pillar of the stand. The manner of using the instrument is this: After having driven out all the ether into the ball *b* by the heat of the hand, it is to be placed at an open window, or out of doors, with the ball *b* so situated that the surface of the liquid may be on a level with the eye of the observer. A little ether is then to be dropped on the covered ball. Evaporation immediately takes place, which, producing cold upon the ball *a*, causes a rapid and continuous condensation of the ethereal vapor in the interior of the instrument. The consequent evaporation from the included ether produces a depression of temperature in the ball *b*, the degree of which is measured by the thermometer *d c*. This action is almost instantaneous, and the thermometer begins to fall in two seconds after the ether has been dropped. A depression of 30 to 40 degrees is easily produced, and the ether is sometimes observed to boil, and the thermometer to be driven below zero of Fahrenheit's scale. The artificial cold thus produced causes a condensation of the atmospheric vapor upon the ball *b*, which first makes its appearance in a thin ring of dew coincident with the

2292.



surface of the ether. The degree at which this takes place must be carefully noted. In very damp or windy weather the ether should be very slowly dropped upon the ball, otherwise the descent of the thermometer will be so rapid as to render it extremely difficult to be certain of the degree. In dry weather, on the contrary, the ball requires to be well wetted more than once, to produce the requisite degree of cold. (Daniell's Meteorological Essays.)

The instrument which has now been described is extremely beautiful in principle; but it may be doubted whether, even when the greatest caution is observed, the temperature which it indicates is precisely that at which the deposition of dew takes place. The deposition first occurs in a narrow ring on a level with the surface of the ether in the ball *b*, thereby indicating that the ether is colder at the surface than a little under it. But if the temperature is not uniform throughout the ball, it is evident that only a small part of the bulb of the thermometer can be placed in the point where the greatest cold exists; consequently, the temperature indicated by the thermometer will be greater than is necessary for producing the deposition of moisture: in other words, the dew-point will be given too high.

HYPERBOLA. A plane figure, formed by cutting a section from a cone by a plane parallel to its axis, or to any plane within the cone which passes through the cone's vertex.

The curve of the hyperbola is such, that the difference between the distances of any point in it from two given points is always equal to a given right line.

If the vertexes of two cones meet each other so that their axes form one continuous straight line, and the plane of the hyperbola cut from one of the cones be continued, it will cut the other cone, and form what is called the *opposite hyperbola*, *equal* and *similar* to the former; and the distance between the vertexes of the two hyperbolas is called the *major axis*, or *transverse* diameter. If the distance between a certain point within the hyperbola, called the *focus*, and any point in the curve, be subtracted from the distance of said point in the curve from the focus of the opposite hyperbola, the remainder will always be equal to a *given quantity*, that is, to the *major axis;* and the distance of either focus from the centre of the major axis is called the *eccentricity*. The line passing through the centre perpendicular to the major axis, and having the distance of its extremities from those of this axis equal to the eccentricity, is called the *minor axis*, or *conjugate diameter*. An *ordinate* to the major axis, a *double ordinate*, and an *absciss*, mean the same as the corresponding lines in the parabola.

HYPERBOLIC LOGARITHMS. A system of logarithms, so called because the numbers express the areas between the asymptote and curve of the hyperbola, those areas being limited by ordinates parallel to the other asymptote, and the ordinates decreasing in geometrical progression. But as such areas may be made to denote any system of logarithms whatever, the denomination is not correct. The hyperbolic logarithm of any number is to the common logarithm of the same number in the ratio of 2·30258509 to 1, or as 1 to ·43429448.

ICE. Water in a solid, crystallized state, owing to the abstraction of its combined heat. Its specific gravity, according to Dr. Thomson, is ·92. The force of expansion exerted by water in the act of freezing has been found irresistible in all mechanical experiments to prevent it. Advantage of this wonderful phenomenon is taken to burst bomb-shells, and other massive vessels, by filling them with water, plugging them up, and then exposing them to the frost. The effects of this expansive force are often observable by the bursting of trees, and the rending of rocks, attended with a noise resembling the explosion of confined gunpowder. Water, after being long kept boiling, affords an ice more solid, and with fewer air-bubbles, than that which is formed from unboiled water; also pure water, kept for a long time in vacuo, and afterwards frozen there, freezes much sooner than common water exposed to the same degree of cold in the open atmosphere; and the ice formed of water thus divested of its air, is much more hard, solid, heavy, and transparent, than common ice. Ice, after it is formed, continues to expand by decrease of temperature; to which fact is probably attributable the occasional splitting and breaking up of the ice of ponds during the time of freezing, and sometimes, independent of other causes, the separation of icebergs from the great frozen continent at the poles. According to Dr. Black, ice requires 147 degrees of heat to reduce it to a fluid.

The *thickness* of ice required for supporting foot-passengers is about two inches; for horsemen and light carts, four inches; and for heavy carriages, not less than six inches: also, if eight inches thick, 24-pounder guns on sleighs may pass over it, or any load not causing a greater pressure than 1000 lbs. per square foot on the surface, covered by the runners or skids on which it moves; and if the ice is weak, they may have balks secured by lashings to the tires of the wheels, for them to slide upon, so as to spread the weight over a larger surface, or lines of planks should be laid down for them to pass over.

Weak ice may be made capable of bearing even heavy loads in a very short time during frost by spreading upon it layers of straw or brushwood crossing each other, and sprinkling them with water so as to form a solid road when frozen; and if any portion of the river remains unfrozen from the rapidity of the current, it may be made to freeze by mooring trees and brushwood so as to float in it.

When the ice is too thin for walking upon it, a man may often skate over it, and ice boats, similar to those used in Canada, might also be used for this purpose. They consist of a slight frame supported on three skates or runners, one of which serves as a rudder; and, provided with masts and sails, they tack like a ship, with great rapidity, directly to windward, and attain a velocity of twenty miles an hour with a fair wind.

Floating ice is very liable to destroy bridges; and its effects in rubbing against the piers, when propelled by a strong current, are amazing, tearing off the smallest projecting portion, even if of iron. To resist this, *ice-breakers* in front of the piers are indispensable; they consist of a frame supported on two rows of piles meeting each other, and forming a small angle against the current; the upper surface should be planked over, and should slope upwards from the water's edge towards the top of the pier, so that the floating ice may rise over it, and thus break itself up, so as to pass laterally between the piers, which, if of piles or trestles, should be carefully planked over, to prevent the ice [illegible]

To *cross rivers* full of floating ice, very strong boats or canoes, cut out of entire trees, are required to resist the pressure; they may be dragged over the floes (even if in motion) which are too solid to admit of breaking canals through them.

Small barriers of ice, or the *keys* of barriers interrupting the navigation, or causing an inundation, may be destroyed by turning streams of water against certain points, so as to melt an opening, or by means of charges of powder in casks or bags, fixed underneath or lodged in holes bored in the ice, and fired simultaneously. A charge of six pounds, placed in the centre of ice two feet thick, will break it up into small pieces throughout a circle of ten feet radius.

Ice and snow, well rammed together, form temporary parapets capable of even more resistance against shot than those of earth.

ICE-BOATS. There are many descriptions of boats which come under this denomination; namely, those that are designed to sail upon the surface of the ice, and those that are employed to open the navigation of frozen rivers or canals, by breaking up the ice. The first mentioned kind of boats is much used in Holland, on the river Maeze and the lake Y. These ice-boats are propelled, it is said, with incredible swiftness, sometimes so quick as to render respiration difficult; they are found very useful in conveying goods and passengers over lakes and great rivers in that country. For this purpose a boat is fixed transversely over a thick plank, or three-inch deal, under which, at the extremities, are fixed irons, turned up forwards, resembling and operating as skates; upon this board the boat rests, with its keel at right angles to it; and the extremities of the boards serve as out-riggers to prevent the boat from upsetting, whence, therefore, ropes are fastened that lead to the head of the mast, in the nature of shrouds, and others passed through a block across the bowsprit. The rudder is made somewhat like a hatchet, with the edge placed downwards, which, being pressed down, cuts the ice, and serves all the purposes of a rudder in the water, by enabling the helmsman to steer, tack, &c.

The other kind of ice-boat alluded to, is a strong and heavy-laden canal boat, fitted up for the purpose of breaking the ice, by arming the fore-part of the keel and the bows with iron, which penetrate and break down the ice as the boat is drawn forcibly along by an adequate number of horses towing it on the path. This measure of opening the navigation of a canal is seldom adopted, except when the ice is only a few inches in thickness, or when a thaw has rendered thicker ice of little tenacity.

ICE-HOUSE. A repository for ice during the summer season. In America and other places ice is kept in deep cellars, from which the external air is excluded as much as possible, and provided with drains to keep them dry. When the surrounding soil is moist, a frame-work or case of carpentry is constructed, having a grating at bottom, and is so placed in the cellar as to be two or more feet distant from the floor, sides, and roof of the cellar. In this the ice is said to be as perfectly preserved as in a dry cellar. Some market-gardeners preserve ice in great heaps, by merely building it upon an elevated base in the open garden, and covering it over and around by a very thick stratum of straw or reeds. This plan of preserving ice is in accordance with Mr. Cobbett's recommendation in his *Cottage Economy*, wherein he observes that "an ice-house should not be underground, nor shaded by trees, but be exposed to the sun and air;" that its bed should be three feet above the level of the ground, and composed of something that will admit of the drippings flowing instantly off; and he adds, that "with some poles and straw, a Virginian will construct an ice-house for ten dollars, worth a dozen of those which cost the man of taste in England as many scores of pounds." The ice-houses built by the Virginians consist of an inner shed, surrounded by an outer one, and having a sufficient vacant space between the two to enable a person to walk round; the walls and roofs of both the sheds are made of thatch, laid on about a foot thick; and the ice is deposited in the inner shed on a bed of straw. In England and France, the common form of ice-houses is that of an inverted cone, or rather of a hen's egg, with the broad end uppermost. The situation of an ice-house should be dry, as moisture has a tendency to dissolve the ice; it should also be so elevated that water may freely run off. It should be exposed to the sun and air, not under the drip, or in the shade of trees, in order that the external deposit of moisture may be readily evaporated. The form of the building may be varied according to circumstances; but in the well or receptacle for the ice, it is desirable to have sufficient room for the deposit of two or three years' consumption, as a provision against mild winters. Where the situation is of a dry, chalky, gravelly, or sandy kind, the pit may be entirely below the surface of the ground; in which case, an ice-house on the following plan may be advantageously introduced.

Dig a pit of about twelve feet deep, and wide enough to permit the erection therein of a frame of rough wood posts. This frame is to be fourteen feet wide each way at the bottom, and sixteen feet each way at the top. The posts may be about nine inches in diameter, placed near enough to each other for thin laths to be nailed upon them, and the inside be dressed to an acute angle, so that as little wood as possible may touch the ice. On the inside let thin laths be nailed at about two feet apart. On the outside, at moderate distances, nail rough boards, and fill the place within with wheat or rye straw set on end. The inside of the roof to be made in the same way, and also the gables. Straw is to be sewed on the inside, and heath or straw on the outside of the door. The outside of the roof is to be thickly thatched with straw or heath; and heath, brushwood, or fir-tops, to be filled in between the outside boarding and the surrounding ground, and then neatly thatched or turfed over. The bottom of the house, for two feet deep, should be laid with large logs or stones, next with heath, fir-tops, or brushwood, and then with straw. The ice-house, thus completed, will look like a square beehive inverted, and is then ready to receive the ice or snow. But, unless the house be in a very shady place, it may be necessary to extend the roof, where the door is placed, five or six feet, making a second gable and door, finished in the same way as the first, and fill up the intervening space, except a passage, with heath or straw.

Mode of filling the house.—When the ice (or snow, if ice cannot be procured,) is put into the house, it must be well beaten down with a pavior's rammer, or mallet, and the surface *always kept concave*, as by this means any snow or ice that may melt will run to the middle, or interstices, and freeze. For the same reason, the ice ought always to be kept concave when it is taken out for use. Should the frost be very intense when the ice-house is getting filled, it may be very beneficial at the close of each day's filling to throw in thirty or forty pails of water, which will fill the interstices and freeze. When the house is full, spread upon the concave surface a carpet, or sail split up in the middle, and upon the top thereof a foot thick of water. When ice is required for the use of the family, or when it is necessary to put in fresh meat to lie on the face of the ice for preservation, or to take out for use, the straw and carpet, or sail, is to be opened in the middle. Should rats infest the place, an iron-wire frame or case may be required to put the meat or fish, &c., into when lying on the ice. A small open surface-drain ought to be dug round the house, to prevent any water running into it. Opening the door of the house does little harm. Damp or dense substances touching the ice are much more prejudicial than dry air.

ICE-SAWS. Large saws used for cutting through the ice, for relieving ships when frozen up. The vessels employed in the Greenland fisheries, and others that navigate the polar seas, are regularly furnished with these machines, as the lives of the crew not unfrequently depend on the expedition with which a passage can be cut, so as to disengage the vessel before the further accumulation of ice renders it an impossible undertaking. The saw, with a weight suspended to it, is introduced by means of a hole broken through the ice, and is suspended by a rope passed over a pulley fixed to a triangle. A party of a dozen or more men run out and back again with a rope, and thus move the saw up and down till it has cut its way so far as to hang perpendicularly from the pulley. The triangle is then moved a foot or two further, and the sawing recommences, the services of the whole crew being required in this laborious undertaking.

In Hood's machine, the saw is suspended by a slight sledge, and is worked by the power of only two or three men at the end of a lever; a bar, called a propeller, is fixed on the lever between the fulcrum and the saw, the other end resting on the surface of the ice, and so adjusted that each motion of the lever shall produce a cut of a given length, and at the same time, by means of the propeller, push the sledge on, so that the teeth of the saw shall always be in contact with the ice.

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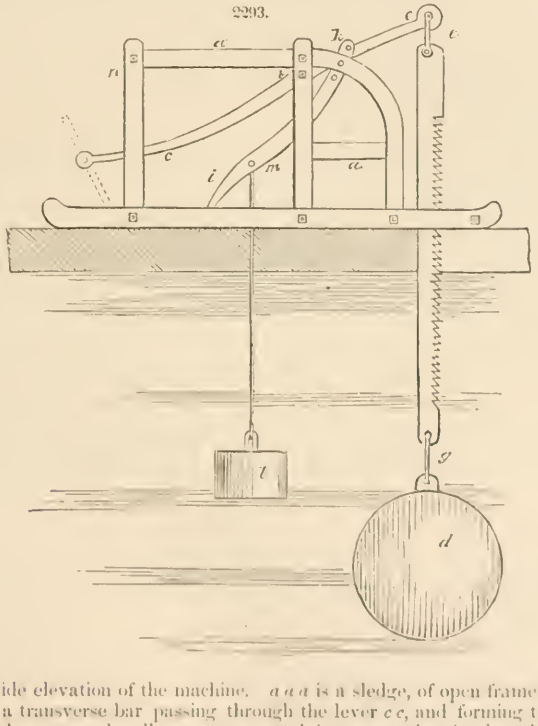


Fig. 2293 gives a side elevation of the machine. *a a a* is a sledge, of open frame work, resting on the surface of the ice; *b* a transverse bar passing through the lever *c c*, and forming the fulcrum on which it moves; this lever has a cross-handle, as represented in perspective in dotted lines; *e* a clamp or brace consisting of two cheeks, one on each side of the lever, loosely pinned at top to the lever, and at bottom to the saw *f*; *g* a clamp similar to *e*, by which the weight *d* (which is of the shape of a double convex lens) is hung to the lower end of the saw; *i* the propeller, an iron bar, terminating below in two claws, and at top in a fork, and suspended on the lever by means of a transverse pin *k*; *l* a weight hung to the propeller at *m*; *n* a transverse bar, limiting the motion of the handle-end of the lever in an upward direction. It should be understood that there is a duplicate frame similar to that brought into view, on the other side of the machine, about 18 inches apart, and connected by transverse bars. To prevent the lever from swerving laterally, there are at the handle ends two upright bars, between which the lever moves. The saw, after having once entered the ice, will only require from two to four men to work it; and it should not be taken out of the ice till after the distance required to be cut through is accomplished. The saw can be guided by the lever in any direction, so as to cut the ice into pieces most convenient for removal, either by pushing them under the adjacent floor of ice, or by dragging them out of the ship's track into clear water.

ICE-TRADE. The ice-trade of the United States was commenced by Frederic Tudor, of Boston, in 1805. The first enterprise resulted in a loss, but was, nevertheless, followed up until the embargo and war put an end to the foreign trade, at which period it had yielded no profit to its projector. After the close of the war, in 1815, Mr. Tudor recommenced his operations by shipments to Havana under a contract with the government of Cuba, which enabled him to pursue his undertaking without loss, and extend it, in 1817, to Charleston, S. C.; in the following year to Savannah, Ga.; and in 1820 to New Orleans. On the 18th May, 1833, the first shipment of ice was made to the East Indies, by Mr. Tudor, and since that period he has extended his operations to Madras and Bombay.

Previously to 1832 the trade had been chiefly confined to the operations of the original projector, although several enterprises had been undertaken by other persons and abandoned. The increase of shipments to this period had been small, the whole amounting, in 1832, to 4352 tons, which was taken entirely from Fresh Pond, in Cambridge, and shipped by Mr. Tudor, who was then alone in the trade. Up to this time the ice business was of a very complicated nature. Ship-owners objected to receive it on freight, fearing its effect on the durability of their vessels and the safety of voyages; ice-houses abroad and at home were required, and the proper mode of constructing them was to be ascertained. The best modes of preparing ships to receive cargoes were the subject of expensive and almost endless experiments. The machines to cut and prepare ice for shipping and storing, and to perform the operations of hoisting it into storehouses and lowering it into the holds of vessels, were all to be invented, involving much expense and vexation. Many of these difficulties have now been overcome, and since 1832 the trade has increased much, and appears destined to a still more rapid increase for some years. It has also been divided among many parties, and its methods have been further improved and a knowledge of them more widely diffused.

The ice has been chiefly taken from Fresh and Spy Ponds, and since 1841 mainly transported on the Charlestown Branch Railroad, which was constructed for that purpose. Quite recently, ice establishments have been made at most of the ponds near Boston, and it is probable that in a few years the product of all these waters may be required to supply the trade. In the year 1839 the great quantity of ice cut at Fresh Pond, and the consequent difficulties which had arisen among the proprietors as to where each should take ice, induced them to agree to distinct boundary lines, which were settled by three commissioners, on the principle of giving to each the same proportion of contiguous surface of the lake, as the length of his shore-line was to its whole border.

The shipments of ice from Boston coastwise, for the year ending December 31, 1847, amounted to 51,887 tons. The ice shipped to foreign ports during the same period amounted to 22,591 tons.

The freight paid during this year is supposed to have averaged as high as $2.50 per ton, at which rate it would amount, on the 74,478 tons shipped abroad and coastwise, to	$186,195
There is a great variation in the cost of securing ice and stowing it on board vessels, caused by winters favorable or otherwise for securing it, and by the greater or less expense of the fittings required for voyages of different duration, or by difference of season when the shipments are made. Taking all these contingencies into consideration, the cost of ice when stowed on board may be estimated to average $2 per ton, which would give for the quantity shipped..	148,956
There were in 1847 upwards of 29 cargoes of provisions, fruits, and vegetables shipped in ice to ports where otherwise such articles could not be sent, the invoiced cost of which, at Boston, would average about $2,500 each........	72,500
To these items may be added the profits of the trade to those engaged in it	100,000
Total returns........	$507,651

The methods and materials for preparing vessels for the transportation of ice have been various. Formerly their holds were ceiled up at the sides, bottom, and top, with boards nailed to joist-ribs secured to the side of the vessel, and with double bulkheads forward and aft. The spaces thus formed were filled with refuse tan, rice-hulls, meadow-hay, straw, wood-shavings, or like materials. These spaces were made of a thickness proportionate to the length of the voyage, and with reference to the season. The immediate surface of the ice was covered with the same materials, excepting tan. At the present time sawdust is used almost exclusively for voyages of considerable length. It is placed immediately between the ice and the side of the vessel. This material is obtained from the State of Maine, and before its use for this purpose was entirely wasted at the water-mills, and, falling into the streams, occasioned serious obstructions. During the year 1847, 4600 cords were brought to Boston, at an average value of $2.50 per cord, delivered.

Almost the whole value of the returns of the ice-trade, including freight, are a gain to this country. The ice itself, the labor expended on it, the materials for its preservation, and the means of its transportation, would be worthless if the trade did not exist.

Ice being shipped and used at all seasons, large storehouses are required to preserve it. Exclusiv of ice-houses on the wharves at Charlestown and East Boston, in which ice is stored for short periods there had been erected in 1847, and previously—

At Fresh Pond, in Cambridge, ice-houses capable of containing....................	86,732	tons.
At Spy Pond, in West Cambridge....................	28,000	"
At Little Pond	2,400	"
At Wenham Pond	13,009	"
At Medford Pond....................	4,000	"
At Eel Pond, in Malden	2,000	"
At Horn Pond, in Woburn	4,000	"
At Sumner's Pond	1,200	"
Total	141,332	tons.

The ice-houses now in use are built above ground. In southern countries, where ice is most valuable, they are constructed at greater expense, usually of brick or stone, and the protection to the ice consists in air-spaces, or in dry, light vegetable substances inclosed between two walls. In this vicinity, on the borders of the lakes, where ice is least valuable, they are usually built of wood, in which case they are of two walls, formed by placing two ranges of joist upright, framed into plates at the top, and placed in the ground at the bottom, or framed into sills; these two ranges are ceiled with boards secured to that side of each range which is nearest the other, and the space between the two boardings filled with refuse tan, wet from the yards. This wet tan is frozen during the winter, and until it is thawed in the spring and summer, little waste occurs; afterwards the waste is more rapid; but, as a large portion of the ice is shipped or otherwise used before this takes place, the loss in quantity is small, and, occurring before the expenses of transportation have been paid, is of less pecuniary moment.

In one instance brick has been used in the construction of an ice-house, which covers 36,000 feet of land, and the vaults of this ice-house are 40 feet in depth, and its walls are four feet thick from outside to inside, inclosing two sets of air-spaces. Such a construction is more costly, but has the advantage of durability and safety from fire, to which ice-houses are much exposed from the frequent juxtaposition of railroad-engines, and the light, dry materials used about them to cover and otherwise preserve ice.

In the winter of 1847, about $650 were paid daily for labor of men, and $230 for that of horses, when the weather was most favorable for cutting ice. Such activity is, however, of short duration, as there are not generally more than 20 days in a season which are really favorable to the operation of securing ice. The price paid is usually $1 per day for horses and men.

At first the implements of husbandry only were used in securing ice; but as the trade became more important, other machines and different methods were adopted, and abandoned when better were brought forward, or when the increased magnitude of the business required greater facilities. More ice is now secured in one favorable day than would have supplied the whole trade in 1832. Ordinarily, before there has been cold enough to form ice of suitable thickness, snows fall on its surface. If this occurs when the ice is four or more inches in thickness, and the snow not heavy enough to sink the ice, it can be removed by using horses attached to the "snow-scraper;" and under such circumstances this is the method in common use. But if snow falls so heavy as to bring the water above the surface of the ice, it is removed, after it has congealed into snow-ice, with the "ice-plane."

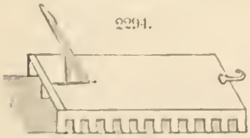
These preliminary expenses are often very great; frequently, after much expense has been incurred to remove a body of snow or snow-ice, the weather becomes warm, and spoils the ice on which so much has been expended. And, on the other hand, if it is not done, and the cold continues, there will be little or no increase of thickness to the ice, which is equally a disaster.

When the ice is made up for transportation, it is employed in ships as ballast, for which purpose it is carefully cut up into blocks to fit the hold, and covered with sawdust, straw, and charcoal dust, all non conductors of heat, under cover of which it is conveyed on the voyage. When the ice is regularly shipped as cargo, being cut into blocks, it is packed on board the vessel, in thin air-tight boxes, with straw and hay. In this manner it is conveyed without loss.

The machinery employed for cutting the ice is worked by men and horses in the following manner:—

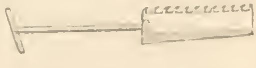
From the time when the ice first forms, it is carefully kept free from snow until it is thick enough to be cut; that process commences when the ice is a foot thick. A surface of some two acres is then selected, which at that thickness will furnish about 2000 tons; and a straight line is then drawn through its centre, from side to side each way. A small hand-plough is pushed along one of these lines, until the groove is about three inches deep and a quarter of an inch in width, when the "marker," Fig. 2294, is introduced. This implement is drawn by two horses, and makes two new grooves, parallel with the first, 21 inches apart, the gage remaining in the original groove. The marker is then shifted to the outside groove, and makes two more. Having drawn these lines over the whole surface in one direction, the same process is repeated in a transverse direction, marking all the ice out into squares of 21 inches. In the mean time, the "plough," Fig. 2295, drawn by a single horse, is following in these grooves, cutting the ice to a depth of six inches.

2294.



2295.

2296.



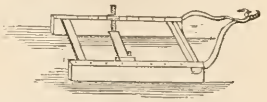
One entire range of blocks is then cut out with the "ice saw," Fig. 2296, and the remainder are split off towards the opening thus made with an iron bar. This bar, represented in Fig. 2297, is shaped like a spade, and is of a wedge-like form. When it is dropped into the groove, the block splits off; a very slight blow being sufficient to produce that effect, especially in very cold weather. The labor of "splitting" is slight or otherwise, according to the temperature of the atmosphere. "Platforms," or low tables of frame-work, are placed near the opening made in the ice, with iron slides extending into the water, and a man stands on each side of this slide armed with an "ice hook." With this hook, Fig 2298, the ice is caught, and by a sudden jerk thrown up the "slide" on to the "platform." In a cold day every thing is speedily covered with ice by the freezing of the water on the platforms, slides, &c., and the enormous blocks of ice, weighing, some of them, more than 200 pounds, are hurled along these slippery surfaces as if they were without weight. Beside this platform stands a "sled" of the same height, capable of containing about three tons, which, when loaded, is drawn upon the ice to the front of the storehouse, where a large stationary platform, of exactly the same height, is ready to receive its load, which, as soon as discharged, is hoisted, block by block, into the house, by horse power. This process of hoisting is so judiciously managed, that both the taking up of the ice and the throwing it into the building are performed by the horse himself. The frame which receives the block of ice to be hoisted, is sunk into a square opening cut in the stationary platform, the block of ice is pushed on to it, the horse starts, and the frame rises with the ice until it reaches the opening in the side of the storehouse ready for its reception, when, by an ingenious piece of mechanism, it discharges itself into the building, and the horse is led back to repeat the process.

Forty men and twelve horses will cut and stow away 400 tons a day. In favorable weather 100 men are sometimes employed at once. When a thaw or a fall of rain occurs, it entirely unfits the ice for market, by rendering it opaque and porous; and occasionally snow is immediately followed by rain, and that again by frost, forming *snow-ice*, which is valueless, and must be removed by the "plane."

2297.

2298.

2299.



The operation of planing is somewhat similar to that of cutting. A plane, Fig. 2299, gaged to run in the grooves made by the marker, and which shaves the ice to the depth of three inches, is drawn by a horse until the whole surface of the ice is planed. The chips thus produced are then scraped off, and if the clear ice is not reached, the process is repeated. If this makes the ice too thin for cutting, it is left *in statu quo*, and a few nights of hard frost will add *below* as much as has been taken off *above*.

In addition to filling their ice-houses at the lake and in the large towns, the company fill a large number of private ice-houses during the winter—all the ice for these purposes being transported by railway. It will be easily believed that the expense of providing tools, building houses, furnishing labor, and constructing and keeping up the railway, is very great, but the traffic is so extensive, and the management of the trade so good, that the ice can be furnished at a very trifling cost.

ICOSAHEDRON, or ICOSAEDRON, in geometry, one of the regular platonic bodies, comprehended under twenty equal triangular sides or faces. It is formed of twenty pyramids, whose bases are the twenty equal and equilateral triangles, the summits of which terminate in the centre of the body.

Let S represent the side; then will surface $= 5 S^2 \sqrt{3} = 8{\cdot}66025403\ S^2$, and solidity $= \frac{5}{6} S^3 \frac{7 + 3\sqrt{5}}{2} = 2{\cdot}1816950\ S^3$.

ILLUMINATION. Without entering minutely into the subject, it is evident that the value of any means of illumination must depend upon two things—namely, upon the *quantity of light* evolved, and upon the *consumption of lighting material* which accompanies it. A candle, or a lamp, &c., will be the more valuable, the more light it gives from as little tallow or oil as possible. Light cannot be measured with reference to its quantity any more than heat; it cannot be estimated how much light a flame emits, but it can be scientifically ascertained how much more or less light it evolves, than another flame.

All determinations of this nature are, therefore, comparative. The most casual observation of two flames, for example, that of a candle and of gas, shows the one, although both are of equal size, to be infinitely brighter than the other.

The dissemination of light is entirely effected by radiation; the intensity may, therefore, be said to express the sum of the rays which are emitted to a certain surface, for example, to a square foot. It is evident, that the sum must be diminished by the distance from the source, as the rays separate more and more from each other. According to the laws of optics, the intensity is in relation to the square of the distance; when, therefore, a surface is illumined to the same extent by two flames, the rays of light from each will be proportional to the square of the distance at which each flame must be placed in order to produce an equal amount of light. It is upon this principle that the actual determination of the intensities and quantities of light depends; the measure for both is, therefore, the distance to which the flames to be compared must be brought, in order to produce an equal amount of light. (See Photometer, in article Gas.) Practically, however, it is not possible to determine, even approximatively, the degree of brilliancy; the degree of light is therefore not observed, but its negation, the *shadow*.

In such experiments a board is used, covered with unglazed white paper, before which, at a distance of from two to three inches, an iron rod is placed, which has been previously blackened by holding it in the candle. Opposite this board, but at the same height, the flames to be compared are so placed that both the shadows (for each throws a shadow) fall close to each other upon the board, and then the stronger flame is so far removed, or the weaker one approached, until both shadows appear equally deep, and lastly, their respective distances from the centres of the flames are measured. The squares of these distances give the relative intensities of light; if a flame, for example, has been three times as far removed as another, its intensity will be to that of the latter, as 3^2 to $1^2 = 9 : 1 = 1 : 9$, or 9 times greater. As such observations are simultaneous, and of like duration, they give likewise the relative quantities of light; for unequal lengths of time, this has only to be multiplied with the respective duration. When one of these flames, therefore, burns 3 hours, and the other only 2, then the quantities of light evolved will be in the proportion, $3 \times 9 : 2 \times 1$ or $27 : 2$.

One circumstance in particular requires notice: that when two perfectly similar shadows of this kind are observed from one side, the one appears brighter than the other, and the same is the case, the order only being reversed, when they are observed from the other side; so that the rule is, to observe them always from a position exactly opposite the board. Practice is here the best guide in forming rules.

The usual dimensions of a candle are not fixed arbitrarily or by chance, but are absolutely necessary to a well-regulated process of combustion. If the wick is too large in proportion to the surrounding mass of fat, as is the case in tapers, no reservoir is then formed, and all the advantages attending it are lost. In the opposite case, which applies to all common candles, the wick which is rather too small produces a flame, whilst the outermost layer of fat is beyond the sphere in which fusion is going on.

A thin ring-shaped wall, as is easily observed in the less fusible stearine candles, remains erect up to a certain height, and is very objectionable from the shadow which it throws, but more so from its being gradually undermined and falling into the reservoir, which it overfills and causes the candle to gutter. When it has once overflowed, the evil is doubled, for all the fat which, by overflowing, has formed ridges, is still further removed from the region of the flame. In night lights, made of stearine or wax, where intensity of light is a secondary consideration, this circumstance has been turned to account. These are made with a common-sized wick, but a disproportionate thickness of fat, so that a very deep and full reservoir is formed; an excess therefore of melted fat, which, as too much of the free part of the wick remains immersed, causes them to give a very small quantity of light. For the sake of safety, they are made so short that they will swim upright upon a basin of water. Several periods must be distinguished in the whole course of the process which is going on in a lighted candle. The heat generated by the flame, and for the greater part carried upwards by the current of air, acts however by radiation to such a degree downwards, that sufficient or rather too much fat is melted, for supplying food to the flame. The fat is supplied directly by the wick, the capillarity of which is constantly at work, sucking up the fluid matter, and carrying it to the sphere of combustion. The lower uncharred portion of the wick (up to *d*, Fig. 2300) acts the part of a sucking-pump; the decomposition takes place in the entire upper black portion: the fat, which arrives there, is immediately exposed to a high temperature, without being able to come into direct contact with the air; it is in the same position as if it were inclosed in an iron retort between red-hot coals, and it suffers, consequently, dry distillation. The gaseous and vaporous combustible products form the dark nucleus *f* of the flame, between which and the surrounding air, the sphere of successive combustion is situated. The air streaming from below upwards, to the gases in *f*, consumes in the first instance the hydrogen, and separates the carbon as incandescent soot; this occurs in the luminous part of the flame *i*. Lastly, on the outside, in the hardly perceptible bluish halo *g*, the carbon is consumed; this occurs chiefly at the base, which does not appear luminous, in consequence of the air exerting its full influence at that part.

2300.

Every portion of tallow, which burns and gives out light, prepares the following portion for undergoing the same process. The different states of the flame may be partially made visible by an interesting experiment that is easy of execution. If a bottle is filled with water, and supplied through the cork with a siphon in a downward direction, and a tube drawn out to a point in an upward direction, and this point be brought into the interior of the flame whilst the water is allowed to run slowly from the siphon, the bottle becomes filled with the combustible vapors in the form of a gray smoke. The vapors obtained from a stearine candle condense, for the most part, to a dry, solid, fatty acid; not so those from oil or tallow. On blowing with the mouth, these vapors may be expelled from the bottle, and they burn, when ignited, with a distinct flame, which is but slightly luminous, in consequence of the admixture of air. The experiment may be made without danger with a common pipe, and by suction with the mouth. The importance of using hard, solid tallow, to prevent guttering, is obvious, and all the materials should likewise be as pure as possible; for whatever is not decomposed in the same manner as tallow, or wax, will obstruct the capillary tubes of the wick.

It is not remarkable from the nature of candles and the mode in which they disseminate light, that their intensity and consequent power of illumination, even under the same circumstances, should be so very variable. In the beginning, when the wick is freshly snuffed, this variation is comparatively slight, and the intensity increases up to a certain point, when, from an excessive length of snuff, deposit of spongy matter, &c., it constantly diminishes, until the candle is again snuffed or the deposit burnt, and then the process is repeated. Peclet found (by comparison with Carcel's lamp) that the primary intensity of a candle = 100, (6 = 1 lb.,) became in 4 minutes 92, in 8 minutes 50, in 10 minutes 41, in 12 minutes 38, in 15 minutes 34, in 20 minutes 32, in 22 minutes 25, in 24 minutes 20, in 28 minutes 19, in 30 minutes 17, and in 40 minutes 14. Another candle, (5 to the lb.,) diminished from its original intensity, = 100, in 5 minutes to 76, in 10 to 55, in 15 to 44, in 20 to 39, in 25 to 32, in 30 to 30, in 35 to 24, and lastly, in 40 minutes to 15. Less than half an hour, therefore, is sufficient to reduce the light from a candle to $\frac{1}{4}$ of its original brilliancy. The same diminution was the result of Rumford's observations, namely, $\frac{1}{6}$ after 29 minutes. When, below, the intensity of candles is compared with Carcel's lamp, the mean intensity of 10 minutes' duration in tallow candles is to be understood, which is about the usual time suffered to elapse between each snuffing; in stearine, wax, and spermaceti candles, however, the highest intensity is taken, which occurs when the wick, without any deposition of snuff has begun to emerge from the flame.

It has already been pointed out, that all determinations of the illuminating power are entirely relative, and hence arises the demand for a suitable point of comparison.

The flame of Carcel's clock work lamp (see LAMPS) is of such very uniform brilliancy, remaining unimpaired for several hours after it has been ignited, that lamps, candles, and gas, are very generally compared with it. On comparing two exactly similar lamps of this kind in such a manner, that one was kept constantly burning, whilst the other was freshly ignited for each observation, it was found that the brilliancy which in the beginning was 100, increased in half an hour to 103; in one hour to [illegible] and in four hours to 117, which it then retained for four consecutive hours.

Illuminating Power of Candles.

Variety of Candle.	Comparison of the intensity of light.	Consumption of material in an hour.	Comparison of illuminating power	
			Directly.	With Carcel's lamp = 100.
[Carcel's lamp..................	100·00	42·00 rapeseed oil.	2·318	100]
Tallow candles, 6s	10·66	8·51	1·253	54·04
" " 8s	8·74	7·51	1·164	50·21
" " 5s	7·50	7·42	1·011	43·61
Wax " 5s	13·61	8·71	1·563	67·41
Stearine " 5s	14·40	9·33	1·543	66·58
Spermaceti 5s	14·40	8·92	1·614	85·68

Illuminating Power of Lamps.

Sort of Lamp.	Breadth of the wick, or diameter of the burner. Inner.	Outer.	Average intensity of light from twelve experiments.	Consumption of rapeseed oil in one hour in grammes.	Quantity of light from an equal quantity of oil, Carcel's lamp=100.
	Lines.				
No. I. Carcel's clock-work lamp........................	6·8	9·2	100	40·64	100
... II. Kitchen lamp	3·2 (thick)		6·65	8·05	33·58
... III. Lamp with flat wick	8·2 (broad)		15·13	9·40	65·71
... IV. Lamp with chimney	7·6		19·37	12·33	63·82
... V. Table lamp with circular oil-vessel, and semicircular wick	12·5		32·64	20·88	63·54
... VI. Astral lamp..	6·2	9·4	44·98	28·70	63·72
... VII. Sinumbra lamp	5·2	8·8	52·50	26·74	79·78
... VIII. Lamp with flat wick and invert'd reservoir	8·4 (broad)		21·50	14·90	54·80
... IX. Wall lamp with inverted reservoir and semicircular wick	13·0	"	39·33	20·15	79·35
... X. The same with round wick	7·4	10·0	52·54	29·33	72·81
... XI. Liverpool lamp with inverted reservoir	6·0	9·2	41·80	26·78	63·45
... XII. Wall lamp with constant oil level and regulator..	5·8	8·0	82·46	35·44	111·60
... XIII. Hydrostatic lamp	7·4	9·2	92·44	38·94	113·90

(See Lamps, Light.)

IMPACT. The single instantaneous blow or stroke communicated from one body, in motion, to another, either in motion or at rest.

IMPENETRABILITY. In physics, one of the essential properties of matter, or body. It is a property inferred from invariable experience, and resting on this incontrovertible fact, that no two bodies can occupy the same portion of space in the same instant of time. Impenetrability, as respects solid bodies, requires no proof; it is obvious to the touch. With regard to liquids, the property may be proved by very simple experiments. Let a vessel be filled to the brim with water, and a solid incapable of solution in water be plunged into it; a portion of the water will overflow exactly equal in bulk to the body immersed. If a cork be rammed hard into the neck of a vial full of water, the vial will burst, while its neck remains entire. The disposition of air to resist penetration may be illustrated in the following way: Let a tall glass vessel be nearly filled with water, on the surface of which a lighted taper is set to float. If over this glass a smaller cylindrical vessel, likewise of glass, be inverted and pressed downwards, the contained air maintaining its place, the internal body of the water will descend, while the rest will rise up at the sides, and the taper will continue to burn for some seconds, encompassed by the whole mass of liquid.

IMPETUS. The product of the mass and velocity of a moving body, considered as instantaneous, in distinction from *momentum*, with reference to time, and *force*, with reference to capacity of continuing its motion. *Impetus*, in gunnery, is the altitude through which a heavy body must fall to acquire a velocity equal to that with which the ball is discharged from the piece.

INCIDENCE, in mechanics, is used to denote the direction in which a body, or ray of light, strikes another body, and is otherwise called inclination. In moving bodies their incidence is said to be perpendicular or oblique, according as their lines of motion make a straight line or an angle, at the point of contact.

Angle of incidence, generally denotes the angle formed by the line of incidence, and a perpendicular drawn from the point of contact to a plane or surface on which the body or ray impinges.

Thus if a body impinges on the plane at a point, and a perpendicular be drawn, then the angle made by this perpendicular and the incident ray is generally called the angle of incidence, and the complement of this the angle of inclination.

When light, or any elastic body, is reflected from a surface, the angle of incidence is equal to the angle of reflection; and in the case of refraction, the sine of the angle of incidence has to the sine of the angle of refraction a constant ratio.

INCLINATION, denotes the mutual approach or tendency of two bodies, lines, or planes, towards each other, so that the lines of their direction make at the point of contact an angle of greater or less magnitude

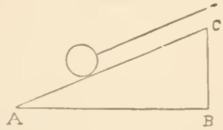
INCLINED PLANE. One of the mechanical powers: a plane which forms an angle with the horizon. The force which accelerates the motion of a heavy body on an inclined plane, is to the force of gravity, as the sine of the inclination of the plane to the radius, or as the height of the plane to its length. If $f =$ force accelerating the body on an inclined plane, of which the inclination is i, and if $g =$ force of gravity, $f = g$ sine i. Hence the motion of a body on an inclined plane, is a motion uniformly accelerated.

If two bodies begin to descend from rest, and from the same point, the one on an inclined plane and the other falling freely to the ground, their velocities at all equal heights above the surface will be equal. Hence the velocity acquired by a body in falling from rest through a given height is the same, whether it fall freely, or descend on a plane any how inclined. The space through which a body will descend on an inclined plane, is to the space through which it would fall freely in the same time, as the sine of the inclination of the plane to the radius.

When a power acts on a body, on an inclined plane, so as to keep that body at rest, then the weight, the power, and the pressure on the plane, will be as the length, the height, and the base of the plane, when the power acts parallel to the inclined surface; that is,

If the weight be measured by A C,
The power will be measured by B C,
And the pressure on the plane A B.

2301.



These properties give rise to the following rules:—

$$\text{power} = \frac{\text{weight} \times \text{height of plane}}{\text{length of plane}}$$

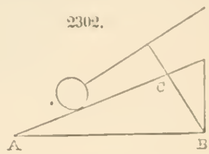
$$\text{weight} = \frac{\text{power} \times \text{length of plane}}{\text{height of plane}}$$

$$\text{pressure on the plane} = \frac{\text{weight} \times \text{base of plane}}{\text{length of plane}}$$

These rules express the conditions of equilibrium, and it is obvious, that if either the weight or the power be increased, (friction excepted,) motion of the body must ensue.

When the power does not act parallel to the plane, the conditions of equilibrium may be found thus: Draw a line perpendicular to the direction of the power's action; the weight, power, and pressure on the plane, will be as A C, C B, A B.

2302.



When the line of direction of the power is parallel to the plane, the power is least.

If two bodies, on two inclined planes, sustain each other by means of a string over a pulley, their weights will be inversely as the lengths of the planes.

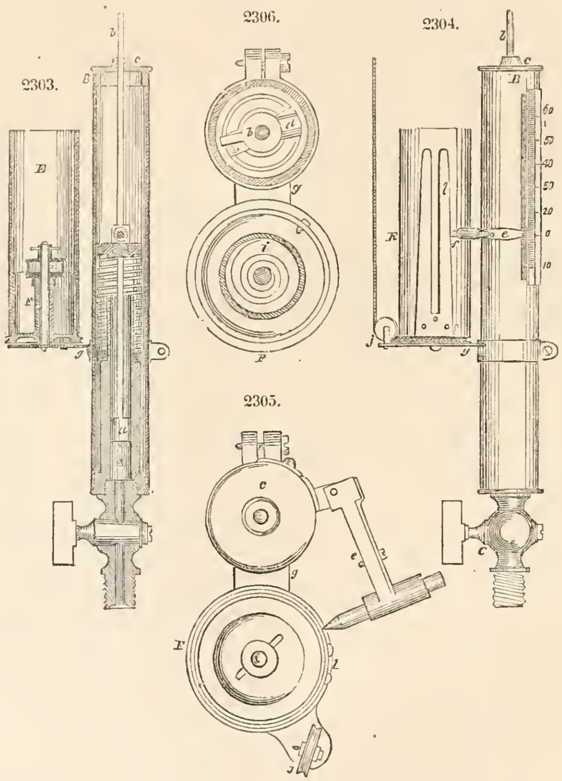
The space which a body descends upon an inclined plane, when descending on the plane by the force of gravity, is to the space which it would fall freely in the same time, as the height is to the length of the plane; and the spaces being the same, the times will be inversely in that proportion.

INDICATORS. The important and useful little instrument which we have represented in the following figures has very materially contributed to the perfection and efficiency of our modern steam-engines; not only by enabling the engineer to ascertain and register the exact values of the forces from which its power is derived, at the point where these forces come into effective operation, but also by pointing out the precise periods, in relation to the different parts of the stroke, at which these elements of power come into action, and thereby conducing to the most economical and perfect combination of them. By its use he is introduced, as it were, into the interior of his engine, and is made cognizant of its most occult and delicate movements.

The idea embodied in this ingenious and beautiful instrument was originated by the justly celebrated James Watt, who, at a very early period in the history of the steam-engine, employed a machine identical in the principle of its operation, though less compact in form than that now so extensively in use. His object was to ascertain with certainty the mean steam pressure, and, more particularly, the proportion which the vacuum in the cylinder bore, at different parts of the stroke, to that in the condenser, in order to determine the dimensions of cylinder required for any given power, as also the relative proportions proper to be given to the steam and exhaust ports, &c. Having attained these objects, and given to the world so many imperishable monuments of his genius, succeeding mechanicians seem to have despised the unpretending little instrument by whose assistance he had been led to such splendid results, and, during the space of nearly half a century, to have trusted implicitly, in the construction of their engines, either to the absolute accuracy of Watt's data, or of their own theoretical deductions, in many cases extremely fallacious. From this state of oblivion, the indicator has been, at a comparatively recent period, rescued by the late Mr. Macnaught, of Glasgow, who has greatly improved its construction, and put it into such a compact and portable form as to be easily applicable to steam engines of every description. Its consequent general adoption has led to some notable improvements, and materially elevated the standard of *duty* in steam-engines; it has demonstrated the economy resulting from a liberal use of the expansive power of the steam, and the great advantage attendant upon a more rapid and complete exhaustion than could be attained by the arrangement of slide valve previously employed.

Macnaught's Indicators.—The figure comprised under this head represents the form of the indicator as at present constructed by Mr. William Macnaught, being that employed to measure the power of high-pressure engines, and is also adapted to those in which steam of a tension not greatly exceeding that of the atmosphere is employed. The two instruments differ in no respect from each other in the principle of their action, and but little in the details of their construction; accordingly one description will suffice for both, in the course of which we shall notice the points in which each respectively differs from the other. The figures are to a scale of $\frac{1}{4}$ of an inch to an inch.

General description.—From a glance at the drawings it will be at once perceived that the indicator is neither more nor less than a small atmospheric steam-engine, with the addition of a spiral spring and graduated scale to mark the degrees of pressure. The steam-cylinder A, Fig. 2303, is of gun-metal, very accurately bored out and fitted with a solid piston *a*, ground into the cylinder so as to be perfectly steam-tight. A slender steel rod *b b* is screwed into the piston, and is guided at its upper extremity by passing through the cover *c* of an external brass casing or cylinder B, screwed to the lower end of the steam-cylinder. At this point is also fixed a stop-cock C, destined to form a communication between the cylinder of the steam-engine and that of the indicator; in the high-pressure indicator this cock is formed with a screw at its lower end, for the purpose of attaching it to the socket-cock, which is permanently fixed to the cylinder cover, while, in the instrument as adapted to low-pressure engines, this attachment is considered to be sufficiently secure by the more convenient method of simply inserting the tapered end of the cock C into a corresponding socket accurately ground to fit it.


2303. 2306. 2304. 2305.

Towards the middle of the piston-rod *b b* a small stud *d* is fixed immovably by soldering, and to it is screwed a brass disk, having the end of a spiral spring D soldered into it. The opposite extremity of this spring is secured, in the case of the high-pressure indicator, to the steam-cylinder, and in that used for condensing engines, to the cover of the external casing. This difference in the arrangement of the springs is owing to the difference in the prevailing directions of the motion of the piston *a*, in either case; it being considered most expedient to make the springs act by distension, rather than by compression. In the stud is a small square socket, into which, through a slot or opening in the external casing B, is inserted a steel piece, part of which is formed into an index or pointer, adapted to work against an adjustable graduated scale, screwed to the outside of the casing B, Fig. 2304.

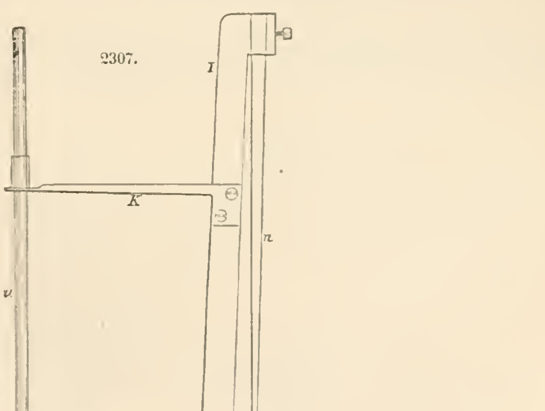
Figs. 2305 and 2306 represent plans of 2303 and 2304 respectively.

The principle on which the strength of the springs is regulated and the scales are graduated is as follows: The area of the piston, the resistance of the spring, and the divisions upon the scale, are so proportioned to each other that one pound of pressure in either direction upon the piston will cause the index to move through one division upon the scale. In the high-pressure indicator, although the size of the piston is invariable, (being uniformly made equal to $\frac{1}{8}$ of a square inch in area,) the length of the divisions upon the scale is arbitrary, being determined by the amount of steam pressure to which the machine may at any time be subjected, and by the length of scale that can conveniently be applied. The instrument represented in the figures is adapted to indicate up to 60 pounds of pressure, and the scale is equally divided into 20ths of an inch, each of these divisions representing one pound of pressure upon the square inch of the piston. From these data the spring is to be very carefully constructed, so that 2 ounces (or $\frac{1}{8}$ of a pound) will move the index through one division of the scale.

In the low-pressure indicator the process is precisely the same in principle, though somewhat less involved. The tension of the steam being low, and the atmospheric pressure limited within 15 pounds to the square inch, the scale is divided into 10ths of an inch. The piston is made equal to $\frac{1}{4}$ of a square inch in area, and the elasticity of the spring is such that 4 ounces (or $\frac{1}{4}$ of a pound) acting upon the piston in either direction, will cause the index to move through one division of the scale, which, consequently, represents one pound of pressure upon the piston of the steam-engine to which this instrument is applied. The zero-point is that at which the index stands when the cock C is shut and the piston *a* remains undisturbed, and, therefore, when the instrument is in action, it denotes that point in the stroke at which the pressures above and below the piston are balanced.

From these explanations it will be obvious that, by attaching the instrument to the cylinder of a steam-engine, and observing the motion of the index upon the scale, the maximum steam pressure and vacuum may be at once ascertained. But this is not the only, nor even the most important function of the indicator. It was desirable to find out the exact periods and modes in which these two elements of power come into operation, and especially the *mean* effective values of each; the rapidity of the motion through so short a space precluding the possibility of taking these observations with any degree of accuracy. These important objects are fully attained by the help of a simple and beautiful contrivance, by which the instrument is made to register its own performances.

An arm or bracket *g* is firmly attached to the indicator by being clamped to the external casing B on which it may be set to any convenient elevation, and there secured by a screw. To this bracket is riveted an upright axis, on which, by a long socket, to insure steadiness of motion, is accurately fitted a cylindrical piece F, formed into a pulley at its lower end. The other extremity of the socket carries a small cylindrical box containing a spiral-spring similar to the main-spring of a watch, and attached at one end to the fixed axis, and at the other to the internal surface of the box in which it is inclosed. The bracket *g* carries also a small friction-pulley *j*, for the purpose of guiding a cord wrapped round and attached to the pulley F, to any convenient moving part of the engine; a small catch screwed into the latter, serving to circumscribe its motion to a single revolution. An external cylinder or drum E, which may be withdrawn from the instrument at pleasure, is fitted over the revolving cylindrical piece F, so as to partake of its motion, and upon it is fixed a slip of brass formed into a double spring *l l*, Fig. 2304, for the purpose of securing the slip of paper on which the instrument is to register its performance. This is effected by means of a pencil *f*, placed in a holder *e*, jointed to the piece of steel on which the index or pointer is formed, and fitted with a small spring, so as to press the point of the pencil gently against the paper cylinder, or admit of its being withdrawn from contact with it at pleasure. From these arrangements it will be seen that if the piston *a* be moved up and down, while the pencil is in contact with the cylinder E, a straight line will be traced upon it in the direction of its length; and if, on the other hand, the cylinder be made to turn upon its axis by pulling the cord, while the piston remains at rest, a straight line will be traced round it at right angles to the former. By the combination of these two motions when the instrument is in operation, a diagram is produced, which represents the performance of the engine at all parts of its stroke.

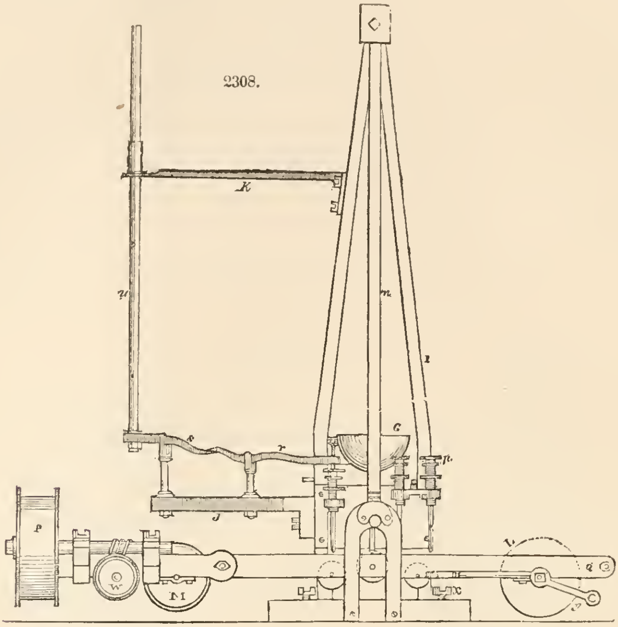


2307.

Action of the instrument.—The cock C is inserted into the corresponding socket prepared for its reception, and the cord which passes under the pulley *j* is attached to the radius-bar or other moving part of the engine, so as to cause the cylinder E to make one revolution on its axis, coincident with and representing the stroke of the engine; on the relaxation of the cord at the termination of the up stroke, it is taken up again by the action of the spring in the upright of the cylinder F, and the cylinder E resumes its original position. The slip of paper is then wrapped tightly round the cylinder, its ends being secured by the pressure of the two springs *l l*. These arrangements made, the pencil *f* is turned down into contact with the paper, and the engine allowed to make a stroke or two with the cock

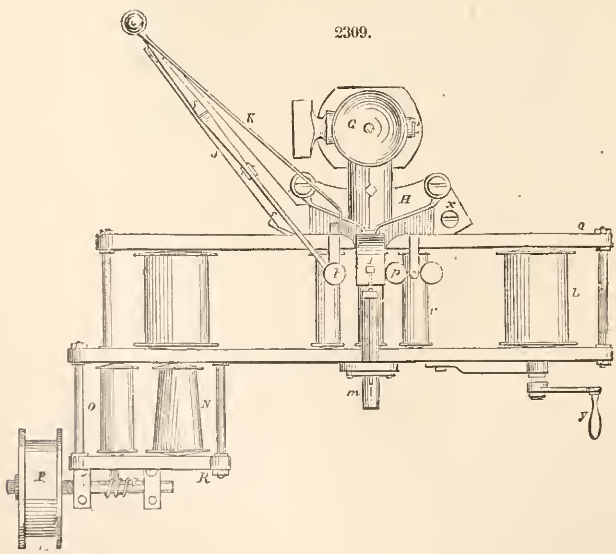
C shut, so as to form an *atmosphere line.* A communication is then opened with the interior of the cylinder of the engine by turning the cock C, and a figure or diagram is traced upon the slip of paper, exactly representing the successive pressures of the steam above, and corresponding degrees of exhaustion below the atmosphere line, at every part of the stroke. To find the mean effective values of each of these pressures respectively, the figure is to be divided, in the direction of its length, into any number

2308.



of equal parts, the perpendicular distances of the outline of the diagram above and below the atmosphere line at each of these points, to be carefully measured upon the scale of the instrument, and the sum of these to be divided by the number of points taken. Hence the actual power of the engine is easily calculated.

2309.



Morin's Indicator.—That eminent French mechanician, M. Arthur Morin, conceiving, with reason, that considerable inaccuracy was likely to result from the difficulty of constructing the spiral springs in Macnaught's indicator, so as at all parts of the stroke to denote equal pressures by equal divisions; and, moreover, considering it desirable to ascertain with greater precision the mean pressures and consequent actual power of engines by taking indications throughout several consecutive strokes, has invented a machine by which the former difficulty is obviated, and the latter object is attained. This instrument we have represented in the accompanying figures.

Fig 2307 is a side elevation, Fig. 2308 an end elevation, and Fig. 2309 a plan of the machine.

This indicator, like that we have already described, is adapted for being fitted to the cylinder cover of the engine; it carries a stop-cock pipe G, furnished with two keys; between these is situated a small horizontal cylinder H, in which a solid piston is accurately fitted to work steam-tight. Towards the middle of the piston-rod *m*, which is properly guided to a rectilinear course, is a square part in which is inserted the lower end of a long parabolic spring *n*, the other extremity of which is fixed to the summit of a standard I, forming part of the frame-work of the machine, the spring being so fitted as to admit of a certain amount of travel in the piston in both directions. The square boss of the piston-rod carries also a small pencil *o*, for the purpose of tracing the different degrees of tension of the steam on the opening of the lower cock G.

Two pencils *p p* are placed in holders fixed to the framing exactly opposite to the point at which the pencil *o* stands when the stop-cock G is shut, and being thus immovable, serve to mark a continuous atmosphere line. A third pencil *q*, which is susceptible of a slight degree of vertical motion in its socket, and is destined to mark the termination of each stroke, is brought into contact with the paper by placing the instrument so that the working-beam, cross-head, or any other rigid part of the engine may touch lightly at the end of the stroke, the top of an upright rod *u*, which is connected by a system of levers *r s t* with the top of the pencil *q*.

A continuous band or roll of paper may be subjected to the action of this machine for an indefinite period, so as to produce diagrams representing the action of the engine during several successive strokes. The manner in which this is accomplished is as follows: The roll of paper is first wound upon the cylinder L, by means of the handle *y*; it is then passed over the three small rollers *v v v* placed to oppose the pressure of the pencils, and is received upon the cylinder M situated at the opposite end of the framing Q Q. The axis of this latter cylinder is produced on one side so as to form also the axis of a conical pulley or fusee N, opposite to which is situated a cylindrical drum O, which receives a uniform motion from any rotating part of the engine to be operated on, by means of a worm-wheel *w* on its axis, geering with an endless screw on the axis of the strap-pulley P. The cylindrical roller O communicates motion to the conical roller N by a cord wrapped round both, and fastened at opposite extremities of each. The object of this arrangement is to compensate for the increased surface velocity due to the increased diameter of the cylinder M as the paper is wound on to it, by imparting to it a proportionally retarded motion.

This instrument, although highly ingenious in many of its details, and capable of giving very correct indications, is wanting in that portability and compactness which has very materially contributed to bring Macnaught's instruments into such general use. Moreover, although in any instrument of this nature the observations will be more or less accurate in proportion as the space through which the spring is made to act is more or less limited, yet a considerable advantage results from the length of range in the common indicators. The diagrams being made upon a large scale, the expert engineer is able, at a glance, and without reference to the scale, to ascertain by the mere contour of the figure whether his engine is performing all its functions properly.

The indicator of the steam-engine appears to fulfil two distinct and very important ends.

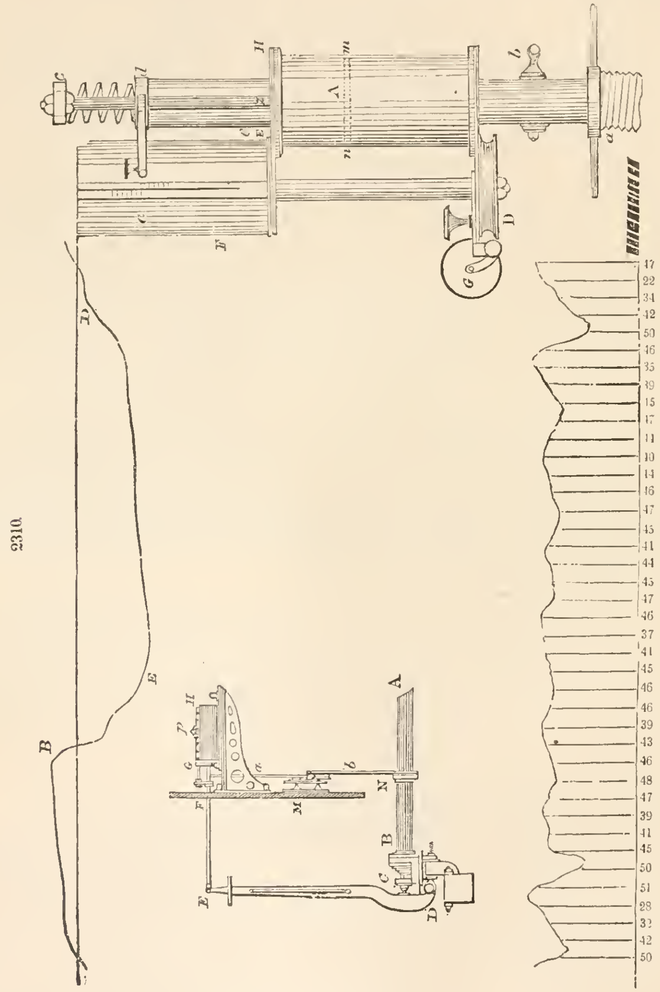
It enables us to discover whether there are any defects in those parts of the machinery by which the steam is admitted to the piston; for instance, it indicates whether the slides are properly set, or leaky; whether the stops on the intermediate shaft are properly placed; whether the steam-ports are large enough; and, consequently, whether a different arrangement of the working part of the machinery would be advisable. In fact, in the hands of a skilful engineer, the indicator is as the stethoscope of the physician, revealing the secret workings of the inner system, and detecting minute derangements in parts obscurely situated.

It discovers, at any instant of time, and under any given circumstances, when it may be desirable to apply it, what is the actual power of the engine.

We will first give a description of the instrument, and then proceed to its various uses.

Fig. 2310 is an external view of the indicator as constructed. The dotted lines are intended to show the internal parts. A is a hollow cylinder, whose upper end E H is open; the lower end being intended to fit into an orifice in some part of the engine (generally the top or bottom of the cylinder) by means of the screw *a*; *b* is a stop-cock, by which, when the instrument is attached, we can, at will, make or cut off a communication with the internal parts of the engine. Within the hollow cylinder A is a piston *m n* packed and fitting steam-tight. In practice this piston must not be packed *over-tight*, for fear of increasing the friction and preventing the free motion of the pencil; but the defect, if any, must be remedied by keeping melted tallow or oil on the upper surface.

Let us suppose, for perspicuity, the instrument to be in communication with the *top* of the steam cylinder. Then, when a vacuum is formed above the steam piston, the atmospheric pressure will force down the piston of the indicator, and it will remain at its lowest position till fresh steam enters; but it would immediately, (unless prevented,) on receiving a new impulse, be blown out at the open top H E. To prevent this, and at the same time to enable us to measure the force of the steam, a spiral spring presses with its lower extremity against the surface of the piston, while its upper end rests against the fixed cross-piece *c*. By this arrangement the pressure of the steam will always vary as the place of the piston varies; for it is a mechanical fact, that the tension of a spring varies as the extension. Hence, the greater the pressure of the steam, the more the spring is compressed; and, on the contrary, as the steam loses its elastic force, the spring expands and the piston descends. So that, to get a clear idea of the instrument, conceive the piston to be acted on by opposing forces; on the lower surface by the pressure of the steam, (continually varying,) and on the upper surface by the pressure of the atmosphere, (constant,) and by the force of the spring varying so as to balance the steam pressure. Now, as the steam-force is perpetually varying, it follows that the piston-tube de will be continually rising or falling. If a pencil be attached to the upper end of this tube de, in which the spring works, it will describe a vertical straight line on a piece of paper brought into contact with it. This, however, is not sufficient for our purpose. It would, after it was traced, tell us the maximum and minimum pressure during the stroke; but the pressure *at any particular portion of the stroke* would still be undetermined. We must, therefore, have some plan similar to that adopted in other cases where the vertical motion of a pencil under particular circumstances is to be *registered*. In all such instances, the paper on which the variation is to be laid down is drawn horizontally at a certain rate. If, for instance, we were desirous of recording how the pressure varies with the *time*, the paper must be drawn *uniformly*, by connecting it with clock-work, or some other apparatus for giving a *uniform* motion. But this, however, is not usually the desideratum in the steam-engine. Our object is here to have represented before our eyes the variation of the pressure for every portion of the stroke of the piston; and this is contrived as fol-



lows: the paper is wrapped round a cylindrical barrel C, which is brought back against a stop by a strong watch-spring contained in the box E F. A string passes round the pulley D, and is led away through a fair-leader G to some part of the engine having a similar motion to the piston cross-head, only much reduced, by which means the watch-spring and the string are always opposing each other. As the piston rises, the barrel will be pulled from left to right; and, on the contrary, as the piston descends the string having a tendency to slacken, the barrel will, by the force of the spring, be brought back from right to left. The pencil is attached to the upper end of the tube dg, and rising and falling with the indicator piston. It can be brought into contact with the paper on the barrel C or removed from it at will, by means of the joint at g. The rod z, and another one on the opposite side of the cylinder, serve as guides to the piston.

The paper is kept on the barrel by means of a strip of metal, which also serves another important purpose. It will be seen that it is graduated, beginning from zero, and proceeding upwards and downwards. Now this zero is the level at which the pencil stands when the instrument is unconnected with the steam-engine, and therefore acted on by the atmospheric pressure above and below the piston. The pencil will be seen at this level in the figure. If the barrel be made to revolve under these circumstances, a horizontal line will be traced out. This is called the atmospheric or zero line. And, therefore, the pencil will also be at this level whenever the steam, taking the place of the atmosphere *below* the piston, exerts the same pressure; and, consequently, wherever the diagram cuts this horizontal line, the pressure of the steam is 15 pounds on the inch;* when on the level of the marks 1, 2, 3, &c., above this zero, the pressure is 16, 17, 18, &c.; and when on the level of the marks 1, 2, 3, &c., below this, the pressure is 14, 13, 12, &c.

The atmospheric line should not be drawn till after the diagram is taken; because, as the parts become warm by the steam, slight variations occur in its position, depending principally on the alteration in the force of the spring; and since this line serves as the origin from which the pressures are dated, it is necessary to have it laid down as correctly as possible.

The small hole in the side of the stop-cock *b* serves to let the air into the cylinder A when the steam is cut off by the stop-cock, and thus enables us to take the atmospheric line; it enables the stop-cock to perform the office of a four-way cock; for by turning it in one direction we allow the steam to enter, and exclude the external air, and by turning it in the opposite direction we admit the air and exclude the steam.

Having an indicator, a diagram is obtained by looking out for some part of the engine whose motion is proportioned to that of the steam-piston,† taking care that the space moved through at that part shall be somewhat less than the circumference of the traversing barrel; that is to say, whatever be the diameter of the traversing barrel, let the movement of the part you are looking for be not greater than *three* times this diameter. Fasten a string firmly to this point, and have a traversing loop in the loose end of the string; it must be of such a length that it may be connected with the string passing round the pulley of the indicator. Then close the stop-cock of the indicator, and fix it by the screw *a a* to some orifice previously prepared in the top or bottom of the cylinder.‡ Insert the pencil you intend to use in the small hole made for its reception, and clamp it there. The pencil should be hard, and have a fine point, to give as clear and distinct a line as possible. Have some pieces of clean writing-paper provided, long enough to be brought round the traversing barrel and overlap about an inch. Wrap a piece smoothly round the barrel, and fix it by means of the clasp containing the scale. Then tear away all the surplus paper, and examine what remains, to see if it be quite smooth; for if there be any ridges the curve will have an irregular appearance, and might lead us to suppose some of the geer for working the slides had become loose, or much worn. Next wind the indicator string round the pulley of the barrel D, and connect the hook at its extremity with the loop of the string attached to the engine. Adjust the string by means of the running loop, till you are satisfied of the motion of the barrel; allowing it to make nearly a whole revolution, but examining it most carefully to see whether it becomes slack, or overtaut. The stop-cock *b* may now be opened wide, and the indicator-piston will immediately start into motion; the piston must be well lubricated, to reduce the friction as much as possible, and at the same time to prevent leakage. Let the instrument work for a few seconds, to allow it to become thoroughly heated; and when it has arrived at the same temperature as the steam-cylinder, it is in a fit state to trace its diagram. When satisfied of the working of the machine, take hold of the pencil when it comes to the *bottom* of its stroke, and bring it gently into contact with the paper. This part of the operation requires some practice; for if the pencil be allowed to come forward too rapidly, the spring at *g*, by which it is pressed against the barrel, will break the point; and again, if held too long, the force of the steam, suddenly acting on the machine, will tear it out of the hand, or break the holder. When left to itself, it will trace out its curve on the paper. As soon as it has made a complete circuit, let the pencil be withdrawn from the paper, (being again careful to take hold of it when at the *bottom* of its stroke.) In order to have the line distinct, the pencil should not go over the same ground twice. Shut off the stop-cock and the piston will become stationary, both sides being acted on by the pressure of the atmosphere. Bring the pencil again in contact with the paper, and as the barrel traverses, the atmospheric or zero line will be drawn. The operation is now complete, so far as the curve is concerned. Withdraw the pencil once more, unhook the line, and take off the traversing barrel. Next take a fine-pointed hard pencil, and mark off upon the paper the scale of pounds, beginning with the atmospheric line, and proceeding upwards and downwards. After taking the paper from the barrel, it is completed by writing on it the date of the month, the name of the ship, that of the engine, (whether starboard or port,) top or bottom of cylinder, as the case may be, the number of revolutions, the pressure of steam by steam-gage, and of condensation by barometer-gage.

It is important to have a running loop, or other means of shortening or lengthening the string attached to the indicator. Too much attention cannot be paid to this circumstance. If too much strain be brought upon the string it will stretch, and if the string be too long it will become slack; and in either case the barrel will be stationary for a small interval while the steam-piston is moving, and the curve will not be a true indication of the motion.

It is well known that the pressure of the steam and the state of the vacuum on the diagram do not correspond with the boiler-pressure and condenser-vacuum. The truth is, the result will always be l[illegible] The difference will depend on the size of the ports, and the work the engine has to do; the distance

* More strictly, 14·75 pounds, or a quantity differing from this slightly, according to the state of the weather.

† That is to say, when you are wishing to find how the *pressure* varies with the *stroke* of the engine.

‡ If the top of the cylinder be chosen, the orifice for the grease-cup will generally answer the purpose. In some cases a pipe leads from the top to the bottom of the steam-cylinder, and the indicator is attached to this pipe. It is provided with stop-cocks, so that when once fixed the arrangement is very convenient for taking two diagrams almost simultaneously from the upper and lower part of the cylinder. The only objection to it seems to consist in the tendency of the steam to condense in the pipe. For this reason it is advisable to have the indicator as close to the cylinder as possible.

the steam has to travel, the impediments it meets with in its passage from the boiler to the cylinder, and from the cylinder to the condenser. It is evident that the diagram taken from the top of the cylinder shows only the pressure and vacuum on the upper surface of the piston, and therefore cannot indicate what is going on below the piston. If our object be merely to calculate the horse-power of the engine, and it be in tolerably good working condition, it is not of much consequence whether the diagram be taken from above or below; but if the actual state of the engine be required, it is necessary to examine into what is passing both above and below the piston, because the errors in one part may have no connection with the errors in another. This will be the case if the slide is too long or too short, so that the upper part may be properly covered, and the lower one disarranged; or the upper slide may be steam-tight, and the lower one leaky; and if the indicator be applied to top and bottom, it will detect all these inaccuracies, and prevent our attempting to improve the working of one end to the detriment of the other. It ought to be remarked here, that in unbalanced engines the diagram from below the piston is generally superior to the other; because, since the steam has more work to accomplish, the piston does not run away from the steam so readily, and, in consequence, the steam-pressure is better maintained; and there is generally a little more lead to the slide, to allow a freer ingress to the steam. And, therefore, if great accuracy be required, the mean of the top and bottom diagrams should be taken for the horse-power.*

The string carrying the running loop must not be attached to any part of the engine indiscriminately. Generally speaking, we wish to obtain the pressure of the steam for different portions of the stroke of the piston; therefore, the string must be fastened to some part of the engine having a stroke proportioned to that of the piston, only much reduced. The part selected must be as near the indicator as other circumstances will permit; for the greater the distance the longer the string, and consequently the greater is the chance of error from its stretching. Caution must be used also to prevent the string from slipping on the rod to which it is attached. One of the best contrivances for giving a free and proper motion to the string is to fasten a wooden pulley to the radius-shaft,† to the groove of which the fixed end of the string can be connected. It will be necessary, in most cases, to make use of fair-leaders for the purpose of conveying the motion from the part chosen to the indicator; and due regard must be paid to this, to ascertain whether the motion of the engine will be fairly represented by the indicator.

We must bear in mind that all *vertical ascending* motions are caused by an *increasing* pressure of the steam, and that the *descent* of the pencil is the consequence of the elasticity becoming diminished: and again, that as the traversing barrel revolves from right to left, the piston is descending; while, on the contrary, as the pencil moves from right to left, the piston is ascending;‡ hence we shall arrive at the following general conclusions:—

1. If the motion of the pencil be vertically upwards, the steam-pressure is *increasing*, but the piston is *not* moving.
2. If the motion be downwards, the steam-pressure is *decreasing*, but the piston *not* moving.
3. If the line traced be horizontal to the right, the steam-pressure *does not vary*, but the piston is *descending*.‡
4. If the line be to the left, the steam-pressure *does not vary*, but the piston is *ascending*.
5. If the line run obliquely to the right upwards, the steam-pressure is *increasing*, and the piston is *descending*.‡
6. If the line run obliquely to the right downwards, the pressure is *decreasing*, and the piston *descending*.‡
7. If the line run obliquely to the left downwards, the pressure is *decreasing*, and the piston *ascending*.‡
8. If the line run obliquely to the left upwards, the pressure is *increasing*, and the piston *ascending*.‡

Let us refer to the accompanying diagram, Fig. 2312, taken from above the piston of an American steamer, and explain it.

First, we will put numbers round the diagram, in conformity with the principles laid down in the last paragraph.§ Then, supposing the pencil to commence at A, and trace out the curve in the direction of the arrows, we see that the steam preserves its first and highest pressure for a considerable portion of the stroke, viz. from A to C; from C to B the downward stroke continues, but the steam rapidly loses its pressure, although at a variable rate, decreasing rapidly at D. At B the motion of the piston ceases, but the steam continues to fall, till at length the pencil moves back nearly horizontally for some space, showing the pressure to continue invariable, although the piston is rising. At F, however, 8 shows the steam-pressure to increase rapidly and suddenly, the piston still ascending, till, as this oblique line merges into the vertical one at G, we perceive that the piston has arrived at the upper end of its stroke, and the fresh influx of steam drives the pencil up to A. From this point the pencil will retrace the same curve. G D is the atmospheric or zero line.

When the pencil is at G (or, it may be, rather before arriving at G) the slide is in the position represented at Fig. 2311, and is rising, so that the steam is about to enter the cylinder. Now this will

* We ought further to remark, that there is a difference between the motion of the slide in the up and down stroke. When the centre of the eccentric has reached that part of its orbit furthest removed from the slide, the motion of the slide is slowest; and when at that part nearest to the slide, the slide's motion, though slow, is comparatively quick. But at such times the piston is moving very quick, and, consequently, in the former case the steam-line is further extended than in the latter. This will therefore help to account for our getting a better diagram from the top of the cylinder of a beam-engine, and from the bottom of a direct-engine; and the difference becomes more marked in engines having a short connecting-rod. This is fortunate, for it assists in balancing the engine.

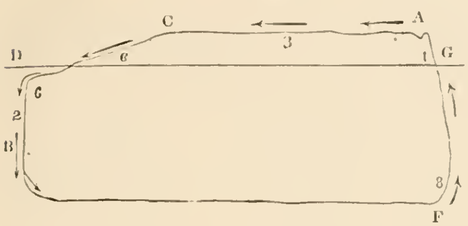
† In most direct-engines a pin can be fixed on the main centre of the air-pump beam. In Seaward's direct-engine the string may be attached to the *centre-line* of the radius-bar.

‡ This will be the case in one engine, but not necessarily so in another engine; and moreover, if the string be led in another direction the reverse will happen; but this the practical man can correct for himself according to circumstances, and substitute *ascending* for *descending*, and *vice versa*.

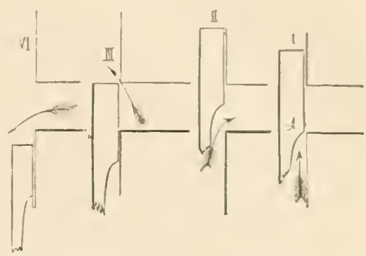
§ These diagrams should be reversed; that is to say, the right side should be in place of the left.

take place, as the diagram shows, very slightly before the upward stroke of the piston is accomplished and since the piston and slide are both on the ascent, the lower edge A will have ascended a trifling space when the piston is at its highest. This slight space, though trifling in amount, is important in its results on the working of the engine. It is denominated the *lead* of the slide. As the piston descends the valve rises, and the admitting orifice becomes larger, so that although the piston is gaining speed in its downward course, yet in well-contrived engines the first pressure is continued, as we find in the diagram, through a considerable portion of the stroke.

2312.



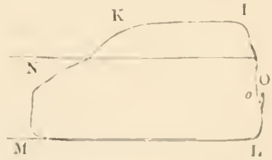
2311.



The slide, however, has already begun its downward motion, and when the pencil arrives at C it has returned into the position it had in Fig. I. It is clear that as it continues to descend no more steam can be admitted; whatever the cylinder contains will remain pent up; and as the piston continues to move downwards the steam relaxes its force, and we trace a corresponding depression in the diagram from C to D. But a still greater change is to be expected before the piston arrives at its lowest place. Ere that happens the slide will have come into the position shown by Fig. III.; for it is found to be disadvantageous to allow the steam to be kept in the cylinder till the end of the stroke, because the entering steam at the reverse stroke would meet with so much opposition, till the vacuum on the opposite side had become tolerably good, that the equability of the motion would be much affected. This being granted, we see that the port will be open for eduction before the end of the stroke, consequently a rapid fall in the curve takes place at D. Moreover, the slide continues to fall, not only after the piston has come to the bottom, but evidently during the greater portion of the up stroke. Although after a very short interval, from the great rate at which the steam rushes into a vacuum, the state of the vacuum is nearly unaltered, and but little different from that in the condenser; hence, after turning the right-hand corner, the pencil runs nearly horizontally. At F, however, the slide has returned to the position represented in Fig. III., and is *rising;* the piston is also rising, and near the top; consequently the steam that has not yet made its escape is pent up, and, becoming more and more compressed, the pencil rises rapidly, till, the fresh steam entering, it starts up suddenly to A and retraces the curve.

The accompanying diagram, Fig. 2313, though being taken from the same engine as that represented in Fig. 2312, differs in many respects.

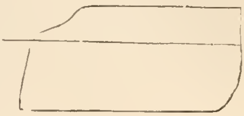
2313.



We observe, in the first place, that the steam-line I K is shorter than in Fig. 2312, while the exhaust-line L M is longer than in the latter; we infer, therefore, that the steam had a shorter time to come into the cylinder, and a longer time to make its escape. We observe, likewise, that the engine had made a considerable portion of its downward stroke before fresh steam was admitted. Now, these phenomena can be explained by supposing, from some cause, the slide to be removed bodily below the place it had when the former diagram was traced. For let us refer to the series of representations of the slide before noticed: Thus the point I shows us the steam comes in later in this diagram than in the former, and the valve is rising; consequently its lower edge will be at some point lower than it would be in ordinary circumstances. Again, the point K of the diagram indicates to us that the steam is cut off again sooner, but the slide is descending, and therefore, also, the lower edge is lower than it ought to be. Again, N being too far from the end of the stroke, we see that the exhaust takes place too early; in other words, the upper edge of the slide is too low. And lastly, the point L (where the cushioning commences) being carried too far to the left, shows us that too great an interval elapses before the upper edge of the slide reaches the upper edge of the port. And, consequently, every part of the reasoning proves to us the fact that the slide is lower than should have been the case. Now, in pursuing our inquiries, we shall find this is caused by one of two defects, viz., either the slide rod is too long, or the eccentric rod is not of the proper length. But in seeking for the remedy, we must look to the slide rod alone, because its length can be more easily adjusted than the eccentric-rod, by means of the nuts and screw by which it is fastened to the cross-head. The derangement of the engine, when the diagram represented in Fig. 2313 was taken, was obtained by lengthening the slide-rod ths of an inch. The projection at the point O remains to be noticed, although it would never appear except in exaggerated cases, such as the one before us. It will be seen that the cushioning takes place from L to O, and consequently the pencil rises because the steam is compressed; but the fresh steam does not yet enter, and therefore as the piston descends, this steam, till now compressed, loses its elastic force and the pencil drops, till at *o* a fresh supply enters and the pencil starts up from *o* to I, taking a motion compounded of the motion of the piston and the pressure of the steam, for it is to be noticed that the line *o* I bends sensibly to the left; this arises from the increasing velocity of the piston, and is not observable in the standard diagram, Fig. 2312, except near the top, because the piston is all but stationary during the short time the steam is entering.

The opposite effects would have taken place if the slide-rod had been shortened; that is to say, the upper portion of the diagram would have been spread out, and the lower part contracted. If the whole slide be of the proper length, it is clear that when we get a faulty diagram taken from above the piston, the one taken from below it will be similar to Fig. 2314, and *vice versa.* Hence, therefore, we see one advantage of taking both a top and bottom diagram. But if the one diagram be similar to one of those just exhibited, and the other be satisfactory, the fault lies with the slide itself, and cannot be remedied but by the engine-makers. The only plan for the engineer is to divide the fault as equally as he can between the upper and lower parts, by lengthening or shortening the rod, according to circumstances. Moreover, we conceive an engineer should not be satisfied that he has done all, when he has obtained a good diagram from one end of the cylinder; because, if the fault lay with the slide, he would be improving one to the injury of the other.

2314.



All the motions of the slide, whether up or down, would take place sooner than ordinary, if the stop on the eccentric were too far advanced; that is to say, the cushioning, the introduction of fresh steam, the cutting off, and the exhaust, would all commence sooner. The curve, therefore, instead of being like the standard diagram, will be similar to Fig. 2315, assuming somewhat of a lozenge-shape, the upper right and lower left corners being acute-angled, and the other two obtuse. Again, a little reflection will enable us to discover that similar defects will be exhibited in the lower diagram under these circumstances, and not opposite defects, as was the case when the slide or eccentric rod was at fault.

2315.

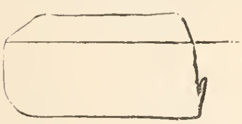
This curve was obtained by inserting a piece of metal, half an inch thick, between the stop on the eccentric and that on the shaft.

It can be readily ascertained, by inspecting the diagram, if the stop on the shaft were not sufficiently advanced; for in such a case all the motions of the slide will be later than they would be in a well-constructed engine; consequently, all the upper part of the curve will be drawn towards the right, and all the lower part to the left. And, as in the former case, the same distortion will be observable if a diagram be taken from the lower part of the cylinder. Moreover, if the defect be great, we shall meet with the hump in the lower right-hand corner, similar to that before noticed.

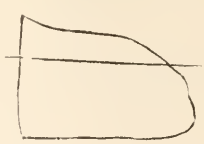
Fig. 2316 was taken after removing back the stop on the shaft 7-16ths of an inch.

When the ports of the cylinder or the steam-pipe are too small, the steam will not be able to enter or escape so freely as it ought; the pressure at first entrance will not be maintained for any length of time, and the vacuum will not be formed rapidly enough, the steam and vacuum lines will therefore lose their horizontality, as is easily discovered in the diagram here given, which was taken from one of our largest engines, afterwards altered by shortening the gab-lever.

2316.



2317.



2318.

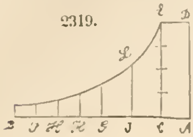
When the steam is throttled the upper line of the diagram will rapidly decline, as in Fig. 2317, for the same reason that it would if the steam-pipe or the port were too small, and it will not be so high altogether as in ordinary cases. The vacuum-line, however, will be better than it would otherwise be; for since the quantity of steam admitted is not so great, the speed of the piston will be reduced. But the exhaust-port is of the same size whether the steam be throttled or not; and therefore there is more time for the expended steam to rush through this orifice into the condenser, and consequently the vacuum-pressure in the condenser and in the cylinder will be more nearly equal, and better in both than when the full power is set on.

Fig. 2318 represents three diagrams taken from the engine before referred to, the steam being throttled to various degrees.

Fig. 2319 will represent a diagram when the expansive geer alone is used. For let A B represent the whole length of the cylinder, and when the piston has traversed the space A C, let the ingress of the steam be suddenly stopped. Then, from this epoch, the steam-pressure will decrease, and the pencil begin to descend. Now if the temperature of the steam be unaltered, the pressure will vary inversely as the space it occupies. Divide, therefore, the space C B into intervals C J G, &c., each equal to A C; and therefore when the piston is at J, the space A J being *twice* A C, the pressure of the steam at J is *half* that at C, at G it will be one-third, at H one-fourth, &c.; and if lines be drawn through C J G, &c., parallel to A D, and of the length we have just indicated, making C E = A D, J L = half A D, &c., and through the upper extremities of these lines a free curve be traced, it will give us an idea of what we ought to expect. But since the slide-valve also acts, we shall have the modification this would produce too, for the slide-valve is placed between the expansion-valve and the cylinder, in most engines; it follows, therefore, that the effective volume of the steam, intercepted by the expansion-valve, is the whole of the space between it and the piston, and the slide-valve interposes an additional barrier when it begins to cut off the steam. The case, therefore, is somewhat similar to what it would be if there were two expansion-valves, one nearer to the cylinder than the other, and the outer one acting first.

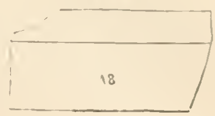
Fig. 2320 represents a series of diagrams taken from the same engine. Here 0 gives the full steam without using the expansion-geer, 1 that produced by the first grade of expansion, 2 that produced by the second grade, and so on. We must here remark, that in the interval that elapsed between taking the diagram in Fig. 2317 and the series here represented, the engine had been improved by shortening the gab-lever, and thus enlarging the aperture for steam and eduction. The effect will be observable by comparing the diagram S with that in Fig. 2317.

2319.



2320.

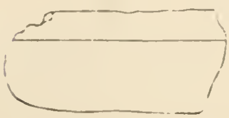
2321.



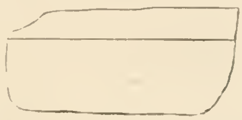
We must always rest satisfied that an engine is in good working condition when the general features of the diagram are satisfactory; for in the hands of an inexperienced person, the indicator may trace an unfaithful representation of the condition of the engine. When the piston is near one end of its stroke, if an undue strain be brought on the string it will stretch, and the indicator-barrel remaining stationary while the steam is entering, the pencil will have a vertical ascending motion, such as is represented in Fig. 2322. On the other hand, if the barrel come back against its stop before the opposite stroke is accomplished, the pencil will fall vertically, as in Fig. 2321. These two figures ought to have been precisely similar, the only cause of difference being the accident of the string.

The series of steps in the right upper portion of the diagram represented in Fig. 2323 arises from the piston of the indicator being packed over-tight, on which account it descends by a series of jerks as the steam-pressure relaxes.

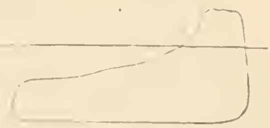
2323.



2322.



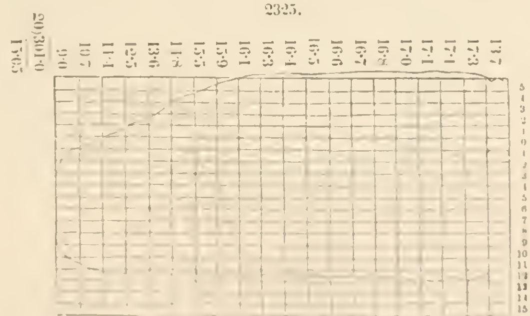
2324.



The steam-line in Fig. 2324 does not descend so rapidly as in the imaginary curve spoken of in the last page, because the expansion-valve of the engine it was taken from was leaky, and therefore did not entirely cut off the steam.

The most accurate way of ascertaining the power of an engine is by means of the indicator, because the diagram gives the pressure on the piston, and hence, knowing the number of revolutions and the length of stroke, the laboring force can be ascertained. The mean pressure on the piston is obtained as follows: Divide the diagram by a series of equidistant vertical lines, as in Fig. 2325, (the closer the better,) and, taking the horizontal line marked 0 as the origin, draw a series of other lines parallel to it at distances equal to the intervals corresponding to the scale of pounds on the indicator. This being

2325.



accomplished, if our object be only to form an estimate of the gross power, observe in the middle of each vertical space the number of pounds included between the steam and vacuum lines to tenths, which will be best done by taking the distance with a pair of compasses, and setting it off on the scale of pounds. Write these in their proper columns, as in the figure, along the diagram, and add them together. Then divide the gross result by the number of columns, and we obtain the gross average pressure on the one side of the piston during the up and down stroke. From this it is usual to deduct from 1 pound to 1·5 pounds, according to the size of the engine, for friction, for small engines have more friction in proportion than a larger; then the result is taken as the effective pressure per square inch, acting *uniformly* during one whole revolution. Take now the diameter of the cylinder in inches, and square it; then multiply the product by ·7854, the result is the number of square inches on the surface of the piston. Multiply this again by the pressure per square inch, as got from the indicator, for the whole pressure in pounds on the surface of the piston. And if this be multiplied by the length of a double stroke, and finally by the number of revolutions we shall obtain the work done by the engine

It is usual to divide this quantity by 33,000, (supposing this to be the number of pounds a horse would be able to raise one foot a minute, and the quotient is then called the horse-power of the engine. If there be two engines, as is usually the case in steamers, this quantity must be doubled.

Example.—In the preceding diagram, let the number of revolutions be 38, and therefore the number of single strokes 76.

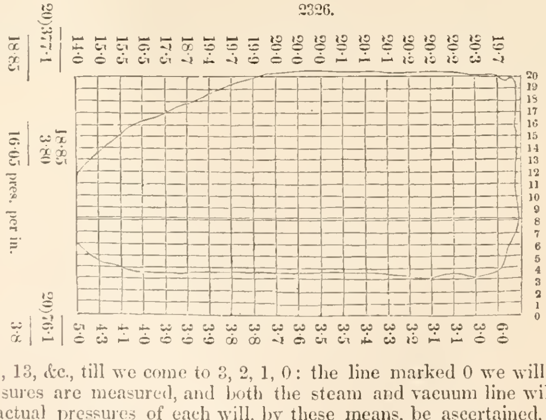
Then, since the diameter of steam-cylinder = 20 inches,

∴ Diam.^{2} = 400
·7854
314·2000 sq. inches.

But pressure of steam = 15·05 lbs.
Deduction for friction = 1·50
∴ Effective pressure per inch = 13·55
314·2
2710
5420
1355
4065
Pressure in lbs. on piston = 4257·410
76
2554446
2980187
323563·16
2
33|000)647|126·62
19⅔ horse-power

If it be necessary to find, *separately*, the value to be given to the steam and vacuum pressures, we must get the actual pressure, and not the difference of pressure between the steam and vacuum lines. And therefore we might measure the height of the spaces above the atmospheric line, and the depth of the vacuum below it. But, in regard to the steam-line, a difficulty has to be surmounted, which would not be easily got over by practical men unaccustomed to analytical investigations. It is this; that part of the steam-line is usually above the atmospheric line, and part below it; and the results of the one must be subtracted from the results of the other. This is more particularly to be noticed in cases where the engine is working expansively, and a great portion of the steam line is in consequence below the atmospheric line. The following suggestion will, however, get over the difficulty: consider the atmospheric line, as in Fig. 2325, to be 15 lbs. (which is its actual pressure,) and reckoning downwards, call

2326.



the lines below it 14, 13, &c., till we come to 3, 2, 1, 0: the line marked 0 we will assume as that line from which the pressures are measured, and both the steam and vacuum line will be above this new zero line; and the actual pressures of each will, by these means, be ascertained, and not the relative pressure, as compared with that of the atmosphere. In the preceding diagram, this second method of computation has been performed; the numbers on the right-hand side beginning from the absolute zero, and the figures along the top and bottom of the curve giving the steam and vacuum pressures respectively. The mean of the steam-pressure is 18·85 lbs., and of the vacuum 3·8 lbs. The difference is 15·05, as we obtained before.

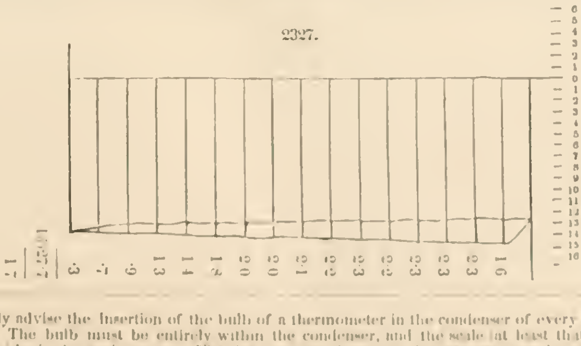
To determine the work done in one single stroke of the piston, we must suppose the piston to be descending; then the steam-pressure acts above the piston, and the vacuum-pressure below the piston; that is to say, the steam-pressure must be got from the top diagram, and the vacuum-pressure from the bottom diagram; and we must, therefore, make use of the method proposed in the answer to the last question. Thus, to obtain the mean pressure during the down stroke, take the steam-pressure from the top diagram, and the vacuum-pressure from the bottom diagram, and subtract the latter from the former. Again, to obtain the pressure during the up stroke, take the *vacuum*-pressure obtained from the *top* diagram, from the *steam*-pressure got from the *bottom* diagram.

To ascertain by the indicator the quantity of steam an engine uses, we have only to fix on any con venient part of the steam-line between that point where the steam is cut off and the opening is made to the condenser; that is to say, between the points C and D in Fig. 2312. Observe, by counting the vertical spaces, what proportion the portion of the stroke, as far as this point, bears to the whole length of the stroke. Notice also the pressure of the steam at this point. Then we shall have a certain fraction of the cylinder filled at each stroke with steam of a given pressure. If now the cubic contents of the cylinder be determined, and the number of times the cylinder is filled per minute, we shall have the quantity of steam of known pressure supplied to the engine per minute. Thus, suppose that in the engine before alluded to $\frac{9}{10}$ of the cylinder were filled with steam of 15 lbs. pressure; then, since the number of cubic inches in the cylinder twice filled is 15079·6, the number of revolutions being 34 at the time of experiment, the whole number of inches in a minute $= 51252·64$, $\therefore \frac{9}{10} \times 512526·4 = 461273·76$, and the number of cubic inches of atmospheric steam in an hour $= 461273·76 \times 60 = 27676425·60$. But each inch of water is supposed to form 1711 cubic inches of steam at the atmospheric pressure, and therefore the number of cubic inches of water evaporated $= \frac{27676425·6}{1711} = 16,175$; and the number of gallons (English) of water evaporated $= \frac{16175}{277·274} = 58$ nearly.

Now, if the theory be correct, this should be the quantity of water evaporated from the boiler, due allowance being made for condensation, &c., in the steam-pipe and passages. But this is far from being the case, for the number of gallons actually evaporated by the boiler was ascertained to be 108 gallons in the hour. We can do nothing more at present than to state the discrepancy, and offer the following hypothesis to account for it. From the violence of the ebullition, the steam is in all likelihood not so dry as that on which careful experiments are made, as is frequently made manifest in boilers that "prime;" so that, even in good boilers, it is very possible for the steam to contain much more watery vapor than it would if it were not so rapidly consumed. If so, an inch of water would not under these circumstances form 1711 cubic inches of steam under the atmospheric pressure, and might perhaps form only one-half that quantity, which would be requisite to give the proper number of gallons of evaporated water. It remains to be seen by future experiments whether this be the fact; and if true, it will throw doubt on the tables of relative volumes of steam and water contained in most works on the steam-engine.

To determine the friction of the unloaded engine.—If we examine the effect of any machine at work, however simple, we shall find a certain amount of power is requisite to overcome the friction of the engine itself. Divest a common crane of its chain, or any load that may be upon it, and it will still be found that some force must be applied to give motion to the geering itself; the amount of force depending on the materials used, the mode of fitting, and the quantity of geer set in motion. So it is with the steam-engine. A certain amount of power is required to overcome the friction of all its parts; and in this respect no two engines will be found alike, so much depending on the goodness of the workmanship, and the nice adjustment of the different parts.

Before proceeding with the method of ascertaining the friction of an engine by the indicator, we would observe, that the greatest care and judgment are requisite in carrying out this experiment; there are many classes of engines in which the experiment ought not to be tried, especially direct-acting engines. The way, however, to proceed is this; the *communication valve* must first be closed, because the engine requires an exceedingly small quantity of steam to work it when the paddle-wheels are disengaged. Then let the blow-valve be opened, to allow any steam that may happen to be in the steam-pipe to escape. In the engine with which we tried our experiments, it was found necessary to destroy the vacuum, befor getting the diagram, by opening the blow-valve, to prevent the engine flying off at too great speed. The throttle-valve must be closed, and the paddles disconnected. After slightly opening the communication and throttle valves, the slide may be opened gradually and cautiously, to admit the steam to the piston, and the injection must be let on as carefully as possible. Work the engine a few strokes by hand, and then let it be thrown into geer, and regulate the working by the throttle and communication valves—the object being to give the engine the same number of revolutions without the paddles as it usually has with them—taking care to have the condenser of the same temperature as in the ordinary working state of the engine.* The indicator having been previously fixed and adjusted,



2327.

* We would strongly advise the insertion of the bulb of a thermometer in the condenser of every engine in addition to the barometer-gage. The bulb must be entirely within the condenser, and the scale (at least that part of it which is above 50° or 60°) outside, in the engine-room. The thermometer chosen for the purpose must be graduated higher than the temperature of the steam in the boiler, otherwise it will burst when the engine is blown through. It must be placed in some part acted on freely by the steam, but free from the splash of the injection water. When the engine is free from air it will then serve as a most delicate test of the vacuum. The temperature preserved should be about 100°.

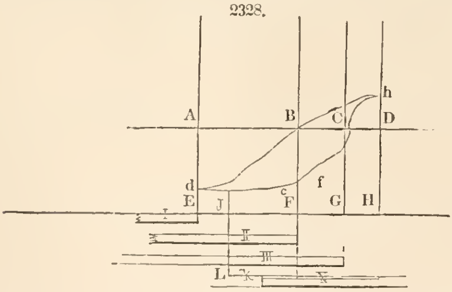
let a diagram be taken: it will be widely different from that when the load is on. Both the steam-line and vacuum-line will be much below the atmospheric line. The diagram may then be taken off, and divided as in the former case. Let the result of this diagram be worked off in the same manner as the common diagram, and the amount is the work the steam has performed, or in other words, the friction of the unloaded engine. This has been accomplished in the diagram, Fig. 2327.

This is what is commonly subtracted from the gross result obtained under ordinary circumstances, and denominated friction; but it is manifest that it is much less than the actual friction of the engine when turning the wheels, for the friction of every machine increases with its load; and moreover, the injection water, &c., raised by the air-pump increases likewise, and all this goes under the head of friction. The friction of large engines is less in proportion than that of smaller ones; in large engines it is usual to allow 1 lb. on the square inch of the piston for friction, and in small engines from 1·5 to 2 lbs.; and in most cases it would be better, except as a matter of experiment, to trust to this than to attempt the difficulty of ascertaining it.

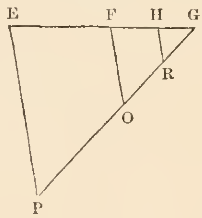
A *slide* diagram is that in which the indicator-string is connected with the cross-head of the slide, and not with that of the piston; so that the horizontal motion of the pencil backwards and forwards corresponds to ascents and descents of the slide, and *vice versa*. And this process will give us many particulars of the slide, without the trouble of taking the engine to pieces for measurement. If the indicator be applied to the upper end of the cylinder, it will give us information of the upper slide-face; and if to the lower end, of the lower slide-face. As was before stated, the string must be connected with some part having the motion of the slide; but generally it will be necessary to reduce the motion, because the stroke of the slide is more than the indicator-barrel will allow; in small engines it may be attached to the cross-head direct. As was before remarked, so long as the pencil is moving from left to right, the slide is rising; and when moving from right to left, it is falling; and any rise or fall of the steam-pressure is due to the change of pressure in the steam, as in the common or piston diagram. Then the difference in the two cases would be this: that in the common case we have changes of pressure corresponding to motions of the *steam-piston;* and in the *slide diagram* we have changes of pressure corresponding to the motions of the *slide;* and the important thing to notice is, that every sudden change of pressure refers to some prominent epoch in the slide's motion; and consequently we are enabled to trace successively on the paper, the various positions of the slide from its lowest point as it cushions the steam, allows fresh ingress, &c., and finally arrives at its highest point.

The following is a slide diagram, obtained by connecting the string to the slide cross-head of our model engine. The whole length of the figure is the same as the travel of the slide. If not, a plan must be adopted to be afterwards explained. When the pencil is at *d*, the slide is at the lowest point, and the vacuum is very good, as the slide rises till the pencil comes to *c*; but since we know *à priori*,

2328.



2329.



that the vacuum remains good in the engine till the cushioning commences, therefore when the slide has risen from *d* to *c*, the cushioning commences; the cushioning continues as the slide rises till the pencil arrives at *f*, when fresh steam enters, and after this epoch the slide still rises till the pencil has reached the point *h*. As the upper line is not so marked in its character as the lower one, we shall not say any thing of the downward stroke. Through the points *d c f*, &c., draw the vertical lines A *d*, B *c*, C *f*, D *h*, cutting the atmospheric line in A B C D, and the horizontal line E H in E F G H. Suppose E H to be the nozzle of the steam-port, on which the face of the steam-slide moves, (the cylinder being for convenience of illustration supposed to be lying *horizontally;*) then, since when the pencil comes to *c*, the cushioning commences, F must be the upper edge of the port. Take F J equal to the depth of the port, (which we will suppose known.) Again, since when the pencil is at *d* the slide is at the lowest, therefore we must suppose it to have started from E; and consequently, at starting, the upper edge of the slide was below the lower edge of the port, the space J E. When the *upper* edge of the slide arrives at G, fresh steam enters; in other words, the lower edge of the port is at J, and therefore the depth of the slide-face is J G. Moreover, since the slide still rises through the space H G, H G will be the greatest amount of opening for steam. The successive positions here spoken of are laid down in the figures under the line E H. F J is the depth of the port. In I the slide is at its lowest; in I I the cushioning is commencing; in I I I the steam is about to enter; in X the slide is at its highest.

When the travel of the slide is greater or less than the breadth of the diagram, let G E (Fig. 2329) be the breadth of the diagram, as in the last paragraph; from G draw G P, making any finite angle with G E, and equal to the travel of the slide. Join P E, and through F and H draw F O, H R, parallel to E P, and then proceed with the line H P, as in the last paragraph with the line H E, considering O to be the upper edge of the steam-port, &c.

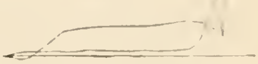
It should be observed here, that the piston diagram does not necessarily return into itself, and form a closed figure, as in the preceding diagrams. This only happens because the indicator-barrel contains the spring which, as has been stated, draws back the barrel directly the string relaxes. But we can by a different arrangement produce a figure, of some value, in which the curve proceeds continuously in one direction, and which, therefore, we shall call the "continuous diagram." Let the spring fitted to the traversing cylinder, for bringing it back, be taken out, and also the stop that prevents the cylinder from going too far; because our object is to let the barrel revolve freely. The clasp, by which the paper is usually secured, must also be taken off, and the paper must be secured by turning it over the top of the cylinder, and be folded in such a manner that the pressure of the pencil will help to keep it down. Let now some part of the engine be selected where a double pulley may be fitted to revolve, one groove of the pulley having about the same diameter as the pulley attached to the barrel, and the other to the diameter of the paddle-shaft. A string must be passed round this latter pulley and the shaft, and they will revolve in the same time. Another string must be passed round the pulley of the barrel and the smaller of the two pulleys; and then the indicator-barrel will revolve nearly in the same time as the engine shaft. And if we suppose the shaft to be revolving uniformly, which it will be nearly, especially where there are two engines, the barrel will have a uniform motion in one direction. If the pencil be put to the paper, as in ordinary cases, when the indicator-piston is at the lowest, it will commence tracing its curve. It should be allowed to remain for one entire revolution, and longer if convenient, provided one line do not interfere with the other in going twice over the paper.

The chief practical utility of these diagrams is, that they serve to show *the rate* at which the steam-pressure increases or decreases. It will be observed by the continuous diagram, Fig. 2310, that the steam-pressure does not increase instantaneously, as many suppose, and as the common diagram would lead us to believe. The vacuum commences at D and continues to E, the cushioning from E to A; the fresh steam enters at A, and causes the pencil to rise till it reaches its highest at B.

If we examine this diagram in page 56 by any of the previous tests, we shall find it rounded off at the corner, a circumstance not easily accounted for. For in all former cases we can only correct a defect in this corner at the expense of the lower corner. As the indicator persisted in giving this outline, and all attempts according to the foregoing principles (by altering the set of the slides, &c.) failed, it was at length proposed to examine the steam-piston itself; and accordingly, steam was let in at the lower port, and the cock of the grease-cup opened, when it was discovered that the piston was not steam-tight in the cylinder; and therefore, although when the engine was working the first impulse of the steam sufficed to drive the pencil up, yet as soon as the piston had got into motion, the escape of steam by leakage did not allow the pencil to rise so rapidly as it otherwise would have done.

It is evident that no part of the diagram can be below the atmospheric line, when an engine is worked without condensation; for the pressure can never be less than that of the atmosphere. And since the steam has not a free escape into the air, but is obliged to force open the foot-valve and delivery-valve, and make its way through the air-pump bucket, the resistance it meets with will cause the pressure to be greater than that of the atmosphere. Engines, whose steam-pressure is not considerably greater than that of the atmosphere, cannot be worked on the high-pressure principle. The next diagram was taken from an engine whose boiler-pressure is 7 lbs. In high-pressure engines, the diagram will be similar; because the steam having to escape by the blast-pipe, is pent up, and causes the lower part of the diagram to be above the atmospheric line. In general, the steam and vacuum lines must be worked out separately by the plan proposed in page 57; for it will be observed, that the lines intersect each other in the diagram. The indicator for high-pressure engines should be made expressly for the purpose; the scale of pounds should have a higher range, but need not go below the atmospheric line.

2330.



This curve presents a singular appearance, from the steam and exhaust line intersecting. Since the cushioning begins at the usual place, that is to say, at the same part of the stroke as when used as a low-pressure engine, the steam pent up on the exhaust side, and commencing with a pressure greater than that of the atmosphere, soon surpasses that of the boiler, so that when the port begins to open, the pressure suddenly falls. Again, when the entering steam is cut off, the pressure gradually falls, and before the end of the stroke it is less than that of the eduction; and when opened again to exhaust, steam enters from the condenser, and the loop of the left-hand corner is formed.

The *Dynamometer*, an instrument somewhat similar to the indicator, has been introduced into screw vessels, for the purpose of enabling the engineer to record the exact amount of pressure given off by screw-shaft, and, consequently, the force the engine, by means of this instrument, is exerting to propel the ship. It is merely a lever, or a combination of levers; the shaft pressing near the fulcrum, and the farther end of the lever, or combination, being attached to a Salter's spring-balance. In the diagram, Fig. 2310, A B is the screw-shaft pressing as it revolves against a movable pin which is contained in the plomer-block at C, and can slide freely backwards and forwards; D E is the lever, having the fulcrum at D; the pin at C presses against a knife edge on the lever, as is seen in the figure. The rod E F is connected with the spring of a Salter's balance, which cannot be seen in the figure, but is concealed from sight by the cylindrical barrel I K; F is also attached to the rod G H. This rod, as we perceive, has several grooves in it, so that the small fork carrying the pencil *p* may be brought in contact with more than one part of the barrel in succession, if desirable.

The barrel is made to revolve by means of a strap *a b*, connecting it with the screw shaft; and it will be seen by the figure, that there are pulleys of different sizes connected with the bulk head at M, and the shaft at N, by which the motion of the cylinder can be regulated, and be made quicker or slower at pleasure. The curve will evidently be somewhat similar to the *continuous indicator diagram*, consisting of a series of undulations according to the force of the steam and its action on the propeller. A zero-line must be got, as in the case of the indicator. When the dynamometer is applied to large engines, the levers can be relieved of the pressure of the shaft; and this being accomplished, the index of the spring-balance will stand at 0, when the zero-line may be traced. The balance will also give the scale of pounds. After the diagram is traced, draw a series of equidistant lines at right angles to the zero-line, as in Fig. 2310, in the article on the indicator, which represents a dynamometer diagram taken on board a man-of-war steam-vessel, the dimensions being reduced one-half. The distance between the curve and zero-line must be measured and compared with the scale of pounds on the balance. Let this be registered on the diagram in its proper space. The sum of all these is then to be taken, and divided by the number of spaces taken into account. Thus we shall obtain the mean force of the lever on the spring of the balance; let this be multiplied again by the *leverage* of the dynamometer, and the result will be the pressure of the screw-shaft on the dynamometer, and, therefore, on the vessel.* To obtain the leverage, if the lever be compound, multiply together all the long arms, (measuring from the fulcrum,) and divide the product by all the short arms multiplied together, (measuring also from the fulcrum.)

The horse-power of an engine is to be found by the dynamometer in the following manner:

Having found the number of *pounds* pressure exerted by the screw-shaft, multiply it by the speed of the ship in knots, and the product by 6080, (the number of feet in a knot;) then divide the result by 60, (the number of minutes in an hour,) and by 33,000, and the quotient will be the horse-power.

Or the work may be shortened, thus:

Multiply the number of pounds pressure by the speed of the ship, as before, and this product by ·00307, and the product gives the horse-power.

This, it will be observed, is the *effective* horse-power after making allowance for friction and loss by useless resistance.

The diagram before referred to will elucidate the process of working out the result. This was taken simultaneously with two others; and the mean of the three pressures was 41·309 lbs. Multiplying by the power of the system of levers, the result was 8086·4 pounds, (the pressure exerted by the screw-shaft.)

The speed of the ship was 9·893 knots.

Hence $8086{\cdot}4 \times 9{\cdot}893 = 79998{\cdot}7$.

And $79998{\cdot} \times {\cdot}00307 = 245$ nearly, the horse-power required.

The horse-power by indicator at the same time was 465·6, showing a loss of 220·6 by friction, resistance, &c.

INDIGO. A blue substance much used as a dye-stuff. The best indigo is obtained from an Asiatic and American plant, the *Indigofera*. The plant is bruised and fermented in vats of water, during which it deposits indigo in the form of a blue powder, which is collected and dried, so as to form the cubic cakes in which it usually occurs in commerce. Indigo is quite insoluble in water; when heated it yields a purple vapor, which condenses in the form of deep blue or purple acicular crystals. When indigo is exposed to the action of certain deoxidizing agents, it becomes soluble in alkaline solutions, losing its blue color and forming a green solution, from which it is precipitated by the acids *white;* but it instantly becomes blue by exposure to air. This *white indigo* has been termed *indigogene*, and indigo appears to be its oxide. It is best obtained by mixing 3 parts of finely powdered and pure indigo with 4 of green vitriol, 5 of slaked quicklime, and 100 of water, repeatedly shaking the mixture. In about twenty-four hours the supernatant liquor, which is transparent, and of a green color, is to be decanted off, and poured into dilute muriatic acid, when the deoxidized indigo is thrown down; but, in order to prevent its absorbing oxygen and becoming blue, it must be most carefully excluded from the contact of air, which may be effected by siphoning it off into the acid, collecting it in vessels filled with hydrogen, and washing it with water deprived of air and holding in solution a little sulphate of ammonia. In this white state indigogene absorbs between 11 and 12 per cent. of oxygen to become blue indigo. It would appear from Dumas' experiments that indigogene is a compound of

	Atoms.		Equivalents.
Carbon	45	=	270
Hydrogen	15	=	15
Nitrogen	3	=	42
Oxygen	4	=	32
	1		359

and that indigo consists of 1 atom of indigogene = 359, and 2 of oxygen = 16. The chemical equivalent of indigo, therefore, is 375.

When indigo is dissolved in concentrated sulphuric acid, it forms a deep blue liquid, known to the dyers by the name of *Saxon blue*. The great mart for indigo is Bengal, and the other provinces subject to the presidency of that name, from the 20th to the 30th deg. of N. lat.; but it is also cultivated, though not nearly to the same extent, in the province of Tinnevelly, under the Madras government in Java; in Luconia, the chief of the Philippine Islands; and in Guatimala and the Caracas, in Central America. The following remarks, from the *Commercial Dictionary*, will exhibit the history of this now indispensable commodity, and the difficulties with which it had to contend before it obtained a permanent footing in the commerce of Europe. "It appears pretty certain that the culture of the indigo plant, and the preparation of the drug, have been practised in India from a very remote epoch. It has been questioned, indeed, whether the *indicum* mentioned by Pliny was indigo; but, as it would seem,

* A doubt has been expressed by some as to whether this is really the force exerted by the shaft on the vessel, on account of the shaft acting on a lever that yields to its force; but independently of the fact that none of the thrust can be lost, it is clear that the thrust at C is equal to the thrust at D and that at E, and these are the two forces acting on the vessel.

without any good reason. Pliny states that it was brought from India; that when diluted it produced an admirable mixture of blue and purple colors, (*in diluendo misturam purpuræ cæruleique mirabilem reddit;*) and he gives tests by which the genuine drug might be discriminated with sufficient precision. It is true that Pliny is egregiously mistaken as to the mode in which the drug was produced; but there are many examples in modern as well as ancient times to prove that the possession of an article brought from a distance implies no accurate knowledge of its nature, or of the processes followed in its manufacture. Beckmann (*Hist. of Inventions*, vol. iv., art. 'Indigo') and Dr. Bancroft (*Permanent Colors*, vol. i., p. 241–252) have each investigated this subject with great learning and sagacity, and agree in the conclusion that the *indicum* of Pliny was real indigo, and not, as has been supposed, a drug prepared from the *isatis* or woad. At all events, there can be no question that indigo was imported into modern Europe, by way of Alexandria, previously to the discovery of the route to India by the Cape of Good Hope. When first introduced, it was customary to mix a little of it with woad to heighten and improve the color of the latter; but, by degrees, the quantity of indigo was increased; and woad was, at last, entirely superseded. It is worth while, however, to remark, that indigo did not make its way into general use without encountering much opposition."

In common painting indigo is seldom or never used without a small mixture of white. A preparation from the leaves of the *anillo* is sometimes fraudulently substituted for indigo, but may be at once detected by throwing a piece into the fire, *as genuine indigo will not burn.*

INERTIA. (See FORCE.)

INVOLUTE CURVE, is that which is traced out by the end of a thread (while being unwound) that is coiled round another curve. This species of curve is frequently used in the formation of the teeth of wheels. (See GEERING.)

IRON, (Sanscr. *ais;* Mod. Hindost. *lohah;* Mod. Pers. *auhun;* Chald. *perzela;* Heb. *barzel;* Gr. *sidêron;* Swed. *jern;* Dan. *jern;* Icel. *jarn;* Franco-theot. *isar, isarn;* Mæso-Goth. *ais;* Germ. *eisen;* Ang. Sax. *isen, isern, iren;* Low Germ. *isen;* Fries. *ixsen;* Dutch, *yzer;* Erse, *jarann;* Welch, *haiarn;* Lat. *ferrum;* Ital. *ferro;* Sp. *hierro;* Fr. *fer,* &c.,) one of the longest known, the most generally used, and most extensively applicable of all the metals. Although found *native*, as it is called, it nowhere exists perfectly pure in nature. In the arts, it occurs under four conditions; 1. as pure iron: 2. crude, or cast iron; 3. malleable, or wrought, or bar iron; and 4. steel. Its precipitate, or release from a chemical solution or combination, is always pulverulent, and does not present the most important practical characteristics of the metal. Deposited in the electrotype-way, it is more coherent, but still friable. It is difficult to be produced by this method in large plates: pieces of an inch square are rare. Seen by reflected light, its surfaces in this condition are more brown than gray, owing to its immediate oxidation. A fresh fracture is, however, clear gray. Its texture is crystalline, or, more properly, an assemblage of crystals loosely cohering, which appear cubic. In this state it is not at all malleable. When fresh it is highly magnetic; but this property rapidly diminishes on exposure to the air or moisture. Its density is not known, and can with difficulty be accurately ascertained. When broken into spiculæ and approached to a wire no longer at a red-heat, or even to the lateral flame of a spirit-lamp, it decrepitates slightly and becomes converted into powder of the peroxide. Its other properties in this condition have not been thoroughly examined; nor are they likely to present much interest except for merely speculative, and, perhaps, for medicinal purposes.

In the condition of *steel*, on the other hand, all the peculiarities and habitudes of this metal are important enough to require a special detail and discussion in a separate article. (See STEEL.) Under this one will be considered what is proper to it in its two conditions of *crude* and *malleable* iron. The means for artistically producing these two different states, *i. e.* the manufacture of cast or bar iron, being different, must of course be detailed separately. In other regards they will be spoken of together, but distinctly wherever necessary; and it will be understood, that when not otherwise expressed, the term *iron* means *malleable* iron.

Physical properties. The *color* of crude iron varies according to the state of combination and proportion of its chief foreign ingredient, carbon, from dark gray to silvery white; passing through divers intermediate stages of gray, mottled, bright, and white. It is upon these indications, coupled with those of texture, (which will be spoken of directly,) that the metal is classified in commerce. Dark gray iron, crystalline, with small facets, is supposed to denote a fitness for foundry purposes, *i. e.* for being cast into various forms; and the denomination of such a whole class is *foundry-iron*, or *founders' pig.* As its color brightens and grows more and more silvery, with a bladed texture, it is considered better suited for conversion into malleable iron; and the whole class obtains the name ordinarily of *forge pig.* These distinctions, further than as applied to *classes*, are extremely loose and uncertain; and we are yet without positive knowledge as to either what causes or is a permanent practical consequence of *color* in crude iron. In malleable iron the distinctions in this respect are much less marked. A full gray hue, with something of a bluish tint, is generally supposed to attach to tho best specimens. Of course, all these remarks apply only to the phenomena of a fresh fracture; and the color and lustre which may be given to surfaces of iron in either condition by finishing and polishing are, it will be readily conceived, entirely artificial, and dependent in no small degree upon the processes that may have been resorted to.

In the same manner, it may be presumed, another property, which is chiefly superficial, is dependent upon the artistical processes employed in developing it, and this is the *adhesion* of iron, *i. e.* the force with which it attaches itself to a liquid surface. This property has not been experimentally examined to any extent, though a research upon it would probably be fruitful for all questions touching the friction of machinery, and, perhaps, would also shed light upon the internal structure of the metal. The indefatigable Guyton-Morveau, only, has made observation upon it in the case of iron and several other metals, by polishing with an equal amount of labor the face of a disk, one inch French in diameter, (1·0658 in. English,) of the metals respectively, allowing each to repose an equal time upon the surface of mercury in a dish, and then seeing what weight was sufficient to overcome the adhesion. He found the weight necessary in several cases (abstraction being made of that of the disks themselves respectively) to be as under:

Gold required	446 gr. Fr.	= 365·72 gr. Eng.		Zinc required	204 gr. Fr.	= 167·28 gr. Eng.
Silver "	429 "	= 351·78 "		Copper "	140 "	= 114·80 "
Tin "	418 "	= 342·76 "		Antimony "	126 "	= 103·32 "
Lead "	372 "	= 305·04 "		Iron "	115 "	= 94·30 "
Bismuth "	317 "	= 259·94 "		Cobalt "	8 "	= 6·56 "

Although the *adhesion* of a surface in contact with the liquid in these experiments would be in part a function of the aptitude of the metal itself to amalgamate with quicksilver, yet these results are nowise accordant with such aptitude, as far as it can be inferred from other observations. And it seems to be equally independent of the density and cohesion of the solid. It is probably dependent in much greater degree upon the absolute perfection and smoothness of surface which, in bodies worked upon with the same force and for the same time, manifests itself according to another property, that of *hardness*. In ordinary speech, and sometimes even in exacter phrase, this term *hardness* is used to express the resistance of a substance to change of form of any kind. Such resistance depends mainly upon cohesion and elasticity, and covers, in part, the characteristics of malleability and stiffness. But *hardness*, in its technical sense, is resistance to removal or abrasion of substance, as in cutting, boring, filing, and the like. Any material which will *scratch* a given substance is therefore *harder* than that substance. Kirwan was the first to classify substances in this respect after a decimal scale, beginning with talc and ending with diamond. The eight intermediate tests are uniform and easily accessible minerals. Measured by such a scale, native iron (which may be considered as nearly the type of the malleable iron of commerce, though it contains a notable proportion both of lead and copper, generally,) is ranked in hardness at 4·5; that is to say, it scratches fluor-spar as much as it is itself scratched by phosphate of lime. Crude iron is harder, and most specimens of gray foundry pig are just scratched by felspar; it may, therefore, hold an average rank on Kirwan's scale of 5·8. But *white* forge pig will generally cut glass, and may therefore be ranked at 7 in hardness by the same scale. It will readily be understood that in applying these tests, something depends upon the shape and sharpness of the fragment used; a dull surface will merely rub without scratching; and in the case of white iron and glass, unless the lamellar crystals of the former be used with their edges, the latter will not be cut. It is the same with the diamond, the hardest known substance; only its spherical edges cut glass. In drawing a practical inference from such observations, regard must be had, too, to the ordinary *texture* of the substances, *i. e.* their mode of aggregation and cohesion. Thus white iron, hardened steel, quartz and granite, &c., have all the same theoretical index of *hardness;* but steel, for instance, is much more coherent than quartz, which is a brittle substance, and still more so granite; it is, therefore, used readily for working both. So sandstone, which is principally grains of silica held together with a siliceous cement, and therefore has an index of 7, is yet ordinarily worked with the same tools that are used for marble, whose index is but 3·5. But the causes and modes of these apparent inconsistencies readily manifest and reconcile themselves upon a little reflection.

So far as metals are concerned, the following table may be taken to give what is known in this particular; the foregoing cautions being equally applicable.

Table of Metals in the probable Order of their Hardness.

Mercury,	Iron,
Sodium,	Cobalt,
Potassium,	Nickel,
Lead,	Crude Iron, (gray,)
Zinc,	Steel, (soft,)
Tin,	" (hardened,)
Antimony,	Manganese,
Gold,	Titanium,
Silver,	Crude Iron, (white,)
Cadmium,	Chromium,
Bismuth,	Rhodium,
Tellurium,	Iridium, Osmium,
Copper, copper and zinc, (brass,)	
Platinum, copper and tin, (gun-metal,)	
Palladium,	Hardest steel, varying from white iron to the
Iron,	top of the list.

How much *hardness* is dependent on *texture*, has been already mentioned; and it is owing to the varying circumstances of this last property that iron in different conditions is found to shift about so much in the list just given. In practice, another property, that of affection by heat, or *specific heat*, (which will presently be mentioned,) has also an influence; and a substance, hard at first, becomes sensibly warm by attrition, and finally yields to the action of a material less hard than itself at low temperatures, but endowed with a greater capacity for heat. It is thus in one aspect that crude iron under a red heat may be cut and sawn almost like wood; and in the other, that a wheel of soft malleable iron, rapidly revolving, may be made to cut the hardest steel. Workmen have the opportunity of appreciating these affections in manipulations with the cold chisel.

The *texture* of crude iron is in most treatises said to be granular. It is in fact crystallized; as we learn from the chemical experiments of Daniell, and the microscopic observations of Schafhaütl and Alexander. According to the last-named, the crystals of gray iron "belong to the octahedral system, [in which the axes of crystallization are equal and at right angles,] and present themselves under the primary forms of several of its classes." "The maximum limit of these, when cubic, is not above $-\frac{1}{5000}$

of an inch in linear dimension, and about $\frac{1}{2000000000}$ of a grain in weight." Crystals in white iron are smaller, and "most frequently occur in six-sided prisms, sometimes connected in fascicles by their sides, at others by their ends, in a sort of stellated or radiated arrangement. The white color of the mass seems to be mainly arising from these arrangements of particles." Malleable iron is supposed to have a filamentous structure; but metallurgists are not agreed how far this arises from (as it is certainly in some degree dependent on) the processes employed in the manufacture. The amount of forging which the bars have undergone, the degree of heat to which they have been subject, as well as the ultimate size to which they may have been reduced, all affect the texture of specimens, whose other characteristics, originally and subsequently, are apparently the same. Nevertheless, this property and that of color are the chief commercial tests of the quality of iron. It is generally supposed that a fracture more pointed than irregular, and a tendency to become filamentous upon being forged into bars of an inch square or under, are indications of the two main characteristics of good iron, viz. strength and stiffness. But there is as yet no criterion by which, on simple inspection, the quality of the metal can be determined, and both the manufacturer and the consumer are compelled to rely (in the absence of actual experiment) upon the constancy of Nature in furnishing materials, and the uniformity of Art in subjecting them to the same processes. The same ores treated in the same way ought to produce the same metal; and so they generally do.

Closely connected with texture is the property of *density*. The variations in this respect between the results of different observers are to be attributed partly to the difference of methods, partly to the inaccuracy of the weights employed, (a much more influential cause of error than is generally imagined,) and partly to the variations of the individual specimens. Their limits are, however, sufficiently close to allow of taking as a probable average (the *density* or *specific gravity* of distilled water being called 1) the specific gravity of

Crude iron, foundry or gray iron,	7·
" forge pig or white "	7·5
Malleable iron, ...	7·6

In estimating absolute weight, it is sufficient for practical purposes to consider a cubic foot of distilled water as equal to 1000 ounces avoirdupois; so that a cubic foot of iron in its different conditions will weigh one thousand times the indices of specific gravity given above, respectively, in avoirdupois ounces, sixteen of which go to the pound. For rough approximations, iron in general may be taken as weighing one-fourth of a pound to the cubic inch. So far as crude iron is concerned, the specific gravity has been recently considered in reports upon ordnance to the American government to be an index of another physical property, (of the greatest interest where cannon and guns are concerned,) viz., the tenacity or cohesive force of the metal. Of course, such indications are not regarded as absolute, but merely relative; and they have been supposed hitherto to apply only to the best sort of gray foundry iron.

Upon this property of *tenacity* or cohesion of iron in its different conditions, experiments have been very numerous and varied, with results as accordant as could be expected. They may be found detailed more or less fully in several special treatises; such as of Barlow, Duleau, Karsten, Navier, and Tredgold. The results of those whose apparatus may be considered as the most reliable, seem to show that cohesion depends not only upon the chemical composition of the metal, but also upon the way in which it has been treated; the amount of heat, for instance, to which it has been subject, the extent of forging it has received, and also the dimensions which have been given to it, and the form in which it has been left. Were the theory of the resistance of materials perfect, the behavior of the metal under one position or set of circumstances would determine for any or all; but in the absence of such theory, it is necessary here to give the observed results in the chief positions and circumstances in which the resistance of iron is practically called into play. These are four, viz.: 1. Resistance to a force tending to pull asunder in the direction of length; this is usually termed *absolute cohesion*: 2. Resistance to a force tending to crush in the same direction; this is termed *relative cohesion*: 3. Resistance to a force applied at any angle with the longitudinal axis of the mass, or a *transverse* force; this is termed *respective* cohesion: 4. Resistance to a twisting force, or to *torsion*. As to resistance to impact or *resilience*, that will be spoken of under the property of elasticity.

1. The *absolute* cohesion of malleable iron may be taken for square bars of different sizes as under; the resistance per square inch being proportioned to the *breaking* weight of the respective sizes.

In bars $\frac{1}{4}$ inch square;	resistance	per square inch	= 90,000 lbs.
" $\frac{1}{2}$ "	"	"	= 70,000 "
" 1 inch and over	"	"	= 56,000 "

When the bars are round with the same area, they will show a somewhat higher resistance than the above; and when forged flat they appear more resistant than when round. Iron wire, from the mode of manufacture, is generally supposed to exert a greater proportionate resistance than hammered iron; but its average may be taken as included in the number given above. In fact, the increase of resistance inversely as the area seems to progress with wire to a certain point, when it changes sign, and the proportionate strength diminishes with the area. Thus, in Telford's experiments,

a wire $\frac{1}{5}$ inch in diameter	gave a resistance	per square inch	of	94,080 lbs.
and " $\frac{1}{20}$ "	"	"	"	80,192 "

Dufour's experiments, however, do not justify this inference. Annealed iron is hardly half as strong as the same wire unannealed. All these numbers being *extreme* loads, it will be readily understood that the metal ought never to be strained to such a limit. Up to a certain point, a bar or wire will stretch, and when the strain is taken off, return to its former dimensions; but beyond, although it will continue to stretch, it returns no more, the alteration and injury are permanent. As a general rule, it is injudicious to load iron with more than *one-third* of its breaking weight. The tables of Tredgold, which are extensively used and found safe in practice, allow the strength of malleable iron in this sense as

17,800 lbs. per square inch, which it can bear without permanent alteration. This may be taken for ordinary use at 18,000 lbs. per square inch.

Crude iron is but rarely employed as a tie; so that a knowledge of its absolute cohesion is comparatively of little practical consequence, and there have been proportionably few direct experiments. The mean of Tredgold's gives 44,620 lbs. per square inch as the breaking weight. The results of Muschenbrock, Brown, and Rennie, the former very much in excess and the latter in defect, do not appear reliable. In practice, we may take 15,000 lbs. per square inch as the strain that gray crude iron will bear in the direction of its length without permanent alteration. It is, therefore, about one-sixth weaker than malleable iron. White crude iron has not been experimented upon in this sense; but it is known, from observations on transverse strains, to be much weaker than gray iron. Iron of the second fusion (*i. e.* melted and cast from a cupola) is, in general, stronger than when run from the high-furnace. The method of casting (*i. e.* in vertical or horizontal moulds) does not, as far as observed, affect its absolute cohesion.

The following table gives the mean absolute cohesion of divers metals cast in pounds per square inch, viz.:

		Ratio.			Ratio
Cast-steel, tilted	135,000 lbs.	3·	Tin, cast	4,700 lbs.	0·104
Crude iron, gray	45,000 "	1·	Zinc, cast	2,800 "	0·062
Gun-metal, (copper and tin,)	34,000 "	0·756	Lead, cast	1,800 "	0·040
Brass, cast	20,000 "	0·444	Antimony cast,	1,000 "	0·022
Gold, cast	20,000 "	0·444			

And the following the mean proportionate cohesion of some of them when drawn into wire; iron wire being 1, or unity.

Copper	0·587	Gold	0·273
Platinum	0·500	Zinc	0·200
Silver	0·342	Tin	0·064
Gold	0·273	Lead	0·051
Iron	1·000		

2. In *relative cohesion*, or resistance to crushing, the two conditions of the metal appear to change places; crude iron being the strongest. The mean of many experiments of Karsten gives the resistance in this sense of crude iron, gray, at 168,750 lbs. per square inch.
" white, " 210,540 " "

The specimens were of the first fusion, cast from a cupola, and poured from a reverberatory furnace; the cupola castings were very uniformly the weakest, and those from the air-furnace the strongest of the sets. Those moulded *vertically* were also at a mean $2\frac{1}{3}$ per cent. stronger than those moulded *horizontally*. Wrought-iron has not been extensively observed in this respect. The mean of the experiments of Rondelet gives 70,000 lbs. per square inch (very nearly) as the weight under which bars from $\frac{1}{2}$ to 1 inch square began to give way. Its texture appears to prevent it from being *crushed*, even with the weight that would crush crude iron; for if the height of the specimen be triple its thickness, it will bend and double up sooner than be crushed. The practical effect in either case upon the equilibrium of constructions is pretty nearly the same. We are warranted, then, in considering the useful *relative cohesion* of wrought-iron at one-half that of gray crude iron. The following table exhibits this property as supposed to be ascertained for some other metals, viz.:

Crude iron, white,	resistance per cubic inch,	210,000 lbs.	ratio	1·0000
" gray,	" "	170,000 "	"	0·8095
Copper, cast,	" "	117,000 "	"	0·5571
Malleable iron,	" "	85,000 "	"	0·4048
Copper, wrought,	" "	55,000 "	"	0·2620
Tin, cast,	" "	9,000 "	"	0·0429
Lead, cast,	" "	8,000 "	"	0·0381

The last four were not crumbled under the pressure, but flattened; their resistance was therefore entirely overcome; although their texture did not allow the same phenomena as belong to the crystallized structure of the others.

3. Experiments on *respective* cohesion of iron, *i. e.* its resistance to transverse strains, have been very numerous. Theoretically, their results should be functions of the *absolute* cohesion of the substance; but, partly from defect of theory, and partly from inherent difficulties and errors in observation, this is not exactly the case. As this is the sort of resistance most extensively required in practice, its determination is of the greatest interest. In addition to the variations arising from the qualities of the metal itself, it depends so much upon the dimensions and position of the mass exposed to strain, upon the angle of direction of the force or weight, and upon the degree of deflection that the equilibrium of construction will allow, that the statement of results can hardly be more condensed than the statistics of the experiments themselves. To give tables for practical use is liable to the same objection of taking up undue space, and also to the inconvenience of being limited in their application. All that will be done here, then, is to furnish general rules which may safely be calculated upon in all cases for apportioning the weight to the dimensions of the beam which is to bear it, viz.:

$$w = 100000 \frac{b\,d^3}{l^2}; \text{ for gray crude iron.}$$

$$w = 62500 \frac{b\,d^3}{l^2}; \text{ for white "}$$

$$w = 135000 \frac{b\,d^3}{l^2}; \text{ for wrought-iron.}$$

Practical Rule.—Divide the product of the breadth of the beam and the cube of the depth by the square of the length, all in inches; and multiply the quotient by 100,000 for the weight in pounds when *gray iron* is used. With white iron multiply by 62,500; and with malleable iron, by 135,000 for the load in pounds. These coefficients correspond to a maximum deflection in the middle of the beam (which is assumed to be solid) of $\frac{1}{80}$ of an inch per foot in length; which it is not judicious to exceed although it is very often surpassed. The use of *white* iron should be as much as possible avoided in resisting strains of this kind. It is not only very little more than half as strong, but it is also less uniform and more uncertain.

These formulæ and rules apply to instances where the beam is supported at both ends, and strained by a force acting in the middle of the length, as in the case of mill-shafts, &c. Where the load is uniformly distributed over the length of such a supported beam, the effect is the same as if *five-eighths* of this load were applied in the middle of the length, and the weight borne in this case will be $1\frac{6}{10}$ times that ascertained by the rule just given.

When the beam is *square*, the formulæ and rules equally apply as when it is merely rectangular. If it be *cylindrical*, supported at both ends and loaded in the middle, divide the weight obtained by the rule for a square beam whose side equals the given diameter by $1\frac{7}{10}$ for the load that will produce the same deflection. If the load is to be uniformly distributed over the length of a *cylindrical* beam, it is near enough in practice to consider that its strength and stiffness will be the same as in a square beam with sides equal to the diameter of the cylinder, and loaded with the same weight in the middle of its length.

In all these cases, the weight of the beam itself must be taken into the account as part of the load, either uniformly distributed or centered in the proportion of 5 : 8, as the case may require. To diminish as far as possible the useless load in such instances, it is not unusual to make the beam or shaft a hollow cylinder. The rule for determining the dimensions becomes complicated; for strength and stiffness do not follow the same ratio of diameters. In general, it may be remembered that when the thickness of the metal is one-fifth of the diameter, (which, if the load is considerable, is not more than a safe proportion,) the strength of the hollow cylinder is nearly two-thirds, and the stiffness one-half nearly of what they would be respectively in a square beam of the same depth, while there is a saving of one-half the quantity of metal.

4. The capacity to resist *torsion* is of great importance in the substance of which the revolving parts of machinery are made; for it is not unfrequently by a submission to torsion that both power and durability are secured. Navier has explored the theory of this resistance; but the experimental constants which are required to make the theory of practical application are unfortunately deficient. The results of the observations made hitherto are remarkably discordant. The following table gives the proportionate resistance in this respect of various metals.

Cast-steel,	19·56	Crude iron, (cast horizontal,)	9·94
Shear "	17·06	Hard gun-metal,	5·00
Blister "	16·69	Fine brass,	4·69
Crude iron, (cast vertical,)	10·63	Copper, (cast,)	4·31
Wrought-iron, (coal,)	10·13	Tin,	1·44
" (charcoal,)	9·50	Lead,	1·00

It appears from this, that iron in all its conditions exercises this resistance pre-eminently; and that crude iron does not differ in this respect materially from wrought-iron. It has been generally assumed in metallurgic treatises hitherto, that resistance to torsion is in proportion to absolute cohesion. The experiments, so far, do not sustain this, as between malleable and crude iron.

In a preceding paragraph, a distinction has been made between *strength* and *stiffness*. Although both are in part functions of the absolute cohesion, yet the latter is a measure more particularly of another physical property—that of *elasticity*. It is in virtue of its cohesive strength that a substance resists *any* change of form or position; it is in proportion to its elasticity that such changes, when occurring, are not *permanent*. Thus, up to a certain point, a bar or wire which has been lengthened by a strain will, when the strain is removed, return to its original length; or a beam that has been deflected by a load will, upon being relieved from the load, reassume its horizontal position. When this point is passed, and the extension or deflection remain permanent after the cause producing them has ceased to act, we say ordinarily that the piece, whatever it may be, has *taken a set*, and, technically, that its elasticity is overcome or destroyed. Gray crude iron will allow an extension, within the limits of its elasticity to recover, of $\frac{1}{1200}$ of its original length when the strain is acting in that direction: it is not safe to allow for a greater deflection in masses which have to bear a permanent load, (such as joists, girders, &c.,) than $\frac{1}{80}$ of an inch for each foot in length, or say $\frac{1}{1000}$ of the length, in round numbers. White iron is not reliable either for extension or deflection. Malleable iron will bear an extension without injury of $\frac{1}{1400}$ of its length, only its deflection ought not to be allowed to surpass $\frac{1}{300}$ of its length. These deflections are of course measured where they are the greatest, viz. in the middle of the length.

There is another manifestation of elasticity in resistance to *impact*, or, as it is technically termed, in *resilience;* in virtue of which a substance yields in form or position to the momentum of a sudden impulse or blow, and then returns to its original state. This resistance is of great importance in machinery, to aid in determining what velocity the moving masses should be allowed to have; for the impact and shock are the same whether the substance in question strikes against a body at rest, or, itself at rest is struck by a body in motion. In theory, *resilience* is a function of absolute cohesion, and of density as well as of elasticity; and hence certain woods possess this property in a higher degree than many metals, and nearly as high as iron itself. Whalebone exhibits it in a pre-eminent degree.

Table showing the proportionate Resilience or Resistance to Impact of divers Substances.

Iron, (crude or wrought,)	1·000	Iron, (crude or wrought,)	1 000
Gun-metal, (copper 8 + tin 1,) cast,	0·819	Brass, (cast,)	0·400
Yellow Pine, (American,)	0·740	Beech,	0·326
Oak, (English,)	0·724	Larch,	0·315
Mahogany,	0·630	Lead, (cast,)	0·246
Elm, (English.)	0·620	Zinc, "	0·190
Ash,	0·600	Tin, "	0·142
White Fir,	0·567	Whalebone,	3·000

The following comparative summary may be taken of the chief practical resistances of iron and some other substances employed in construction and in machinery.

	Strength.	Extensibility.	Stiffness.
Crude iron, (gray,)	1·00	1·00	1·00
Brass,	0·44	0·90	0·49
Gun-metal, (copper and tin,)	0·65	1·25	0·54
Iron, (malleable,)	1·12	0·86	1·35
Lead,	0·10	2·50	0·04
Marble, (white,)		1·00	0·14
Oak,	0·25	2·80	0·09
Tin,	0·18	0·75	0·25
Zinc,	0·37	0·50	0·76

The remaining properties of iron connected with its texture do not, as yet, admit of being numerically valued or proportioned. Such is the case, for instance, with *malleability*, or the capacity of being extended in one or more directions by hammering. White crude iron does not display this property at all; gray iron possesses it generally in a slight, and sometimes in a considerable degree. Wrought-iron in this respect is inferior to gold, silver, copper, tin, cadmium, platinum, lead, and zinc; the order of the names here representing the order of malleability in actual extent of surface which can be given to a unitary mass of the same volume, by the most suitable treatment. All other metals are inferior to iron in this aspect; though, if the question were as to the extent of surface which could be gained by a continuous hammering, its relations would be altered. It tends to become very brittle by forging; and, besides requiring the application of great force in the aggregate, has to be frequently softened by heat during the process. The *harder* the iron is in its original state as wrought-iron, the more often such softening has to be resorted to; whence it may be inferred that, *ceteris paribus*, the softer the iron the more malleable it should be. And the same inference attaches in the property of *ductility*, or capacity for being drawn into wire. This is in so far different from malleability, that heat is a necessary part of the process if it is carried to any great degree; and the order of ductility of the several metals varies from that of their malleability accordingly. Gold, silver, and platinum are the only metals more ductile than iron.

Magnetism, or the property of permanent polarity, was formerly supposed to belong to iron only. Later researches show that this is to be shared, though not equally, with nickel, cobalt, and chromium. Occasional magnetism may be excited in most substances; as is shown by their influencing the oscillations of a freely suspended magnetic needle. But this influence is much weaker in all other substances than the four named. *Silver*, which stands the highest of all the other metals, is nine times feebler in this respect than iron; gold fifteen times, and marble nearly twenty times, more weak. Iron acquires magnetism by contact or suitable friction with a magnet; by being suitably rubbed or struck in a proper position; by exposure to refracted light of the sun; and even by being left to stand in a nearly vertical position. The processes for this purpose will be described under the proper article. (See Magnetism.) It is enough to say here, that owing to the ease with which it is accidentally developed, it is extremely difficult to find in the shop of a philosophical instrument-maker, for instance, a tool or scrap of iron which is not in some degree magnetic. In all its conditions and states it is susceptible of this property, but develops it differently in each. Thus, gray crude iron becomes sooner and more intensely magnetic than white iron; but yields in both these regards to wrought-iron and to steel. Soft ductile iron is more easily and more strongly magnetizable than steel, but does not retain its magnetism as well. A similar relation is observable between untempered and tempered steel. The magnetism of iron may be weakened or lost by methods similar to those which originally impressed it. The filings of a magnet are less magnetic than the solid mass. A heavy, sudden blow or shock, against a hard body, will sometimes destroy magnetism. Heat always diminishes it; although there are some peculiarities which have been observed in this regard that are difficult of explanation. It undergoes deterioration whenever similar poles of two equally strong magnets are kept in prolonged contact; and finally, is always abated by alloying with other substances, and may be destroyed entirely by increasing the proportion of alloy. Arsenic is, in this regard, the most active of the metals; though an alloy of two-thirds arsenic does not entirely prevent the mass from being attracted by the needle. Mushet, however, affirms that twenty-two per cent. of manganese effectually destroys magnetism in an alloy of iron.

Malleable iron is an excellent conductor of *electricity;* and although in this respect inferior to copper and zinc among the easily oxidized metals, and to gold, silver, and platinum among the others, it is yet, for economy, universally employed for lightning-rods. In the Voltaic pile it follows zinc in the order of electro-positive metals.

Its *electro-magnetic* properties are very remarkable, in the facility with which it is converted into a magnet of great energy during the passage through it of an electric current. It is to this that the electro-magnetic telegraph owes, in part, its adaptation and success.

Hitherto the properties of iron have been considered as manifesting themselves at ordinary temperatures. It remains to speak of the modifications and peculiarities which arise from its affection by heat. Of all the metals, this has the greatest *specific heat; i. e.* the greatest capacity for heat, or faculty of resisting change of temperature. It bears a greater quantity of caloric for a longer time, and with less alteration of its own sensible temperature. The index of its specific heat has been observed by Dulong and Petit as follows:

32° F. to 212° F.	0·1098
392° F.	0·1150
572° F.	0·1218
662° F.	0·1255

Supposing the capacity for heat to augment in the same ratio, we would have at the supposed epoch of *red-heat* an index = 0·1402, and near the probable point of fusion = 0·3282; that of water in equal weight being 1·000. The specific heat varies according to the condition of the metal, and appears to be in some proportion to the quantity of carbon associated in each. Thus the specific heat of steel, as observed by Regnault, is represented by the index = 0·11848, and that of white crude iron = 0·12983. Gray crude iron, as far as may be inferred from observations of refined iron, would have a lower index than white iron, but there are not observations to settle this.

The *expansion* of iron by heat presents it in a similarly advantageous character. It expands less than any of the metals except platinum, palladium, and antimony. The observations hitherto have been made principally upon its expansion in one direction; *i. e.* its linear expansion, or *extension.* It is supposed to be accurate enough for practice to consider this extension as equal in all directions, and as, therefore, the one-third of the cubic expansion. All the experiments upon the extension of crude iron have been with metal of the second fusion, which is almost always gray. It may be presumed from practical phenomena on the large scale, that white iron expands less than gray. The mean of the results of Roy, Lavoisier, and Daniell with cast-iron, gives an extension in length of 0·0010974249 between 32° F. and 212° F.; the original length being 1· at 32° F. This corresponds to an extension (sufficiently accurate for practical use) of $\frac{6}{1000000}$ of the original length at 32° for each degree of Fahrenheit. The extension of wrought-iron has been more frequently and more variantly observed. The results lie between 0·000600 of Bonguer and 0·001446 of Hallström, as the extension on a length originally 1· at 32° F. Theoretical considerations, as well as an average of the most reliable observations, determine this extension at 0·0011356 for 180° between the melting of ice and the boiling of water; corresponding to $\frac{63}{10000000}$ of the original unity for 1° F. The extension of steel appears to be uniformly higher than this, and to vary according to the temper of the metal in that condition. (See Steel.) Between the limits given, the rate of expansion may be taken as constant for each degree, although in strictness such is not the fact; beyond 212° F. it would not be proper to rely upon such an assumed constancy: but at these higher temperatures a knowledge of the dilatation is chiefly interesting in theoretical science. Rinman supposed, from some observations, that between ordinary summer-heat (say 76° F.) and what is called *red-heat*, crude iron extended $\frac{1}{80}$ and wrought-iron $\frac{1}{145}$ of its original length: but these estimates can hardly be relied upon. The following table presents the most probable values in this particular, as well as certain other phenomena:

Table showing the actual Extension of Wrought-Iron at various Temperatures.

Degree of Fahrenheit.	Length.	
32°	1·	
212	1·0011356	
392	1·0025757	Surface becomes straw-colored, deep yellow, crimson, violet, purple, deep blue, bright blue.
572	1·0043253	
752	1·0063894	
932	1·0087730	Surface becomes dull, and then bright red.
112	1·0114811	
1852	1·0216024	Bright red, yellow, welding heat, white heat.
2192	1·0348242	
2732	1·0512815	
2912	cohesion destroyed.	Fusion perfect.

In the property of *conducting* heat, iron occupies a low rank. The following statement is warranted by the observations of Dergnetz:

Substances	Conducting Power.	Substances.	Conducting Power.
Gold	2·6728	Iron	1·
Platinum	2·6223	Tin	0·8121
Silver	2·6009	Lead	0·4801
Copper	2·4010	Marble	0·0625
Zinc	0·9722	Porcelain	0·0326
Iron	1·	Brick-clay	0·0302

These observations refer to malleable iron. Crude iron, whose specific heat is greater than its dilatability is less than the same properties of wrought-iron, is, it may be inferred, a worse conductor. Upon its power of *absorption, radiation,* and *reflection* of heat, in either condition, there have been no reliable observations.

Besides the influence upon dilatation, an effect seems to be produced upon the *cohesive force* of iron by temperatures either higher or lower than ordinary. In regard to low temperatures, it may be assumed, in general, that they promote fragility. It is uniformly observed that iron is much more brittle in winter than in summer; and this holds good equally for all conditions of the metal. Cold weather is, therefore, unfavorable for any practical test of quality, (such as for cannon, chain cables, &c.;)

especially one dependent in any way upon impact. On the other hand, with temperatures higher than ordinary, but yet below the point of boiling water, Tredgold supposes the absolute cohesion to be diminished $\frac{1}{3000}$ by an elevation of 1° F. in temperature. Under temperatures which transcend the boiling point of water, the table given above has already indicated the most remarkable phenomenon—the *iridescence* or succession of colors during the augmenting application of heat. To what this effect is owing is not known; partially, perhaps, to the color produced by the contact of thin plates, and partially to an oxidation of surface. This last cause is assured by the permanence of the color after the heat has ceased to be applied. The *straw* color is developed fully at 400° F., the fusing point of tin; the deep *yellow* occurs at 420° F.; *crimson* follows at 450° F., where bismuth fuses; from that *violet, purple,* and *deep blue* succeed, till 540° F., the melting point of lead; this blue brightens, passes into sea-green, and at last disappears at 700° F., the fusing point of zinc. Beyond this, the epochs of temperature have no distinctive test. But if the heat is continued, there occurs a secondary, and, finally, just before red heat, a tertiary succession of the same color and in the same order, only less vivid and less lasting. If the metal be withdrawn at the close of this tertiary series, its surface will be found covered with a thin pellicle of oxide, whose constitution has not yet been examined. The practical utility of these color-tests is principally found with *steel*, where they serve as guides to determine the probable temper imparted. The deep-blue color is also used in the arts as an ornamental and anti-oxidable tint. Iron, in its different conditions, is not similarly affected in this respect. In general, steel is colored at a lower temperature than what has been given as applicable to the case of malleable iron, and gray iron at a higher one. White iron has not been as yet experimented on. But as there is reason to conclude that the colors occur in the direct ratio of the hardness of the metal, white crude iron may be expected to surpass steel. Of the same bar, the harder and softer portions are emphatically designated in this process. The coloring thus depending on hardness, its brilliancy is determined by the state of polish of the surface. And as the hardness of the metal thus influences the phenomena of colors, so it is in its turn reacted on by the heat which produces them. It is on this account that iron which has become hard in being wrought and hammered, is exposed to heat in order to soften it, as has been noticed before. The degree of heat requisite is in proportion to the hardness existing and to the softness required: in practice, however, it is generally a full-red heat. Iron, in all its conditions, appears to be permanently softened by being thus heated, whatever may have been its character or treatment before. The hardness and brittleness which may be cured by this resort, must be distinguished from the same characteristics arising from a peculiar chemical composition. Thus, there is a sort of iron which becomes brittle by the application of heat. Metal of this class is well known under the name *red-short*, or *hot-short*, and is met with in all conditions. Again, there is a kind of iron precisely opposite: brittle at ordinary temperatures, it becomes tenacious when hot; though, like the other, it undergoes no permanent change, and the modified characteristic belongs only to the modified temperature.

Sudden cooling appears to augment the effect of low temperature, and to impart greater or less hardness to the metal, according to its previous quality. In the case of steel, this is of the utmost interest; for on it depends the whole business of *tempering*. In other conditions the effect is less marked, but sufficiently sensible whenever the conducting power of the cooling material is not out of proportion to the mass of metal acted upon. The conducting power of the air is never sufficient, ordinarily, to produce any of the phenomena of sudden cooling: exposed to that, the cooling is always slow, and, according to its temperature, follows, more or less, the softening effects which have been already spoken of, and which are technically known as *annealing*. But this will be spoken of more particularly under the metallurgic treatment of iron.

The effect of sudden cooling is more manifest in temperatures higher than red heat, and especially upon the metal in fusion. The observation of this is more readily made upon crude than wrought-iron; and the most remarkable effect is the conversion of gray iron into white, which takes place more or less completely in proportion (other things being equal) to the mass operated upon. On the other hand, white iron can be converted into gray by an opposite method of treatment; and this not only on the small scale, but also in large. Indeed, as was said before, iron of the second fusion, allowed to cool slowly, is almost uniformly gray. But gray iron, cast in moulds of any sort which conduct heat with sufficient rapidity, (such as cast-iron moulds,) uniformly *chills*, as it is termed; i. e., becomes converted, to a greater or less depth from the surface, into white iron. Practical advantage is taken of this in the manufacture of wheels for railroad cars, which are always purposely chilled to increase their durability.

It is at temperatures above red heat that the most important and practically useful modifications of this metal take place in all its conditions. Not to refer any further to steel, the *welding* of malleable iron and the *fusion* of crude iron, by which either of these are made applicable to the arts and wants of mankind, occur at about the same epoch of temperature, somewhat further removed from red heat than this last is from ordinary states. The table before given has already indicated the temperature of the probable fusion of malleable iron, which is a little above that of crude iron. The uncertain indications of Wedgwood's pyrometer for a long time induced an erroneous estimate of the amount of heat required for the fusion of metals generally, and especially that of iron. Daniell has shown, by experiment with a much more reliable apparatus than that of Wedgwood, that cast-iron (so called) cannot require a higher temperature for fusion than would be expressed by 2786° F.; while Alexander has demonstrated, from the known relations and properties of cohesive force and specific heat, that bar-iron (whose utter infusibility was long maintained) must become fluid at about 2774° Fahr. We are yet deficient in a pyrometer whose indications would be uniform when applied in temperatures as high as this, a desideratum whose supply would contribute materially to the filling up of the theory of the manufacture of iron. It is probable that an air-thermometer, whose tube, where it entered the furnace, is of platinum, would afford the most unexceptionable and reliable results.

The capacity for being *welded*, i. e. performing an intimate and perfect union of two surfaces, occurs at the epoch of incipient fusion. This property is possessed by iron alone of all the metals, except platinum and palladium. White crude iron, under ordinary treatment, does not show this characteristic at all. Gray iron is weldable, but in such narrow limits of temperature that the operation has to be effected with great quickness in order to succeed. With bar-iron and steel, in sufficient masses, welding is of every-day application. If the masses be very small, they cool too quickly to be welded in the ordinary way. Crude iron in fusion occupies a less space than when solid; in this respect its anomaly (which is to be traced to crystallization) is shared with antimony, bismuth, sulphur, and zinc, among the metals, all of which shrink in melting. The same may be observed of water, which is more dense when fluid than when crystallized in the shape of ice. If a mass of crude iron be made hot and laid upon a bath of melted metal, it floats; but if it be cold, it tends to sink. Perhaps this may be owing to the repulsive effect of heat. White iron, in this respect, shrinks less than gray. On an average, good gray foundry iron shrinks rather more than the $\frac{1}{9000000}$ of its volume when cold. The general allowance of the founders in making their patterns is $\frac{1}{8}$ of an inch to the foot lineal.

Exposed to heat at any temperature from red heat upwards, with access of air, iron, in all its conditions, is readily covered with a coating of oxide. Bar-iron is thus oxidated more easily than crude iron; and of this latter, gray iron forms, at the same temperature, a more friable oxide than white. The following contrast may be taken to exhibit the most important characteristics of the two conditions of crude iron when exposed to high temperatures, viz.:—

Gray Iron

Is less easily oxidated; preserves its character longer, but loses it (cohesion, &c.) more completely at last; suffers these changes more when protected from the air; heated below the fusing-point, with access of air, demands more heat and more air to assume a certain malleability; requires a higher temperature for fusion; when fused is more liquid; expands more in cooling; fused rapidly and cooled quickly, tends to become *white;* fused rapidly and cooled slowly, retains its character or becomes more soft.

White Iron

Is more easily oxidated; loses its character sooner, and becomes granular, grayish, and steel-like in malleability and temper; suffers these changes more when protected from the air; heated below the fusing-point, with access of air, becomes quite malleable, and may be tempered to take an edge; fuses at a lower temperature; when fused is less liquid and more pasty; expands less in cooling; fused rapidly and cooled quickly, becomes extremely brittle; fused rapidly and cooled slowly, becomes *gray*.

The precautions necessary in view of these peculiarities, as well as the general processes, will be described under the head of FOUNDING; and what has been said may be considered as covering the chief physical properties of the metal.

Chemical affinities and reactions.—These have been observed for the most part with the iron of commerce, which is never entirely pure, but contains carbon, silicon, phosphorus, sulphur, arsenic, chromium, titanium, magnesium, aluminum, and manganese, in very minute proportions. Nitrogen is sometimes met with; but oxygen, which was formerly considered a constituent, has not been recognized in the later researches of the most accurate chemists. The chemical symbol of iron is **Fe**, and its atomic weight 339·205, oxygen being taken as 100. In the system where hydrogen = 1· the atomic weight of iron is 28·, as an average round number.

With *oxygen*, iron combines in two proportions, whose resulting compounds appear capable of fresh combinations, so that in point of fact *four* compounds are known to exist. The first is the state of protoxide, which does not exist naturally nor artificially, except as a hydrate. The second in the proportion of oxygen is the *forge-cinder*, formed on the surface of the metal by heat, with access of air, and thrown off under the hammer or squeezer. The third is the *black* or *magnetic oxide*, (the *oxidum ferroso-ferricum* of Berzelius,) which exists also naturally; and the fourth is the *peroxide*, *red oxide*, or *sesquioxide*, the first and last of which epithets are used according to different theories of its constitution. This also exists as a mineral, under the name of *red hematite*, and is massive, fibrous, or crystallized, according to circumstances. Its hydrate is known to mineralogists as *brown hematite*.

The following table contains all that need be given about these oxides:—

Name.	Composition. Iron.	Oxygen.	Iron.	Oxygen.	Atoms. Iron.	Oxyg.	Proportionate Index of Oxygen
Protoxide	0·7723 +	0·2277	100 +	29·48	3 +	6	24
Forge-cinder	0·7516 +	0·2474	100 +	32·90	3 +	7	27
Magnetic oxide	0·7178 +	0·2821	100 +	39·30	3 +	8	32
Peroxide	0·6934 +	0·3066	100 +	44·22	3 +	9	36

The three first are attracted by the magnet, the last is not. The colors which have been before spoken of as accompanying different degrees of the application of heat, are also doubtless due to the formation of oxides, whose constitution, however, is not known. The affinity of iron for oxygen appears to be in proportion to its own purity, and also, though in a less degree, to the state of its surface. So, in respect to that peroxidation which is very familiar as *rust*, and which tends to occur more or less upon this metal when exposed to the action of the air, (and especially damp air,) white iron is less affected than gray, and any crude or cast-iron less than the malleable metal. This difference of the different conditions holds good in the case of moisture alone, and in general with most chemical agencies.

Pure *water*, disengaged of air, does not act upon iron at all at ordinary temperatures. Above 120° Fahr., the water is slowly decomposed, and yields its oxygen; at 212° Fahr., the decomposition is quite sensible; and at a red heat it is very rapid, hydrogen is given off, and magnetic oxide formed. At intermediate degrees, the action is nearly in proportion to the temperature. In practical cases where the oxidation of the metal is an inconvenience, (as in steam-boilers, &c.,) it may be remedied to a considerable extent by the introduction of other metals having a greater affinity for oxygen. Pieces of zinc, for instance, will serve the purpose very well, to keep the boiler clean and unimpaired. Impure water acts in proportion to the activity of the salts it may happen to hold in solution, and differently upon different conditions of the metal. Thus, *sea-water*, which merely gives a coat of oxide to bar iron (anchors, chain-cables, &c.) to a depth proportionate, but in a diminishing ratio, to the time of immersion, converts cast-iron (cannon, cannon-balls, &c.) into a substance resembling *plumbago*, or *graphite* i. e. into carbon, associated with metallic and oxygenated iron. Such conversion appears to be less with white than gray iron.

Air and moisture together appear to exercise a more powerful agency in producing oxidation than either separately, and as this is precisely the joint influence to which this metal is in most practical cases exposed, there is the more interest in providing a preservative. This is found not only, as was said just now, in the polish of the surface, but also in the means by which such polish is produced, in special coatings of substances which resist humidity, and also in the protecting action of incipient oxidation itself. Thus, in the first instance, a polish acquired under the use of oils (and still more as those oils may be themselves unalterable) is more lasting than one obtained with water. One of the best preservatives of the second kind, is a solution of caoutchouc in oil of turpentine, which is applied upon the polished surface, and is then removed, or rather brought down to extreme thinness, by a brush dipped in the same oil, heated. Among the third sort has been already mentioned the *bluing*, which is effected by a temperature of about 550° F.; and *bronzing*, as it is called, is of similar result. This is done by washing the surface, which should be smooth, with acids, and mostly hydrochloric acid, exposing it for a suitable time to the air, until it becomes thoroughly covered with a uniform coat of oxide, and then removing that rust with olive-oil as a menstruum, until the surface ceases to soil white linen. This is the common resort for gun-barrels. Electric gilding, (see GILDING,) although beginning to be extensively used in the bright parts of machinery, which are not subject to friction, does not come properly in the category of the preservatives we have been considering.

The combination of *carbon* with iron gives rise, in fact, to the different conditions of this metal. In white iron and steel it is chemically combined with the mass; in gray iron it is partly combined in polycarburets dispersed about the mass, and partly free, as graphite, (called, by the workmen, *kish*;) in malleable iron it does not exist at all, or only in insignificant proportions. Karsten considers 5·3 per cent. as the limit of saturation, which would give for the atomic constitution of the percarburet, *one* atom of carbon to four atoms of iron. In gray iron the whole quantity of carbon does not, at a maximum, exceed 4 per cent., of which 1 per cent. may be taken as *combined*, and 3 per cent. to be mechanically associated as graphite. Although the occurrence of carbon is the principal modifier of the condition of this metal, it is probable that the differences, so far as crude iron is concerned, are owing to other associations also. Thus, as *nitrogen* has been found only in *white* iron, it is likely that some of its characteristics depend upon the formation of compounds of nitrogen and carbon, and, ultimately, of cyanurets of iron. It is very much to be desired that this suggestion could be studied in the synthetic way. The practical precautions which have to be taken in consequence of the affinity of iron for carbon, will be referred to hereafter, under the head of *Foundry*, and also under the article STEEL.

Sulphur combines with iron in several definite proportions, both artificially and in nature. Until the proportion reaches 2 atoms of sulphur for 1 atom of iron, (or 53 per cent. sulphur nearly,) the compound is attracted by the magnet. This proportion may be considered as that of the natural *magnetic pyrites*. Four atoms of sulphur to one of iron constitutes the common iron pyrites. Sulphur promotes the fusibility of iron extremely, so much so that a plate or bar of iron, kept only at a red heat, may be pierced to a considerable depth (say an inch, or more) by a stick of sulphur. Unfortunately, the quality of the metal becomes so far impaired as not to allow avail of this peculiarity in the arts. Sulphur combined with iron causes brittleness at all temperatures, and especially what has been before spoken of as *red-shortness*. Experiment has shown that $\frac{1}{3000}$ of sulphur is enough to produce the first characteristic, and $\frac{1}{10000}$ the second. It is hence that many ores cannot be advantageously (and some not at all) applied in the reduction of this metal. Where the proportion of sulphur is minute, it may be partly volatilized by previous roasting, and partly taken up by excess of lime in the flux. By this last application, the sulphur in the coke of some of the English furnaces is gotten rid of. The remarkable action of sulphur upon iron-filings, when made with water into a paste, (which, after a while, develops intense heat, and finally bursts forth in spontaneous flame,) belongs more properly to the formation of sulphuric acid, but may be mentioned, once for all, here. The influence of compounds of sulphur and carbon together has not yet been satisfactorily studied.

As sulphur gives the property of *red-shortness*, so *phosphorus* seems to impart that of *cold-shortness*, or brittleness at low temperatures, but not to an equally prejudicial extent. There is hardly any iron in which a trace of this substance cannot be found. With bar-iron occurring in proportions as high as $\frac{1}{4}$ per cent., it only hardens the metal without diminishing tenacity; at $\frac{3}{4}$ per cent. the tenacity is seriously diminished; and over 1 per cent. makes the iron of very bad quality and very limited use. Phosphorus lessens the capacity for heat of the metal, and increases the facility with which bar-iron can be welded. Crude iron it makes more fusible and retains longer melted, so that in minute proportions it is rather an advantage for castings. Phosphorus appears capable of uniting with iron in all proportions, but at a high temperature there is but one definite compound, consisting of 2 atoms of iron and 1 of phosphorus, or iron 0·776 + phosph. 0·224. The natural kingdom does not afford any phosphuret of iron, but phosphates are widely extended and numerous. Phosphorus is supposed to behave with carburets of iron in a similar manner with sulphur, but, like this last, has not in this respect been studied.

The effect of *acids*, of whatever kind, upon iron, appears to depend upon the presence and decomposition of water; and hence, in an anhydrous or concentrated state, their action is uniformly more feeble than when dilute. The presence of carbon, too, and its state of combination, also affect, and in their proportion weaken, the influence of the acid. Thus steel is distinguishable from iron by the ease with which it is attacked and stained by nitric acid, and white iron is more affected in this manner than steel. Hard iron, in all conditions, is less easily attacked than soft; and upon this, as well as the state of combined carbon, rests the art of *damascening*, or watering the surface of iron and steel.

Acetic acid acts readily upon iron and upon its peroxide, but slowly upon the protoxide. The acetate of iron thus produced is used extensively in calico-printing, under the name of *iron liquor*.

Carbonic acid, without the presence of water, does not act at all on iron or its oxides, artificially, though *carbonates of iron* form a very extensive and important class of minerals. The different sorts of coloring-matter known as *Prussian-blue*, are carbo-azotic compounds, or hydrocyanates of iron, whose practical use is better understood than their theoretical composition. (See Prussian Blue.)

Gallic acid, which is a compound of oxygen, hydrogen, and carbon, acts very feebly upon iron and its protoxide, or, perhaps it may be said, not at all; but upon the peroxide it acts energetically, striking a deep, black, and permanent color, and constitutes, in fact, the basis of all ordinary black inks.

Hydrochloric acid acts with great readiness upon iron and its oxides. For all applications in the arts where the object is to produce or remove oxidation, it is undoubtedly the best, though not the most economical agent. Upon crude iron it is best to be employed concentrated.

Nitric acid, highly concentrated, has but a feeble action upon iron; at its average concentration it acts with great energy. On account of its peculiar behavior towards carburets of iron, it generally enters as an ingredient in etching-liquors. Thus, for making damascene designs upon cutlery, Rinman recommends a wash composed, by weight, of 4 nitric acid + 2 sal-ammoniac (hydrochlorate of amm.) + 1 sulphate of copper + 72 water. Where the etching is required to be deep, as, for instance, in mosaic damascening, where gold is to be inlaid, the nitric acid is inconvenient, in depositing a salt difficult to be cleaned out.

Phosphoric acid attacks iron with great avidity, but not its oxides at ordinary temperatures. The artificial phosphates thus produced are without interest to the arts as yet; the natural ones form an extended mineral class.

Dilute *sulphuric acid*, as well as *sulphurous acid*, act upon iron at ordinary temperatures, and with energy as the temperature, and to a certain extent the dilution, increase, forming, ultimately, sulphates of iron. They also combine with the oxides of iron in various proportions. The crystallized sulphate of the protoxide is known in commerce as *green vitriol*, or *copperas*. When this is heated in close vessels it parts with its water of crystallization, and upon continuance of the heat, after divers changes and disengagements, becomes converted into pure peroxide of iron, which is the *colcothar* of commerce, or the *crocus martis* of the old druggists, and the plate-powder or *rouge* of the silversmiths and polishers of steel and speculum-metal.

Solutions of the *alkalies* or *alkaline earths* do not appear to act upon iron or its oxides. On the contrary, their presence seems rather to retard the decomposition of water. At a red heat iron will take up about 10 per cent. of *ammoniacal gas*, becoming white and extremely brittle, but less liable to alteration from air or moisture. At the same temperature, *potassa* and *soda* are deoxidized by malleable iron; if crude iron be fused with these alkalies, it parts progressively with all its carbon, and becomes bar-iron. It has been generally supposed that the metallic bases of the alkalies do not combine with iron, or rather, are sublimed at the temperature required for such alloy. But more recent observations disaffirm this supposition. *Potassium* and *sodium*, for instance, can be combined synthetically with iron, and *magnesium* and *calcium* are often found, though in minute proportions, in the crude iron of commerce. How far they influence the character and quality of this metal is yet obscure. Karsten observes that $\frac{1}{2000}$ of *potassium* causes the alloy to be hard, and to be welded with difficulty, while $\frac{1}{1000}$ of *calcium* is enough to impair materially the qualities of iron. Magnesium appears to be got rid of entirely in the processes of refining and puddling. Barium no otherwise affects the metal than by embarrassing the operations of the high-furnace, when present with the minerals there as sulphate of baryta.

The *earths*, so called, (of which need only be mentioned *silica* and *alumina*,) exercise, at ordinary temperatures, or even at any temperature below fusion, no appreciable chemical action upon iron. Associated with carbon, at this last temperature, they are reduced to their metallic bases, (either by the iron or by the carbon,) which enter into combination with the iron, and modify it more or less. *Silicium* is found more abundantly in gray iron than in white; its maximum, as yet observed, may be stated at 4½ per cent., including that which is found free in the condition of silica in the cavities of crude iron. Its average hardly exceeds 1 per cent. There is no reason to suppose that this proportion affects the quality of the metal; on the contrary, it may be assumed not to interfere with, if it does not promote the fusibility and fitness for castings. The opinion among practical iron-workers (which is not, however, partaken of by chemists generally) is, that a certain small proportion of silicium augments tenacity. The operation of refining generally drives off 9-10ths of the silicium contained in the crude metal; but a proportion is often restored in subsequent processes, of which it would be well for manufacturers to take account, in view of a particular quality that may be desired. Thus Boussingault found bar-iron, melted in a Hessian crucible, to have taken up more than ½ per cent. of silicium. Synthetic experiments in the small way warrant the belief that a smaller proportion than this hardens iron and makes it less tenacious. Karsten presumes the action in this last respect of silicium to be more injurious than that of phosphorus. Whether, as has been supposed, the conversion into *steel* is due to silicious as well as to carbonized combinations, is not yet understood. No higher than a trace of *aluminum* has been observed either in crude or in malleable iron. Such traces are more distinctly marked in gray than in white iron, and most distinct in cold-short iron. There can be no doubt that this base injures the tenacity of the metal. Stodart and Faraday's experiments upon the manufacture of *wootz* or Indian steel, (in which ¾ per cent. of aluminum has been found, and which is considered to owe its peculiar properties to the association,) will be spoken of under the article Steel.

Iron forms an alloy with most of the other metals in varying proportions, dependent chiefly upon temperature. With *antimony* it has a great affinity, and associated with ¼ per cent. of this last, it becomes very brittle, either cold or hot. When united in the proportion of single atoms, (when the antimony is 70 per cent. of the mass,) the elements are inseparable by the highest degree of heat.

Arsenic in the proportion of 1 6/10 per cent. has been observed to destroy entirely the tenacity of iron. On account of the extreme volatility of this metal, it is difficult to effect directly so high a combination. There is no doubt that a very much smaller proportion acts injuriously.

Bismuth does not readily form an intimate union with iron. At the temperature of fusion of this last a great part of the former is volatilized, and its effect seems more felt in the treatment than in the quality produced; $\frac{3}{10000}$ of bismuth do not affect the strength or malleability of the metal.

Chrome unites with iron in all proportions, making alloys very hard, brittle, crystalline; more brilliant than iron, less fusible, much less magnetic, and much less oxidable. And these characters are more marked as the proportion of chrome increases. An alloy containing 60 per cent. of chrome is very fragile, whiter than platinum, and so hard that it scratches glass as deeply as a diamond. On the other hand, from 1 to 2 per cent. of chrome hardens cast-steel, and gives it the property of damascening beautifully, without diminishing its malleability.

Cobalt unites with iron in all proportions and without altering its properties, at least until the quantity of the former becomes considerable.

Copper can hardly be said to make a true alloy with iron, though when fused together a small proportion of the former will be taken up and retained upon subsequent fusion. Of *crude* iron it increases the tenacity when in the proportion of 1 or 2 per cent., and it might, therefore, be advantageously and economically employed for certain castings. As much as $\frac{1}{4}$ per cent. in bar-iron injures its capacity for being welded; a larger proportion makes a metal brittle at a red heat.

Gold may be alloyed in all proportions with iron, for which it has a remarkable affinity, and to which it imparts no new quality until its own quantity becomes considerable. When the gold is from 20 to 25 per cent. of the mass, the alloy is silvery and very hard, so much so that cutting tools may be made of it. On the other hand, when the iron is from 15 to 20 per cent. (to be classed more properly as an alloy of gold) it makes what the jewellers know as *gray gold*, of late much used for little trinkets, and admired for the beautiful polish that can be given it. Gold is also used as a *solder* for delicate steel-work.

Lead does not form an alloy with iron directly, with crude iron not at all, and with bar-iron, treated with litharge, in proportion not exceeding 2 per cent. This (and even a smaller proportion) renders the mass more brittle and more fusible. The ores of lead, which are sometimes found associated with those of iron, and have to be treated together in the high-furnace, are reduced, but the metallic lead lies in the hearth without uniting with the iron. It is sometimes found there when a furnace is blown out, not only in this state, but also as red-oxide or *minium*, and as a crystallized silicate.

Manganese, on the contrary, has a remarkable affinity for iron, and of all the metals is found most frequently in association with it. In small proportions the manganese renders the alloy harder, without impairing its tenacity; the limit in this respect is not ascertained, but it may be safely assumed at $1\frac{3}{4}$ per cent. The addition of manganese diminishes the fusibility of iron, but increases its oxidability. Alloys of these metals almost always exhale an odor of hydrogen upon being breathed on, and this greed of manganese for oxygen is one of the means by which the crude iron from manganesian iron-ores may be refined, so as to part with nearly or quite all of its alloy. The tendency of such manganesian ores to yield a metal easily convertible into *steel* has caused them to acquire the name of *steel-ores* with some persons. But this tendency, as well as the uniform liability of such ores (unless treated suitably) to give a white iron in the high-furnace, does not appear to arise directly from the manganese, but indirectly only, from the influence which this last has upon the behavior of carbon.

Molybdenum, like tungsten, unites with iron in moderate proportions, without altering its qualities, further than augmenting its hardness. An alloy of 1-5th molybdenum in iron is fusible, extremely hard, with small resistance to impact, but tenacious in other respects.

Nickel behaves with iron very much like cobalt, especially in the white color it gives, and in the facility and variety of its combinations. An alloy of 1 atom of nickel to 12 atoms of iron, (which corresponds to about $8\frac{1}{3}$ per cent. of the former,) is one often met with in nature, under the name of *meteoric iron*. This is less oxidable and less ductile than iron unalloyed, but in other respects the metal is of good quality. Not to speak of the sword of Alexander, which is said to have been made of an alloy like this, nor of the sabres of Jehanguire, fabricated of a similar metal some 2000 years later, the sword presented to Bolivar in 1821 was forged of the meteoric iron of Santa Rosa, near Santa Fé de Bogota, whose atomic constitution is almost precisely what has been given above.

Palladium renders iron brittle when in even moderate proportions; when the proportion is small, it induces no further alteration than increased hardness. The same affinities and effects belong to alloys with *rhodium*, *iridium*, and *osmium*. A proportion of 3 per cent. of either of these in bar-iron prevents rusting, and renders the alloy capable of being tempered like steel. It is with *steel*, however, that the alloys of all these metals are the most remarkable. The same may be said, too, of *platinum*, whose alloys with steel are of great interest, and present some remarkable peculiarities, but which hardly unites directly with iron, except in the presence of carbon.

Silver does not form a real alloy with iron. Fused together, the iron will take up a small proportion of the other; which, when it is as low as $\frac{1}{3000}$ only, injures the malleability and weldability of the mass. In these effects, Karsten ranks it as very nearly equivalent to sulphur.

Tantalium does not unite with iron directly; except at a very high temperature, and in the presence of carbon. So formed, it is tenacious, without ductility, and readily scratches glass.

Tin and iron have a great affinity for each other; unite in all proportions, and at last so permanently as not to be separated by fusion. The alloys in which tin predominates are without the peculiar characters of this metal, while they have gained none of the properties of iron; and the same may be said when the proportions are reversed. This does not apply at all to that superficial alloy which takes place in what is known as the *tinning of iron*, and which is manifested both with crude and malleable iron. The particulars of this art will be given under the article TIN-WARE.

The alloy of *titanium* will be spoken of in connection with the so-called *titaniated* iron-ores.

Tungsten behaves like molybdenum; and its principal effect is to increase the hardness of the alloy. Even when the tungsten is 37 per cent. (which is equivalent to 1 atom of tungsten to 6 of iron,) the physical characters of the alloy are very much those of *white iron*.

When *zinc* is kept in fusion in iron vessels, it gradually corrodes and dissolves them; a proof of the capacity of these metals to form alloys. At the high temperature, however, required for the fusion of iron, the zinc is volatilized; and so is never found, even in trace, in the metal from high-furnaces where iron-ores containing zinc are used. It is the opposite when the ores used for the extraction of zinc contain iron; this last is very hard to be gotten rid of, and even in small proportions injures the malleability and embarrasses the lamination of zinc. There is also a superficial alloy, like that mentioned just now in the case of *tin*, which is produced when clean sheets of iron are plunged in a bath of melted zinc. The preparation of this zincked iron, known in commerce as *galvanized iron*, is a late application of art, which will be particularly described under Zinc.

Iron is one of the few metals which do not form an amalgam with *mercury* directly. It is possible by the medium of a third metal, as zinc or tin, to produce indirectly amalgams which are of no interest in the arts.

Mineral characters and geological occurrence of productive ores of iron.—1. *Native iron, bolide, meteoric iron, &c.*—Although these are not strictly *ores* of iron, yet, as they are both workable and productive when they occur, it is proper to include them here. The means of distinguishing with certainty those which are terrene from those which are formed in, or at least fall from, the atmosphere, are yet so vague, that the two classes are here counted together. The occurrence of *nickel* is generally held to mark a meteoric origin. The most remarkable specimens are those of Siberia, discovered by Pallas; of Louisiana, sent to New York by Gibbs; and of Buenos Ayres, found by Rubin de Celis. This last more than doubles the size of any of the others; weighing about fifteen tons. Besides these, Africa, near the Cape of Good Hope; North America, at Canaan in Connecticut, and Randolph County, North Carolina, and in Bedford County, Pennsylvania; South America, along the eastern cordillera of the Andes, and in Brazil, and Peru; Asia, in Hindostan; Europe, from Bohemia, Croatia, France, Italy, Saxony, and Switzerland; and the Esquimaux settlements near Davis' Straits, (which belong to no continent,) have all contributed specimens. The color of these varies from silvery to bluish white; their hardness may be taken at between 4 and 4·5 of Kirwan's scale; they are all magnetic. Their specific gravity varies from 5·95 to 7·34, according to the associations, which are principally, and sometimes wholly, nickel, apparently in definite proportions. Arsenic, chrome, cobalt, copper, and molybdenum have also been found united with the iron, as well as a small proportion of carbon in the shape of *graphite*.

2. *Magnetic iron-ore, octahedral iron-ore, fer oxidulé, black oxide of iron, loadstone, &c.*—This is the only ore of iron acted on by the magnet without application of heat, except the titaniferous iron grains of Brazil. Its geological occurrence is in primary formations; and it is apt to be accompanied with quartz, hornblend, calcareous and fluor spars, and asbestos, which modify variously its fusibility and workable properties. Its chief deposits are in Sweden and Norway, and in Siberia, where it occurs in bands; sometimes it is found in beds, as in Savoy and Piedmont, Tyrol and the Vosges; it forms the mass of considerable mountains, as at Taberg in Smoland; and is also worked, as in Naples, in small grains like sand. In the New World it is found also, as in La Plata, Brazil, Mexico, and the United States; but generally not in sufficient extent to work. The mines at Schooley's Mountain, in New Jersey, have been, it is believed, abandoned; and the new works for this ore near Sykesville, in Maryland, have not been long enough in operation to determine their reliability. This ore frequently occurs in crystals, whose primary form is the regular octahedron, and whose cleavage is perfect. Its color is black; its lustre generally metallic; its fracture generally conchoidal; its hardness 5·5 to 6·5; its specific gravity 5 at a mean. When pure, it is composed of 1 atom of iron and $1\frac{1}{3}$ atoms of oxygen. The metal from this ore, known as Swedish iron, is of the best quality in commerce: and its properties, although attributed sometimes to the methods of its treatment, are probably more owing to the materials.

3. *Specular oxide, anhydrous peroxide of iron, iron-glance, red hematite, fer oligiste, eisenrahm, &c.*—This mineral is generally found in primary formations, but occurs also among sedimentary rocks. Varieties of the species, apparently of daily formation, are to be met with amid the lava of Vesuvius, and in ancient and existing solfaterras, as of Tolfa and Guadaloupe. The most celebrated deposit of it is in the island of Elba, where it has been worked for more than 2000 years, and where the extent of the excavations and deblais attests the industry more than the skill of the ancient miners. The Elba mines are continuations, probably, of the Tuscan ores. At present there are three workings in a hill of about three miles in extent, and elevated only about 600 feet above the sea. The rock in which it occurs is a whitish talcose slate, called there *bianchetta*, easily worked, but, after all, not very productive in modern times; the whole quantity exported not long since, being not more than 15,000 tons. The ore here is often slightly magnetic, and contains, in fact, an admixture of magnetic oxide, and often titanium. The wash from the actual workings, presenting the ore in the shape of octahedral grains like sand, is also exported under the name of *poulette*. The same granular occurrence is met with at Framont in the Vosges, the only point at present in France furnishing specular oxide. There are some other striking localities, such as Gellwara in Lapland, and Sommorostro in Biscay, (where it forms the mass of large mountains,) Norberg in Denmark, and the Minas Geraes in Brazil, where it exists in very extensive beds. The crystals of this ore are varied; but the primary form appears to be a rhombohedron nearly cubic. Its color is a brilliant black, very often iridescent, with a metallic lustre. Its fracture is sometimes lamellar, but more generally irregular. Thin laminæ show a deep blood red color. Hardness, from 5·5 to 6·5; magnetism, when it exists, attributable to admixture of magnetic oxide; and specific gravity at a mean, 5·10. When pure, it is entirely a peroxide of iron, and consists of 1 atom of iron with $1\frac{1}{2}$ of oxygen. The metal from this ore may be taken as equal to that from the former [illegible], the Celtiberian iron of old time, and the Bilboa blades of more recent periods, were made with it, and in Sweden even, in many mines, it is not separated from the magnetic ore. The *micaceous* variety crystallizes in hexagonal tables, which are divisible into thin translucent plates. Its powder is a bright red: its specific gravity about 5·25. This is found of extreme beauty near Northampton in Massachu

setts. *Red hematite* occurs massive, stalactitic or fibrous, and mamelonated. Its color is a dark red with very often a metallic lustre and aspect. Hardness, about 7; powder, which is red, never magnetic; and specific gravity, at a mean, 5. Thomson gives the specific gravity of a specimen from Muirkirk at 6·305. It is often mixed with oxide of manganese, and is then a reddish-brown, almost black. Of this variety are the deposits in Cumberland, (Eng.,) so useful in admixture with the ores of Wales; and in this also is the principal mining about Lauterberg and Altenau in the Hartz. This is the *blood-stone* of the metal-polishers. The *compact red iron-ore* of Lavoulte, in France, occurs massive, in veins 50 to 60 feet thick. It is also sometimes found in pseudo-morphous cubic crystals. Its color is a brownish-red; its fracture uneven; its specific gravity about 4·25. *Red ochre*, which is chiefly used as a pigment, but also as an ore, may be regarded as closely allied to this last variety, in which it is principally distinguishable by a softer texture and more lively red color.

All these classes of ores, when pure, contain the iron associated only with oxygen. The others which follow contain also *water* as a permanent additional element, in the proportion of from 10 to 15 per cent. Such are,

4. *Hydrated peroxide of iron, fibrous and compact brown hematite, brown ochre, umber, ætites, limonite, bog-iron ore, &c., &c.*—This class is very extensive, and is found as well in primary formations as in newer rocks. Its principal deposits are in the oolite series and chalk equivalents. *Bog-ore* is considered of daily formation. It is sometimes found in octahedral and cubic crystals, but most generally massive. The color of the mass is in various shades of brown, but its powder and streak always yellow. Its hardness is from 4·5 to 5; its specific gravity, at a mean, 4. It does not act on the magnet. Chemically, it is composed of 1 atom of water, 1 of iron, and 1½ of oxygen; or otherwise, 1 atom of pure specular oxide with 1 atom of water. From this class (principally, the compact brown hematite) comes a great part of the iron of France; the deposits about Whitehaven in England, which are of enormous extent, are a variety (the *reniform*) of it; the *oolitic* ores, which are small globules held together by a calcareous or argillaceous cement, cover a considerable extent in Burgundy and Lorraine, and occur also in Carinthia and Styria; the *granular hydrates*, or ferriferous sand, are worked in Normandy and other parts of France, in Switzerland, in Silesia, Bavaria, and Poland; and, finally, the *bog-ores* are profitably mixed with other ores in many places, as in Silesia and Livonia, and in the coal region of Maryland, or worked alone as in the last-named state. Phosphate of iron, however, which occurs frequently in this alluvial variety, prejudices its unmixed use. *Brown ochre* is principally used as a pigment; and the *ætites*, or eagle stones as they are called, which occur along the Rhine, are almost as much used by the French shepherds as amulets, to be hung around the neck of a favorite ram, as for any other purpose. The metal from this variety, however, as well as from the whole class, is unexceptionable whenever (as is the case generally, except with the bog-ores,) there is no adventitious impurities or associations, in sufficient proportion to be injurious. Ordinarily, the associations are from three to ten per cent. of silica, alumina, and manganese, in nearly equal quantities; amounts which in nowise embarrass the smelting or the result.

5. *Carbonate of iron, brown spar, argillaceous iron-ore, spathose or sparry iron, spherosiderite, fer spathique, fer carbonaté lithoïde, stahlstein, &c.*—Under these synonyms and varieties may be included a class more widely extended and more productive than any other on earth. Two principal divisions may be made of it—the crystalline or *sparry*, and the compact or *lithoïd*—the former occurring in beds and pockets in the primary rocks, the latter belonging to newer formations, and especially stratified among the coal-measures. The facility with which the former can be reduced rendered it of abundant introduction into the smelting-houses of the ancients; it was from this ore that the Styrian works turned out the metal so favorably known before our era as the *Norican* iron; and the name of *steel-ore*, under which it has been designated, from the readiness with which it yields a *steel* at the first treatment, is not less a test of its appreciation. This variety is both massive and crystallized. In the latter case, its primary form is an obtuse rhombohedron, nearly approaching the form of calcareous spar. Its derivatives are more complex; but not unfrequently it is converted, as in the very large Cornish crystals, into regular six-sided prisms. Its color is gray of various shades, yellowish and greenish, but sometimes almost red. Fracture is imperfect conchoidal, with a vitreous and somewhat pearly lustre. Thin fragments are often translucent. Its average hardness is about 4; its specific gravity, at a mean, 3·75. It is not magnetic. Abstraction made of the impurities, which are generally carbonates of lime and magnesia, this mineral is composed of 1 atom carbonic acid and 1 atom protoxide of iron. The compact or *lithoïd* variety occurs in nodules and in regular veins or strata; this last is especially the case in the coal-measures, with which it is always more or less associated. Its color is a dark gray, and when the allied carbonaceous matter is abundant, almost black. Its specific gravity is from 3 to 3·5. Its composition is the same essentially as that of the other variety, but with the uniform addition of notable proportions of silica and alumina, and coaly matter; protoxide of manganese is very often found with it and in the coal-measures, sulphur but in small quantities. The value of this ore is more in the facility with which it is treated than the quantity or quality of the metal produced. When in an unaltered state, it rarely yields more than 33 per cent. of metallic iron; the *altered* carbonates, which occur most generally in accidental beds among the primary rocks, may give 45 per cent. *Mushet's black band*, as it is termed, a seam of high reputation near Airdrie, in the Glasgow coal-field, returns about 41 per cent. Even when made with charcoal, the iron from this ore is inferior in its physical properties to the Swedish, to the Spanish, and to the Styrian iron, and, in general, to the metal produced from any of the preceding classes; when coke or coal is used its inferiority is, of course, more strongly marked. Yet improvements in the methods of manufacture have gradually cured these natural disadvantages to an extent which, though it still leaves something to desire, is yet sufficient for most practical purposes, and may well be balanced by the economy of production and the cheapness of the metal furnished. Indeed, without the use of coal and the association of this ore with the beds of fuel for smelting it, some of the most important contributions to the civilization of the present day would have been either impossible, or at least unattempted. From this last variety comes now nearly the whole enormous prod-

uct in iron of Great Britain; is is being extensively used in France, where, as in the departments of the Nord, Loire, and Allier, it exists in abundance; it returns a part of the metal from the Hartz; it was the earliest worked of the iron-ores of America along the Atlantic coast, when, as little more than a century since, it was seriously looked to as an available resource for the supply of crude iron for the English market, and, worked with charcoal at many points, still continues to yield a profitable return; and finally, when foreign competition is, for an interval only, set aside or guarded against, will enable the bituminous coal-fields of Maryland, Pennsylvania, Ohio, and Virginia to supply the entire consumption in iron of the whole American continent.

Such are the principal classes of available ores of iron. Mineralogists, and metallurgists even, often extend their number to include others, which should be, in theory, and sometimes may be in practice, used to advantage. So the *silicated iron-ore* of Kupferrath, the *chamoisite* of the Valais, the *garnets* of Henneberg, the *titaniated ore* of Maryland, are actually smelted; while the *volcanic basalt* of France, Germany, and Ireland, and the *jasper* of Piedmont and Siberia, contain iron enough to render its extraction hopeful. So the *franklinite* of New Jersey, which contains 46 per cent. of metallic iron, might be supposed as proper for the domain of the iron-master; but in fact, it has only been employed, hitherto, (as twelve years ago for the weights and measures of the United States,) in the fabrication of brass, and probably will ever continue to be invoked solely to surrender its zinc. As for the other mineral combinations in which iron is found—the arseniets, chromates, columbates, phosphates, and sulphurets, &c.—they may be omitted here. Some (as, for instance, the *chromates*) are worked for and applied to purposes in the arts other than the reduction of the iron they contain; others (as, for instance, the *phosphates*) yield an iron of such inferior quality, when treated alone, as not to be of desirable employment, while others, (as the *sulphurets*, &c.,) even were there no objection on this last score, require such expensive processes to effect a separation, as to be quite useless as ores of iron. The following table is of interest, as showing the normal proportion of metallic iron existing in the types of the classes and varieties that have been mentioned:

Class.	Variety.	Iron per 100 parts.
1. Native or meteoric iron		94·
2. Magnetic iron-ore	In purity	72·40
" "	Mean of seven analyses	67·47
3. Specular iron-ore	In purity	70·
" "	Red hematite	67·67
" "	Compact red iron-ore	56·50
" "	Red ochre	40·53
4. Brown hematite	Compact	59·18
" "	Fibrous	56·98
" "	Œtites	54·97
" "	Oolitic	44·45
" "	Granular	42·21
" "	Brown ochre	45·85
" "	Bog-iron ore	29·54
5. Carbonate of iron	Sparry	44·91
" "	Lithoïd; altered	40·79
" "	"	33·54

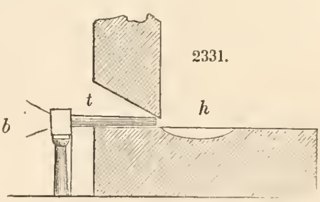
Metallurgic treatment of iron.—Under this head belong the *smelting* of the ores to produce *crude* iron; the *founding* or remelting of that product when required to be in certain forms and of metal properly termed *cast*-iron; the *refining* of crude or cast-iron, and its *forging*, so as to give malleable or *bar*-iron; and, finally, the operation, by hand, upon comparatively small masses of bar iron, known as *smith's* work. For the first of these processes is required a *furnace*; for the second, a *foundry*; for the third, a *forge*, or *rolling-mill*; and for the fourth, a *smithy*. Under this last denomination will be included as well the manipulations—which, from the color of the work turned out, (and perhaps, also, from the soiled externals of the workmen,) are ordinarily termed *black*smithing—as the operations with the lathe, &c., which are demanded in what is technically termed a *finishing*-shop.

1. Smelting.—This is, both in theory and in fact, a chemical operation: depending, first, upon the tendency of most earthy and metallic substances to melt by heat; next, upon the affinities of the materials usually put in furnaces for new combinations, while in a state of fusion; and then, upon the excessive gravity of metallic iron, which, in this state, tends to make it separate from and sink through the melted mass. In this last regard, it may be said, that while the specific gravity of all the other solid materials likely to come together in smelting (even in a coal or coke furnace) is not much more than twice that of water, the specific gravity of metallic iron is seven times as great, and its gravitating tendency is, therefore, at least three times that of any other element. In charcoal furnaces, this average tendency downwards is still greater. The following paradigm, in which only the chief materials and products in smelting are shown, will serve to illustrate the character of the affinities that are exercised and the recompositions that result:

MATERIALS.			PRODUCTS. Carbonic Acid. Gaseous.	Crude Iron. Solid.	Furnace Cinder. Solid.
Gaseous	Atmospheric Air	Oxygen	——		
		Nitrogen	——		
Solid	Iron ore	Oxygen	——		
		Carbon	——		
		Iron		——	
		Silica			——
		Alumina, &c.			——
	Fuel	Oxygen	——		
		Hydrogen	——		
		Nitrogen	——		
		Carbon	——	——	
		Silica			——
		Alumina, &c.			——
	Alkaline Flux	Oxygen	——		
		Carbon	——		
		Lime			——
		Silica			——
		Alumina, &c.			——

The success of these results depends upon the means employed. Thus, it is well known that, with fuel enough and air enough, heat can be generated sufficient, both in intensity and abundance, to fuse the most refractory and voluminous materials. But as both air and fuel are costly in their supply, the task of the furnace-manager is so to admix his ores and fluxes as that their simultaneous fusion shall take place at the lowest possible temperature; that it shall be the most perfect, to allow the utmost chance for the entire separation and descent of the melted metal; and that on its continuance, and by the presence of substances suitable for taking up and neutralizing all accidental or necessary impurities, either in the ores, fuel, or flux, there should be the least possible opportunity for the iron, after separation, to enter into new and detrimental combinations. All this was expressed long ago, with great practical terseness and almost sufficiently comprehensive caution, by Rogur, the Welch founder, in saying that "In order to make iron, you must first make glass." It is to produce this glassy cinder out of all the solid materials in the furnace, (except the iron,) that the founder aims; it is by this cinder that, from hour to hour, he judges how his furnace works. In earlier times, and with many still, this task was matter of routine, or of tact, which habits of observation had rendered almost intuitive. At the present day such tact can be guided and helped by accurate theory, which, upon a nearly perfect knowledge of how different chemical elements behave towards one another, can calculate arithmetically the dimensions of the furnace and the proportions of ingredients proper to a given result. This will be better understood after some details upon the construction of the furnaces themselves, and description of their parts.

Figs. 2331 and 2332 are respectively a section and ground-plan of the hearths, or furnaces, in use about the middle of the sixteenth century, as described by Agricola. The letter *h*, in both, shows the hearth proper; *t*, the tuyère; and *b*, the bellows. This form is not unlike the blacksmith's hearth of our own times; and has, in fact, been perpetuated, with but small modification, in the Catalan forges of the present day, where a malleable iron is produced from suitable ore by the first process. More refractory ores were treated in crucibles (as it were) of a somewhat different shape, as under; where Fig. 2333 is a ground-plan, and Fig. 2334 a section through *x y* of that plan. The same scale answers for all four figures.



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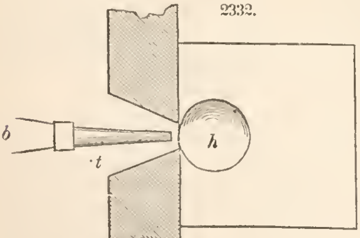
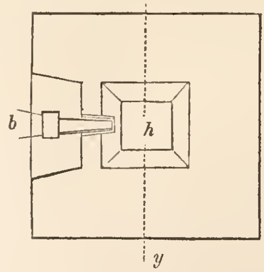


2333.



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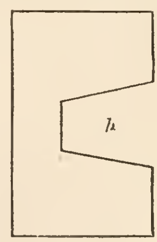
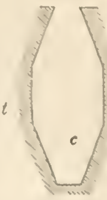


Both of these constructions belonged to a period when iron, more or less malleable, (an object of earlier utility in the arts than crude iron,) was produced direct from ores whose choice and value depended then greatly upon such a property. And both are of the kind which the Germans call *stück-ofen*, and the French *fourneaux à masse*, (in English, *pot furnaces*)—such as until very recently, and still, indeed, are used in Hungary, Carinthia, Styria, and along the Pyrenees. Both furnish the reduced metal in a solid lump, *loupe*, *stück*, or salamander, which has to be lifted by main force out of the hearth—the fires, of course, being suffered to go down for the purpose. The second kind appears to have had, like the modern stück-ofen, a tap-hole for cinder or slag to be removed. The stück-ofen, used at present in what was formerly the principality of Henneberg, are shaped internally like the adjoining Fig. 2335. They are from seven to ten feet high, built of sandstone; but the crucible proper, *c*, is of cast-iron. There are two openings: one at *t*, where is the tuyère; the other in front, for working—i. e., removing the cinder and the metal. The cinder is always running out; the metal is kept in (it is never very liquid) by a temporary wall of brick, which is taken down when the stück is drawn. In older times, the *loupe*, which weighs from 500 to 800 lbs., and which was formed in six or eight hours, was drawn every day. The improvement of deepening the hearth left room for several loupes, which were separated in the workings by dry charges of fuel only, and were removed every Saturday evening. At present, the loupes, separated as before, are drawn whenever the hearth becomes full, but without emptying the furnace, which continues in blast several weeks.

2335.



These Henneberg furnaces are types of an improvement which was beginning in the time of Agricola and is known in Germany as the *fluss-ofen*—in France, as *fourneaux à manche*—in England, as *tap furnaces.* The aim of this was to let the metal run out as well as the cinder; and the method of attaining the aim was a contraction of the crucible proper, whereby the heat became more intense and the metal more liquid. The stück-ofen—which, to be sure, always yields an excellent quality of metal—is very expensive, both in ore and in fuel: the low temperature it affords is not sufficient for the reduction and subsequent combination of divers impurities (such as manganese, silicium, &c.) in the ore, so that the iron is left comparatively pure; and as the slag contains ordinarily about 40 per cent. of metallic iron, the metal, which sinks down on the hearth after having been enveloped in this slag, becomes also partially decarbureted, and is, in fact, a mixture of crude iron, malleable iron, and steel. The fluss-ofen rendered the greater part of it crude iron; and is, therefore, the germ of the modern high-furnace. In its actual state, and like the Henneberg furnaces, only higher, (from 20 to 35 feet,) the fluss-ofen continues in use to this day in various parts of Germany, and in some places of Sweden. The Swedish furnaces were, indeed, until recently, all properly fluss-ofen. Since the intervention of Berzelius, they conform more to the models generally followed in other parts of Europe and America.

The following figures will serve to show the probable march of improvement, as longer observation, and greater range of materials that might yield iron, suggested the successive steps. For greater gen-

2340. 2339. 2338. 2337. 2336.

erality and simplicity, these figures show only the cuvette or inside section of the furnace, which necessarily regulates the externals. Thus, there is no doubt that the earliest shape was the prism, or cylinder, shown at Fig. 2336, which we know to have been in use in the time of Agricola. As it would soon be observed that, with such a shape, the materials were too heavily pressed below to allow free passage for the blast, relief in this respect would be sought by battering the sides inwards, as shown in Fig. 2337; while as, upon experience, it could not fail to be noticed that, if the materials, in descending, had more room, they would spread more easily—on this account the shape of Fig. 2338 might be preferred. The suitability of one or other of these forms would be regulated by the less or greater fusibility of the materials. But for average fusibility, as well as to combine the greatest advantage of these two experimental principles, the form of Fig. 2339 would be seen to be the best; while a slight alteration of this, and a combination, in fact, of all previously known forms, brings us to the form of Fig. 2340, which is exactly the modified fluss-ofen of Henneberg, before described. If the angles of

2341. 2342. 2343. 2344. 2345.

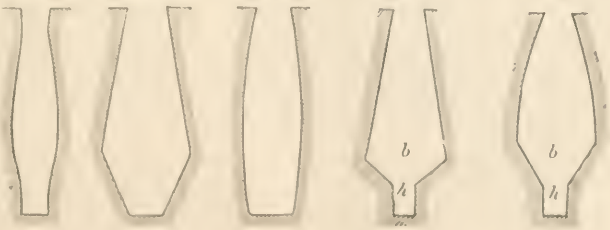
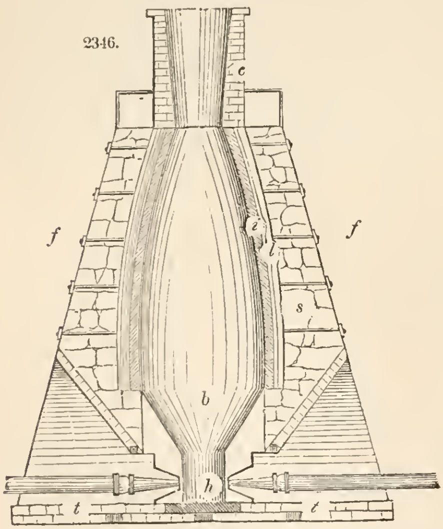


Fig. 2340 be rounded off, either designedly or by the degradations consequent upon its use, it will assume the form of Fig. 2341 which is that of the ordinary fluss-ofen of Europe. Fig. 2342 is a modification of Fig. 2339, bringing the belly, or widest part of the cuvette, nearer to the blast, as would be found desirable for less fusible ores; while for those more refractory, a general narrowing, as in Fig. 2343, would be resorted to. Finally, as the use of earthy ores became prevalent, it was found better to bring the top of the *boshes* (in German, *böschung*, a talus, or slope) nearer to the tuyère, and to narrow the crucible below, as shown in Figs. 2344 and 2345, which are the types of the modern high-furnace. In both these figures, *h* shows the crucible, or hearth, and *b* the boshes. The slope of these last is more or less steep according to the fusibility of the materials, and their less or greater fragility under pressure of a superincumbent. In this last regard, the height of the furnace-stack is an element in the calculation; although, for the generality intended to be illustrated by the figures, as well as for the distinction between different kinds of furnaces, the height is immaterial. It is usual to call, now, every thing above 27 feet a *high-furnace;* although, in the method of treatment, as well as in the character of metal produced, it may be, as in parts of Germany and France, a *fluss-ofen*, and although it may have no hearth proper, as in many places in Sweden. The different shape of the in-walls—straight in Fig. 2344, curved in Fig. 2345, of either of which many examples are found—arises more from caprice than from any logical conclusion. The latter is more retentive of heat, but more embarrassing to the blast; in the latter, therefore, the different stages of the process will be more distinctly marked than in the former. If the object be to gather combustible gases at the trundle-head, (as in the method of Faber-Dufaure,) the shape of Fig. 2345 is preferable.

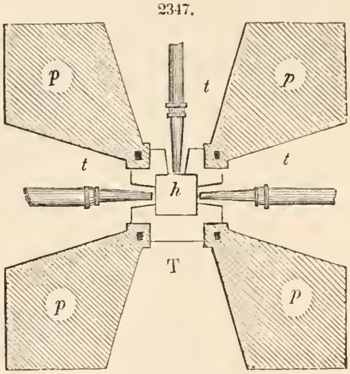
In some localities, the furnace is built upon the flat, and a veritable bridge connects with the hill. In places where there are no hills—as in Staffordshire, for instance—a long ramp is constructed, either of earth or carpentry, along whose inclined plane the materials are carried up by suitable machinery.

Figs. 2346 and 2347 are a section, parallel to the front, and a ground-plan of a blast-furnace, which may be taken as a type for all, whatever may be the materials employed. In these figures, *h* is the

2346.



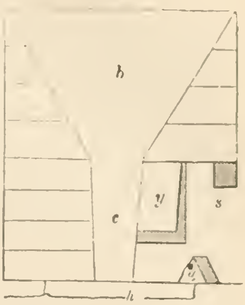
2347.



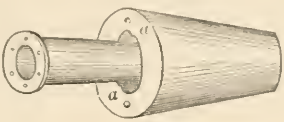
crucible, or *hearth* ; *t*, *t'*, indicate the passages and *tuyères* (pronounced *tweers*) for the blast. In Fig 2346, *b* shows the *boshes*, a term applied as well to the space where the letter is as to the stones which inclose it; *s* is the general mass of masonry, called the *stack;* *i* are the *in-walls*, of refractory materials, (stone or fire-brick,) defining the cuvette; *l* is the *lining*, of broken stone, pounded cinder, &c., loosely interposed between the in-walls, to allow them to expand without thrusting more than can be helped against the stack, and also helping as non-conductors of the heat; and *f f* indicate the ties, of bar-iron, which run quadrangularly through the mass of the stack to secure it still further. In-walls are sometimes made double, with a void space between them. It is obvious that, within the limits of their general aim, the particular dispositions of these are at discretion. A chimney, generally of brick-work, is shown at *c*. On Fig. 2347, *p p* indicate the piers, connected by arch-work, for supporting the stack vertically. These piers are generally themselves still further pierced with low and narrow archways, (as shown by the dotted lines on the northeast pier,) to allow of readier communication between the *tuyère-arches*, *t t t*, where the blast-pipes are. The arch T, in front, where the working is done, is termed the *tymp-arch*—generally larger than the tuyère-arches. This plan shows *three* tuyères, which is an establishment for a furnace of the largest class; yet very many have but *two*, and smaller ones are worked with but *one* tuyère.

Fig. 2348 gives an enlarged view of the disposition of the hearth and boshes. Here, besides the parts already indicated by letters before used, *s* shows one of the cast-iron girders, or *sows*, for supporting the thrust of the arch; *y* is the *tymp-stone*, protected by a casting called the tymp-plate, (*tymp*, in Welch, means a *delivery*, and hence is applied to the place where the product of the furnace is *brought forth*,) both from the iron *ringards*, or long crow-bars, of the workmen, and from the adhesion of the cinder, which is very strong to heated stone; and *d* is the *dam-stone*, protected, for similar reasons, by a casting called the *dam-plate;* *h* shows here the *hearth-stone*, or sole, which is a single, large, refractory stone, and ought to underlie, in part, the dam-stone. This hearth-stone ought to have a fall of at least ½ inch to the foot, towards the front, to assist the tymp of the metal, which comes out through a shoulder cut in the lower face of the dam-stone. The cinder pours over the top of this last. The place for the tuyère, which was first a square opening left in the masonry, is generally filled up now (since the use of hot air especially) with a double hollow cone, called a *water-tuyère*, made of wrought-iron, of wrought-iron with a mixture of copper, or of cast-iron, and built in with fire-clay on the tuyère-shelf. Fig. 2349 is intended to show this utensil. The openings at *a a* are intended, the one to admit, the other to let out, the water which circulates in the tuyère, and preserves it from the action of the heat in the hearth.

2348.



2349.



After stating the general principle that the hearth and boshes should be of the most refractory material possible, the choice of that material, of its position and treatment, it is obvious, depends, within certain limits, upon circumstances. Thus, they are built of sandstone, dressed or undressed; of soapstone; of fire-brick; or of an artificial puzzolana of cinder and fire-clay. The joints are always laid in fire-clay, worked up into the consistence of mortar.

Having now the nomenclature of the principal parts, some precautions as to their dispositions, and some requisites as to their proportions, may next be stated. The first thing after a *secure*, is a *dry* foundation, particularly in the vicinity of the hearth; and, therefore, too much provision of drains, active enough to take off promptly all possible moisture, can hardly be made. Under the hearth-stone should be constructed a false-bottom, with pieces of brick or stone, so as to avail of the non-conducting power of air. But currents through this are to be avoided. In some places in Sweden, it is, to be sure, the practice still to provide means for passing water under the bed of the hearth-stone, with the view of increasing its duration. But such a practice cannot be approved on any score.

The plan of the hearth is square, oblong, or circular, or elliptic. The two last forms agree best with theory; the others are more convenient in construction. With three tuyères, an oblong hearth is necessary, on account of the less resistance opposite to the third tuyère at the tymp: with two tuyères, it is still advisable, because the two nozzles should never be opposite exactly, and room for their play is desirable, as well as a better distribution of the blast. So far as the resistance to the blast is concerned, it will be in equilibrium by an addition of $\frac{1}{3}$ of the width to make up the length.

The *jambs of the hearth* are made vertical, or with various degrees of batter, from $\frac{1}{24}$, at a minimum, to $\frac{1}{5}$, at a maximum, of the height; and generally inversely as the height. This last proportion seems unreasonably great, and must embarrass the blast. But the absolute capacity of the hearth must be taken in as an element for determining the batter; as also the quality of yield which is aimed at. To make foundry-iron, the batter should be less than for forge-pig. The proportions of $\frac{1}{12}$ of the height for the former, and $\frac{1}{6}$ for the latter, seem to be warranted by the best examples.

The *slope of the boshes*, or angle which a section of their face makes with the horizon, varies from 55° to 70°. There are some instances in the Harz of less inclination than this; but it is not recommendable. A slope of 60° might be taken as a constant to present the maximum advantage; for, strictly speaking, the pressure of the blast can be regulated so as to compensate for unsuitability of slope, in any particular case, to the materials. In respect to these last, refractory ores and soft charcoal are best treated with a less slope; but fusible ores, and coke, or charcoal of hard wood, will behave better with steep boshes. The length of the boshes, which are now always circular, corresponds with the greatest diameter of the furnace, or, as it is technically called, the *width at the boshes*.

This *width*, it is obvious, must be proportionate to the *height* of the cuvette, or, it may be said, the whole height of the stack; i. e., the higher the furnace, the wider it may be with the same materials. But with a given height, the width should vary according to the materials, and *vice versa*. These two items, therefore, will have to be considered together in this respect; and, along with them, another of the greatest importance—the quantity and pressure of the blast furnished. And, after all, we can only deal in generalities, and not in arithmetical proportions, which can only be derived, for a given case, with materials of known composition and properties. The object of the furnace, at all, is to generate heat to melt some of the materials, and to melt them, also, at a proper place. This heat is produced by the combustion of others, (viz. the fuel;) and the amount of such heat depends upon the quantity of these last burnt in a given time; which quantity, again, depends upon the weight and volume of air furnished in the same time—i. e., upon the amount of blast. The greater the blast, the more fuel will be burnt, the more heat generated, and the more matter melted in a given time. Assuming, then, the blast as constant and suitable, the stack should be of such a height as that none of it will pass out unaltered at the trundle-head. It is manifest that, with a low furnace, a part of the air of a strong blast will come out at the top without having promoted combustion at all, and, therefore, at a loss. With the blast constant and the height suitable to that, the next thing is to consider the effect of the width at the boshes. At this point the materials have attained their greatest extension, and are ready, some for being burnt, some for being melted. If this space is too narrow the ores will arrive too soon at a high temperature; fusible ones will liquefy in the upper part of the furnace, refractory ones will fall in fragments into the crucible, not having had opportunity to be properly cemented and reduced. If, on the other hand, the width be too great, the temperature will be insufficient, and even fusible mines will descend unaltered into the crucible. This will be especially the case with charcoal furnaces, whose fuel, more friable, does not afford the same resistance. So far as fuel is concerned, then, boshes for charcoal other things being equal, must always be less wide than for coke; and even for another reason, that the light charcoal is easier blown aside by a strong blast, in which case it is burned against the sides of the stack, where its combustion is comparatively useless. It may be concluded, then, that the *width of boshes*, with a given height of stack and given blast, should be less for a friable fuel and for refractory ores than for a compact fuel and fusible ores.

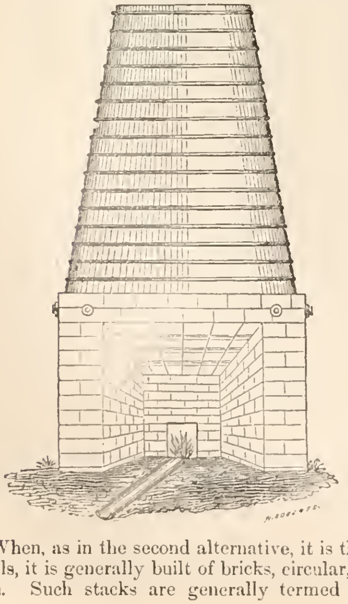
Upon the boshes rest the *in-walls*, and their junction should be effected to present the least angle possible. The materials of these, as well as of the non-conducting and elastic lining between them and the solid masonry of the stack, have been already spoken of. Their horizontal section is always circular, the vertical projection of their face sometimes a straight, sometimes a curved line. The former is more easy to build, the latter more retentive of heat, and, with a mould-board revolving round a central shaft, presents no difficulty in construction. In forming the curve of this mould-board, the shape of a common parabola is the most advantageous to be employed in respect to the distribution of heat.

The *width at the trundle-head* depends upon the quantity of blast intended to be furnished, and also, in a less degree, upon the quality of the materials. If the blast is very strong, it should be less than with a weak blast; it should be large with friable fuel, and ores that tend to stick together. The widening below should not be rapid, as if, for instance, the parabola before spoken of were cut off near its vertex, for the materials in that case would tend to distribute themselves unequally; relieved suddenly from lateral pressure, the heavier ores would descend quicker than the charcoal or cokes. The general practice is to make trundle-heads narrower than theory would dictate, under an apprehension of loss of heat; their width should not be less than 2-5ths, and in most cases might be advantageously ½ that of the boshes.

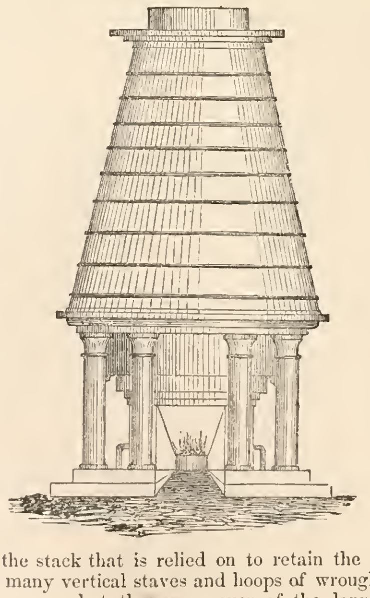
The *chimney* surmounting the trundle-head is not always adopted; in proportion to the size and temperature of the furnace it is more and more necessary. It is built uniformly of brick upon a cast-iron bed-plate, with mortar only enough to hold it together, and further retained in shape by ribs and hoops of iron. Its height is from one-fifth to one-fourth that of the stack, and its inside top-diameter is generally wider by the length of a brick than its base, the outside face of the wall being plumb.

The only remaining part of the construction which has not been mentioned is the *stack*, whose function, it is apparent, is only that of a retaining-wall to hold the cuvette, boshes, &c., in place. This function it may perform either by its *inertia* or by its *cohesion*. In the first alternative it is generally built of stone-masonry, laid dry where it approaches the lining, and mortared elsewhere; externally it will be square, the width of the base will be equal, or very nearly so, to the height of the whole stack above the foundations, and the outside face will be battered at from 2½ to 3 inches per foot, thus making the width at top about half the width of the base. These are, of course, only average and generally unobjectionable proportions. Besides this, in levels of every 4 or 5 feet, binders of bar-iron are laid in channels of 12 or 16 square inches of section left in the masonry parallel to all four sides, which binders are held at the ends by suitable *hold-fasts* that can be tightened either with a key or with a nut. When these bars break, (as they not unfrequently do,) they can be drawn out of their channels and others substituted. Besides these horizontal channels, there are vertical flues left in various parts of the stack to promote the expulsion of moisture, which otherwise would volatilize into steam, and accelerate the cracking of the masonry. This tendency to crack in the stack seems so confirmed that there is hardly a furnace of any considerable size in the world which does not show it. Except for a certain loss of heat these cracks do not injure a furnace, provided the in-walls remain unhurt. Finally, there is a dust-flue (in large furnaces) communicating from the top with the tymp-arch.

2350.



2351.



When, as in the second alternative, it is the *cohesion* of the stack that is relied on to retain the in-walls, it is generally built of bricks, circular, and tied with many vertical staves and hoops of wrought-iron. Such stacks are generally termed *cupola blast-furnaces*, but they are never of the largest dimensions. The external proportions vary according to the fancy of each builder. Fig. 2350 shows an ordinary furnace of this sort; Fig. 2351 another, remarkable for appropriateness, ingenuity, and taste.

Blast-furnaces have universally a roof, over the ground adjacent to the front and sides, of greater or less extent, called the *moulding-house;* and one, adjacent at the top and approaching more or less near to the chimney, called the *top-house*, or *bridge-house*. The necessity of these in protecting from weather the workmen, materials, and metal, is obvious. They are also advantageous in proportion to their extent, the spouts with which they are furnished, &c., in keeping the foundation, &c., of the furnace itself dry. As far as possible, the materials used in these buildings should be iron, to avoid risk of fire.

The difference of materials in furnaces has been frequently spoken of already as entailing a difference in dimensions. The principal influence in this respect is due to the fuel; and hence there is a marked difference in size between *charcoal* and *coke* furnaces. The necessity for this is apparent, when we consider, that with equal volumes, the heating effect of charcoal is but one-half that of coke; of two furnaces, then, of the same size, the one fed with charcoal can never be raised to so high a temperature as the other, for even the most obvious steps towards equalizing them (viz. continually supplying fresh charges of charcoal) have of themselves a cooling tendency.

The following table will show, at a glance, the comparative dimensions, &c., of these two classes of furnaces, established upon what is considered a fair average of each. The particulars under the head of anthracite are taken from what may be regarded as the latest improvements for the use of that fuel

Dimensions.	High-furnaces, using Charcoal.	Coke.	Anthracite.
Stack, height from foundation............	35 feet,	50 feet,	35 feet.
width at base	28 "	50 "	40 "
width at top...........................	$16\frac{1}{2}$ "	25 "	33 "
Cuvette, diameter of trundle-head......	4 "	8 "	6 "
height of conical in-walls............	$25\frac{1}{2}$ "	33 "	11 "
do. cylindrical	—	—	8 "
width at boshes	$9\frac{1}{2}$ "	15 "	12 "
angle of boshes........................	55 degrees,	65 degrees,	75 degrees.
height of boshes......................	$4\frac{1}{2}$ feet,	$10\frac{3}{4}$ feet,	11 feet.
Crucible, height of hearth...............	5 "	$6\frac{1}{4}$ "	5 "
mean of length and breadth at top	$2\frac{1}{2}$ "	5 "	6 "
do. do. at bottom	2 "	4 "	4 "
height of tuyère above hearth-stone	$1\frac{1}{2}$ "	2 "	$1\frac{5}{6}$ "
Approximate capacity.....................	1000 cub. feet,	4500 cub. feet.	
Descent of charges in about	20 hours,	40 hours.	

These dimensions and proportions undergo changes, necessarily to be accommodated to different ores, they are often arbitrarily modified besides, or follow a routine established at earlier periods of the art of smelting. Thus, in South Germany, the old *fluss-ofen* is still substantially retained; in Sweden, many high-furnaces are still erected without a crucible, *i. e.* with a continued talus from the top of the boshes to the hearth-stone; in Wales, where the product surpasses that of any other part of the world, the furnaces are lofty and vast—some (but an unsuccessful model, it is said) attaining a height of 70 and a width of 20 feet; the English furnaces of Staffordshire are lower, but, in proportion, more wide; the Scottish are more cylinder-like and squatter, still. In America, there cannot be said to be any prevailing type for charcoal works; the coke furnaces are said by Overman to be generally on the model of the first successful one,—that at Lonaconing in Maryland: while the use of anthracite as a fuel has yet received so little extension as hardly to present more than a few instances.

With these explanations of the means made use of, we can now pass to the materials employed in the smelting of iron, and their respective preparation.

1. *Fuel.* This is one of the most important materials, both in regard to quality and cost. We have already seen that it constitutes the index in a classification of furnaces; and when it is considered that there are many situations whose ores cannot be availed of because of the inconvenient supply of fuel, the propriety of placing it first in the list of materials will be apparent. The object in the use of fuel is principally to obtain heat, but it also acts in the furnace upon the other materials as a reducing and deoxidizing agent. In both of these aspects, its value is in proportion to the *carbon* which it contains; and in the last aspect, it is not mere *flame* or heat which is wanted in the furnace, but the contact also of carbonaceous matter with the materials to be reduced. *Wood*, whose chemical constitution may be taken in general at 50 per cent. of carbon and 50 per cent. of oxygen and hydrogen, in proportions forming water, contains too little carbon in its natural state to be advantageously employed in a furnace. Compared with coke, its calorific effect under equal volumes is but one-fifth of the latter; it therefore would not raise the temperature sufficiently. It has been attempted to be applied in a baked or *torrified* state, but not with sufficient success to induce a further use. The presence of *hydrogen*, which promotes inflammability, and which, although under some circumstances it acts as a deoxidizer, does not so act in a furnace further than upon the combustible itself, is a permanent obstacle to the employment of all fuel in proportion as it exists. Hence *raw* coal is, in general, improper; *turf* and *lignite*, or *brown coal*, are in the same category. The last named burn too much in the attempt to carbonize them; but pressed and charred turf is quite extensively used in France, Germany, and Russia, for the manufacture of iron. For smiths' work, it is said to furnish a charcoal of peculiar excellence. In America, where there is so much other fuel of a character as unquestionable and of supply more convenient, its consideration may as yet be left out of question; and all that will be treated of here is the preparation of *wood* and *coal*, the one by *charring*, the other by *coking*, for the purposes of the iron master. The gen-

eral principles of carbonizing either fuel are the same: viz., the expulsion, by heat, without contact of air, of the volatile constituents of the fuel. These constituents go off in part as gases, containing more or less carbon, and, in part, as new combinations which are still liquid at a high temperature; as, for instance, acetic acid, tar, &c. The distillation of wood or coal, with a view to economizing any other products than residual carbon, does not form any part of the business of iron-working.

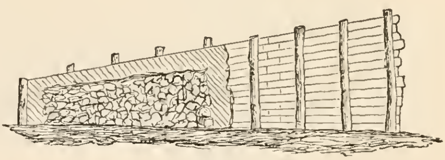
The means, too, for carbonizing either fuel for this special metallurgic use are similar, in kind, though the details of the methods vary for both considerably. These details may, however, be grouped into two great classes: 1. Where the carbonization is effected in a permanent, air-excluding *oven*: 2. Where it is done in *clamps*, or *kilns*, or *heaps*. In the general aspect of carbonization, the means employed would have to be antecedently classed according as use may be made, *first*, of other fuel than that to be carbonized, in order to generate the requisite heat, or *secondly*, of a part of the mass itself, for the charring of the other part. The type of the first system is seen generally in all the apparatus where other products than carbon are sought to be collected, and where the coke or charcoal are incidental to the operation; as in gas retorts, or the cylinders for pyroligneous acid or wood vinegar. Although a system like these might, in some localities, where fuel was abundant or in different qualities, be advantageously introduced, there is probably no iron establishment where it is resorted to; and the other classification, of *ovens* or *kilns*, remains as the only one that need be discussed here.

The relative advantages of these two methods can only be ascertained by a comparison of their products in quantity and quality. With respect to the first element, *quantity*, it may be assumed (though it is not universally admitted) that *ovens* produce a greater quantity, by weight, of carbon from the raw material. Hardly any collier can claim a yield of more than 20 per cent. of charcoal, for instance from heaps; while the best ovens, with perhaps less trouble, though not less expense in individual cases, will give about 25 per cent. Again, in the assemblage of cases, the expense for ovens is probably less; being less exposed to accidents from weather, neglect, &c., which sometimes result in the combustion of an entire kiln.

With respect to *quality* of product, the evidence is less decisive. It would seem in theory that the oven, producing a greater weight of carbon, ought also to produce a heavier material, *per se*. But such is not always, nor even generally, the case; and where the oven charcoal or coke are of the highest specific gravity, (and the economy of a high specific gravity is, in general, undoubted,) yet from some cause, such as a peculiar arrangement or disarrangement of fibres, it is not found to develop so much heat as that prepared in kilns. This point of *quality*, therefore, and, indeed, the whole question as between ovens and kilns, need a more profound and extensive investigation. All that will be done here is to describe the most usual and simple details of both methods; first, for charcoal, and then, for coke.

Charring of wood is still practised in Austria after methods which seem to have originated under the period of Roman domination, for the manufacture of the celebrated Norican iron. These may be denominated charring *in heaps*, (Germ. *haufen*,) or *clamps*; and will be understood from the accompanying sketches, of which Fig. 2352 shows a side-view, and Fig. 2353 a ground-plan of the arrangement. The ground for this may be either levelled or sloped. In either case, pipes are sometimes, but rarely, laid in the upper parts of the clamp, to carry off some of the liquid products. The length of the clamp (and, of course, the number of posts) is arbitrary—generally from 40 to 50 feet; the width depends upon the length of the logs, which, being ordinarily 4 feet, and being laid in a double row, with a very small space, to the casing of the sides, will make the width very nearly 9 feet across, from post to post. In Fig. 2353 the logs are given as if in but one length, which can very well be if the sticks are light. The casing may be of plank, slabs, or split cord-wood. The ground is well pounded; and, if in an old burning, with charcoal and dust. The logs are then piled, beginning from the upper part, to within a few inches of the top of the casing. Then it is covered with chips, twigs and leaves, and finally with sand or (better) dust, which material is also filled in against the casing, to protect it from fire. After all this is ready, fire is put in at the lower end, and some of the dust is removed from the upper end to make a draught. Draught-holes are also opened at discretion in the sides of the casing. When the smoke comes out where the dust is removed, it is necessary to throw it on again, and open elsewhere with caution. In this manner the fire is led on till the heat has charred the whole. The peculiar advantage of this method is supposed to be, that with a clamp, say of 50 feet, charcoal may be drawn from the lower end after the fire has progressed about ten feet, which it will do, ordinarily, in twenty-four hours. This is still further helped by making it on sloping ground. If well packed, a clamp of 50 feet by 9 feet, 6 feet high at the head, and 3 feet at the foot, will hold about 15 cords.

2352.



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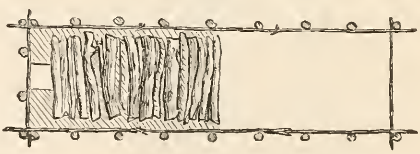
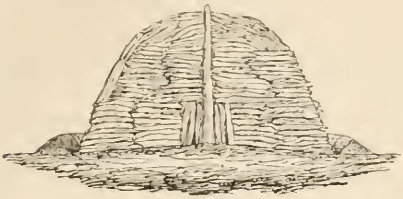


Another method, more extensively and commonly practised, is that of *kilns*, (Germ. *meiler*; Fr. *meules*.) These kilns are of two kinds, *standing* and *lying*; the wood standing on its end in the one, and lying on its side in the other, as shown in Figs. 2354 and 2355.

The circle, to be levelled and pounded down, for a kiln of this sort, will be from 40 to 50 feet in diameter; the driest ground must be selected for the purpose, and a place sheltered from winds. The best period for burning, in America, is from the middle of May until the middle of August; and then again in October and November, during the season known as the Indian summer. Wood which has been felled, and lopped, and barked in December and January, will be sufficiently seasoned to char in the autumn following. After the logs have been arranged, as in the figures, around the three long stakes of ten or twelve feet in length, (which are to serve as a chimney,) and piled as evenly and compactly as possible, the whole pile must be covered to keep out the air. A site for a coaling improves

2355.



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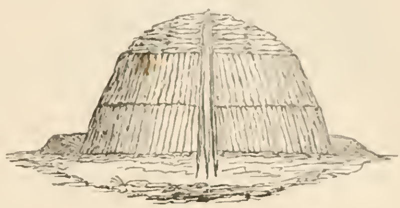
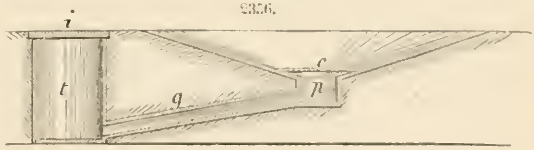


by use, for the charcoal and loam get trodden and mixed together, forming the best material for the covering. On entirely new ground use must be had of sod. When covered, fire is applied, either through the top and suffered to fall through to the centre, where provision has been made of some light wood to catch readily, or through a horizontal flue left along the ground, which is closed at its entrance as soon as the fire has taken. For the first twelve hours the kiln must be closely watched, and, therefore, it is usual to light at daybreak. At the end of that period, or a little longer, according to the kind of wood, its state of seasoning, and the skill of the collier, the fire will have taken sufficiently, and the top may be covered in with dust and loam. From that time, it is better that the operation should proceed as gradually and slowly as possible. In three or four days the cover begins to shrink and fall in, and fresh watchfulness is required to stop every opening thus made, and even new ones are made to effect an equable distribution of heat. These are points that cannot be taught by talking; they are lessons of experience and observation. When the cover sinks gradually, and the smoke grows less and less, regularly, the work is known to be going on well. Expert colliers find indications of the process in the *color* of the vapor and smoke, which varies at different stages. After all smoke has ceased, the kiln is entirely and thickly covered, and left for four or five days less or more according to its size, *to cool.* The coal is begun to be drawn from the foot, but cautiously at first, until it is found to be too cool to re-ignite upon admission of air. If so, the drawing may be continued all round for coal that is wanted, peeling it off, as it were, like an onion; the whole contents may be hauled off to store, or it may be left (covered up again) to be resorted to when wanted. In proportion as the kiln is well piled, flues in various places are unnecessary. It sometimes happens that the fire takes in particular parts, or does not take at all. In this last event, the advantage of a horizontal firing flue is tested. A kiln of ordinary size, of this kind, holds about 30 cords; the largest contain 50 cords.

When the circumstances are such as to render it likely that the same charring-ground will be used for a considerable period, it is worth while to adapt to it some permanent accessions, as indicated in Fig. 2356; which represents the section of a basin laid in dry brick, to serve as the ground of the kiln. This basin has a pit at *p*, with a cast-iron cover *c*, to keep ashes out, and a gutter, *g*, communicating with the tank *t*, which receives the liquid products of carbonization. With resinous wood, these products are advantageously removed as soon as possible from the charcoal, and are valuable when caught. The tank has a lid, *i*, which must be laid over it and luted when the kiln is fired.

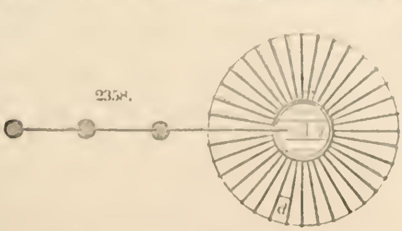
2356.



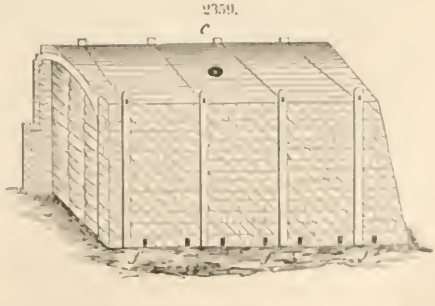
Midway between ovens and kilns comes the shroud or *abri* of Foucauld; of which a side-view is shown in Fig. 2357, and an orthographic one in Fig. 2358. It consists, in fact, of a series of trapezial ladders, made of light frames, and capable of enclosing a circle at the base of 30 feet, at the top of 10

2357.

2358.



2359.



feet, with an elevation of 8 or 9 feet. The sides of these frames are furnished with mortises or lugs, by which two adjoining strings can be keyed together with wooden bolts. The top is a flat cover of scantling, with traps that can be opened or shut for the passage of air, and also for that of a conduit made of three pieces of light plank, for the condensation of gaseous products. The effect of these ladders is to allow of a better packing (and, as it were, thatching) of the ordinary loam covering of kilns. Fire is applied, and air furnished at first through the door *d*, left in one of the ladders. The charcoal furnished by this method is said to be of superior quality; its yield is stated at 24 per cent. of the wood, with 20 per cent. besides in crude pyroligneous acid. This yield of charcoal is about one-fifth more than from the kilns that have been described.

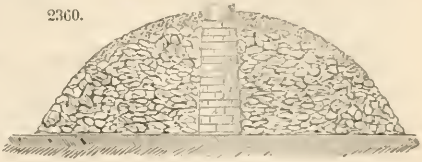
Of *ovens* there is a great variety of form; but as the most of them are embarrassed with apparatus for collecting other products besides charcoal, they are more connected with distillation than carbonization for the manufacture of iron. Only one, of the most simple and economical form, and yet yielding good results, will be described. A portion of it is shown in Fig. 2359, which is supposed to give a tolerably clear idea of the plan. The building from which this is taken is about 50 feet long, 12 feet wide in the clear, and 12 feet high, and will hold, well packed, about 60 cords, a quantity that has been found to present the maximum of convenience and economy. *c* shows the chimney-hole in the centre for firing, *f f* flue-holes for the draught, of which there are others on top which cannot be seen. At the ends there is a small door for charging and drawing. The stays are of cast-iron or wood, the horizontal binders on top of bar-iron. Wooden scantling was first used for both these, but it is neither so safe nor so strong. The arch which is sprung for the top is low, but yet, when the fire is in, there is considerable thrust against the walls. These walls are 1½ brick, and must be well laid and joined. As the acetous products in the oven are apt to attack the lime, asphalt, or a bituminous cement made of coal-tar and loam, is used instead of ordinary mortar. Coal-tar is also advantageously used for coating the outside. The wood is piled lying, as is seen in the figure. Under the chimney-hole, a chimney (so to call it) is left in the pile, at the bottom of which the fire is placed. The wood may be kindled through the draught-holes or at the doors, but less economically. When the fire is first started all air-holes are shut; when it is fairly caught the chimney may be filled up with dry wood, the hole closed, but not tightly, and air-holes opened at the ends. This will happen in seven or eight hours. The operation must now be watched, and by the emission of smoke and vapor through the air-holes, a judgment may be formed as to where they should be shut and where opened. In 45 to 50 hours the whole oven will have been heated; all openings are then closed and luted, and the concern left for three or four days to cool. On the fourth or fifth day at latest the coal should be fit to be drawn.

To what has been said, may be added some generalities as to the choice of wood and quality of the charcoal. The denser woods are to be preferred, because, other things equal, they afford a denser and harder charcoal. Decayed or doted wood will not yield a good article; and charcoal from green wood is more light, more friable, and less calorific than from dry, besides being less economical in the manufacture. The trees should be felled when the sap is down, i. e. in the winter, from December to February. Small timber is in general, and young timber always, worse than that which has attained a larger and more mature growth. Yet *very* old wood is not so good, because there is always more or less decomposition of the fibre. Branches of trees give less and a lighter charcoal than the boles, and the best of all is furnished by that part of the trunk and roots nearest the ground. In the ordinary felling of trees this part is all lost. Hence it would be better for the purpose (and the land would be left in a better state) to extract the trees at once by the roots, as is very easy, and then saw the timber instead of cutting. Heavy charcoal produces more heat, but its *reducing* effect is not in every case in proportion. There are some mines with which lighter charcoal acts better; but that it should be *hard* is an important characteristic universally. Charcoal just from the kiln burns quicker and produces less heat than that which has been kept some time in store, yet very old charcoal is admitted to be less valuable than what has not passed over one season. To what this is owing is not clear, for the affinity of the material for moisture is exercised very promptly, and after the first 24 hours, in an ordinary atmosphere and with reasonable precautions, it does not materially increase in weight. It is better to keep charcoal in store than to leave it stored in the kiln. After it has grown cool enough to handle, the sooner it is made quite cold the better; all gradual expulsion of heat, such as occurs in a kiln, is at an expense of carbon. With ovens this caution is unnecessary, for the circumstances there always compel removal of the charcoal as soon as manufactured. The product in charcoal ranges from 18 to 22 per cent. in kilns, and from 20 to 25 per cent. in ovens. By volume a cord of wood, 128 cubic feet, well corded, ought to give, at a mean, 40 bushels of charcoal. The price depends, of course, upon the value of labor in every locality, and the distance of hauling. The chopping of a cord of wood is equivalent to about one-third of a day's labor in the abstract, and the coaling of it in kilns or clamps afterwards to about a half day. The computations of the charcoal-burner are usually made upon the 100 bushels of charcoal delivered. Coaling in ovens, although in fact less laborious and demanding less experience, requires more tact, and wages there are generally higher.

The *charring of coal*, or *coking*, (from the German word *kochen*, to cook,) is the same in principle as that of wood, and the processes are very similar, though in some respects the considerations are different. Thus the coker does not fear, like the charcoal-burner, either air or moisture, nor is he troubled with the shrinkage and falling in of the kiln. On the contrary, for coke there has to be a large supply of air to determine combustion at all; the volume is in general increased during the process, while moisture, during the earlier stages, (but after the fire has obtained full way,) is recommended as a desulphuretting agent. It does, in fact, so act, but hardly to the extent that is claimed for it in theory, and some times supposed in practice; for the proportions of sulphur remaining in the coke from the same coal, treated either way, do not appreciably differ. On the other hand, coke-burning, subject to the same general category of regularity and manageability of temperature, and therefore when in the pure air liable to accidents from high winds, &c., of the same sort as occur to charcoal kilns, has to undergo constantly a greater per centage of loss from combustion. This loss is, on the average, about 6 per cent., so that coal which, on analysis, shows 85 per cent. of carbon and earthy matter, will rarely give 80 per cent. of coke, allowance being made for the quantity (from 5 to 10 per cent.) converted into slack.

Coke is made in *heaps*, in *clamps*, and in *ovens*. A suitable contrivance, and much used for heap-coking, is shown in Fig. 2360, the central shaft of which is a cylindrical or conical chimney loosely built of brick, (terminated in the sketch as in Staffordshire, with a cast-iron chimney-head,) against which the coal is piled conically, not tightly, and often with regular flues and intervals left between the masses. As with wood, the heaviest lumps are near the centre, the lighter outside. Coke-dust and slack-coal are used as a cover and for stopping. Ignited coal or coke is thrown in the chimney, and fire is sometimes introduced by the horizontal flues below. After the fire is started, similar precautions are required as with charcoal. The height of the chimney is from 5 to 6 feet, the diameter of the heap from 14 to 16 feet, and it will take from 10 to 12 tons of coal. As the process advances, slack-coal is thrown on in some places, and openings with a crow-bar made in others, according as the coker wishes to direct the heat, and water is injected plentifully, both to control the heat and desulphurate the fuel, if it is supposed to need it, and finally to put out the fire. A heap of the size given will be thoroughly coked in two and a half or three days; it is then left four days to cool, the whole operation requiring about a week.

2360.



In Wales *clamps* are more used for coking, which are long piles 5 or 6 feet wide, 2½ to 3 feet high, and in lengths varying according to the extent of coke-yard, from 60 to 100 feet or more. One of 60 feet will be of 30 to 40 tons. The coal is piled as in the other method, the largest pieces inside, loose throughout, and with horizontal flues. In place of the chimney, however, a stout stake is driven in the middle of the width and at every two yards of the length, to serve as a guide in piling. When the coal is piled the stakes are pulled out, and the space they leave becomes a chimney, into which the fire is placed as before. Sometimes the clamp is fired in its whole length at once; most usually it is fired at but one end, (regard being had to the state of the wind at the time and its probable permanence,) and even before the piling at the other is finished, so that it is a common thing to see coke drawn from one end and coal piled on the other end of a clamp at the same moment. The coke yielded by either of these methods is supposed to be better for iron-making than by any other way; but they are both costly in coal consumed, the latter especially. Where, however, as in the districts of its principal employment, coal is abundant and cheap, it presents divers conveniences which are probably cheaply purchased.

Slack-coal, i. e. coal beaten and comminuted in very small fragments or powder, (Germ. *schlag*, a *stamp*, a *blow*, and, by metonymy, a *crushing*, and the *thing crushed*,) of suitable quality, is also capable of being converted into good coke by a somewhat similar process. If the slack be from very *dry* coals, i. e. which do not contain much bitumen, it will not, however, coke at all; if the coal be too *fat*, i. e. with too much hydrogen, it will run together on the application of heat, embarrass the circulation of air, and yield a small proportion of a very friable and inferior article, if it does not defeat the whole operation. Assuming the coals to be of suitable quality, it may be treated by being mixed in small quantities, well wetted, in a kiln or clamp with larger coal. But the best method is to screen it first, and thus separate all the egg and nut-sized lumps from the mere slack, or pure powder. This last is mixed with water abundantly, and can be beaten from within against a wooden mould or shroud. Provision must be made by laying smooth and somewhat conical tampers of wood horizontally and vertically through the mass, for air-flues. These tampers are afterwards drawn out, and some larger than the rest, towards the top, leave the means of introducing already ignited coal to fire the mass. It is better to fire at the top than below.

2361.

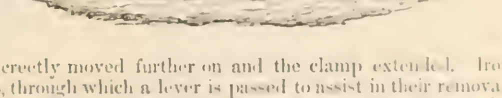
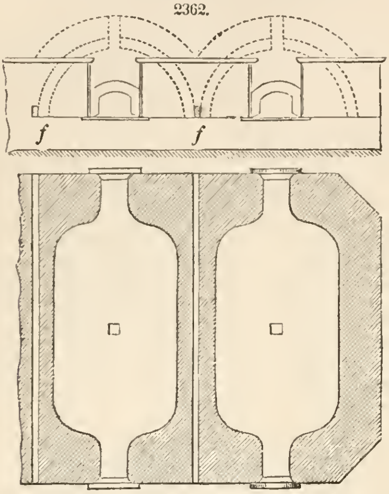


Fig. 2361 will give an idea of the arrangements proper for this method, which, preserving the main principle, are of course susceptible of many variations in detail. Thus they are sometimes made circular, but the most usual form is, as in the figure, an elongated prism, 50 to 60 feet in length, from 4 to 8 feet wide at the base, and from 2½ to 6 feet at the top, and 3 or 4 feet high. A greater width, up to 15 feet, has been tried, but not to advantage. Of course a mould and cores of the whole length are not necessary, but after a portion has been finished the shrouds and tampers can be discreetly moved further on and the clamp extended. Iron rings are indicated at the end of the tampers, through which a lever is passed to assist in their removal. The quantity and quality of coke made, due care being taken in the process, is in proportion to the quality of the coal, and about 80 per cent. of the quantity yielded from the same slack in ovens. A clamp of the size mentioned will take about ten days to coke and cool. It is better, on divers accounts, to leave it to cool, rather than extinguish it by cold affusions.

Fig. 2362 is an elevation and plan of two ovens of a series, especially applied to the coking of slack, but also capable of being used as well for lump coal. It is supposed that the sketch makes it quite intelligible, without further description. The doors at each end render the emptying of the oven very convenient. The average dimensions are about 16 feet long, 8 feet wide, and 4 feet high to the arch. The diameter of the chimney (which is generally a cylinder of a single brick, or refractory pottery) is ordinarily 16 inches. The hearth and arches are best made of fire brick. The foundation of the hearth may be of stone or common brick, with a filling of a foot at least of sand or furnace cinder interposed between it and the floor of the hearth proper. Such an oven will hold from 10 to 12 tons, and the coking, including cooling, is done in from 40 to 50 hours. It is not well to let it cool too long, or to such a degree that the slack will not be speedily ignited on contact with the hearth. In this respect, the oven, like a common bake-oven, works better for longer use. The first yield of coke from the cold oven is inferior to what is made afterwards. There can be no doubt of the greater economy of *ovens* for slack-coal.

Another sort of oven suitable for slack-coal resembles very much the *bank-ovens* for lump-coal that will be spoken of presently. The ground-plan is circular, the roof slightly arched, the only mortar used fire-clay. Flues are carried all round, communicating at generally three points with the interior. There is but one door for drawing, and the filling is done through the top; for greater convenience in which, they are generally built against a bank or sloping ground.

2362.



2363.

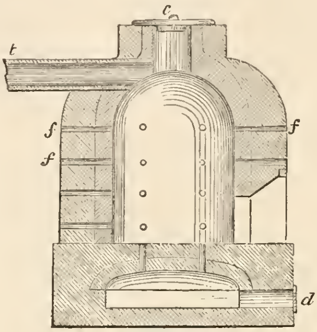
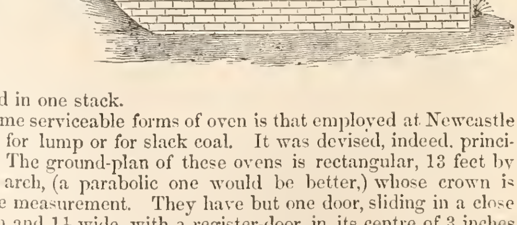


Fig. 2363 shows an oven of a different construction, much used in Silesia, both for coking and also for *coal-tar*. For the former purpose alone the ash-pit and damper *d* may be dispensed with, sufficient draught being furnished through the flues *f f*, &c. The opening in the section shows the door through which the fire is introduced, and which is afterwards bricked up. The filling is done from above through the throat, whose cover *c* is, after firing, luted down. The flue for the escape of the *tar* is shown at *t*.

The oven in most general use, both on the Continent of Europe, in England, and in America, has a circular or ovoid ground-plan, with a low, arched roof, to allow for the swelling of the coal. The draught is regulated by a damper in the door, and sometimes by flues communicating with the interior; the filling is in part effected by the door, and in part through the chimney, the fire applied generally through the last. The backing of the arch is filled up square, and, to save masonry, the building is generally made against rising ground, whence they have the name of *bank-ovens*.

Fig. 2364 shows a section of one of these ovens, for holding about two tons of coal. In England they have generally more or less of a chimney, and not unfrequently two more smaller apertures in the same axial plane to assist the draught. Also, there, the doors are usually of iron, sliding vertically in a frame and balanced; in America, the doorway is generally bricked up, and as this is always but temporary masonry, in such case iron staples are let in on each side for receiving a bar that may resist the thrust from within of the expanding coal against the brick-work. For economy of building and heat, several ovens are generally ranged in one stack.

2364.



One of the most simple and at the same time serviceable forms of oven is that employed at Newcastle and its neighborhood, which serves equally for lump or for slack coal. It was devised, indeed, principally in the view of economizing the last. The ground-plan of these ovens is rectangular, 13 feet by 10 or 11 feet, covered with a low elliptical arch, (a parabolic one would be better,) whose crown is about five feet above the hearth, clear inside measurement. They have but one door, sliding in a close joint, as before mentioned, about 2 feet high and 1½ wide, with a register-door in its centre of 3 inches square for admitting or shutting off the air. The draught is further managed by three chimneys in the arch, the main one, of about 1 foot square, in the middle, the others, about 4 inches square, at equal distances from the central one. This last has, as usual, a cast-iron cover; the others are closed with a brick. The coke from these ovens is supposed to be very good.

In regard to the advantages of the two methods of coking, in the open air or in ovens, it may be said that there is less loss and less labor of attendance with ovens, but more skill is required in managing the temperature. Thus, for instance, if the heat is got up too quick, (as it is very apt to be,) the coke with *fat* coals is spoiled by burning out too swoln, light, and friable; with *dry* coals, it burns up and causes loss. Also, ovens yield, on an average, about 10 per cent. more coke, but generally of less specific gravity and more friable. Whether less care is taken in the selection of the coal for ovens, as is probable, it is certain that the almost universal experience of iron-masters is in favor of coke made in the open air on the score of useful effect. Again, the yield from ovens is more uniform, and less subject to accidental discounts. Besides, ovens allow more readily the use of slack or refuse coal, to produce an article of the same value. The oven-coke, then, charged, too, with the greater labor required in drawing and the higher average wages of the cokers, is the cheaper in actual outlay; but its final cheapness, in which the quality of the product is an element, because of the varying degrees of its inferiority, which depend too much upon the constitution of the coal used in different places, hardly allowing a satisfactory comparison. Coke made in retorts is undoubtedly the *cheapest* of all, but its quality unfits it for use in the smelting of iron.

So great an effect has the physical constitution of the coal upon the coke produced, that experience shows the quantity of coke ranges in different places from 45 to 90 per cent. of the original weight of coal employed. About $\frac{5}{8}$ths of coke would be, most likely, a fair average of all known results on the large scale. Experiments made in small, or calculations upon the chemical analysis of coals, are no further admissible or of use, in this respect, than to stimulate the manufacturer to an investigation and economization of his actual results.

Regard being had to *volume* yielded, most coals expand in coking; some are unaltered, and some, even where a large proportion of earthy matter is principally aluminous, shrink. The resulting volume with the swelling coals is nearly, but not quite, nor always, in proportion to the loss of weight. Thus, Johnson, in his report to the Navy Department of the United States, in 1843, states, for a specimen of coal from Allegany County, Maryland—

Loss in weight, $17\frac{28}{100}$ per cent.; gain in bulk, $42\frac{25}{100}$ per cent.

The physical properties of this coal are stated by the same observer as under:—

	Weight of a cubic foot.		Per centage of		
Sp. grav.	Calculation.	Experiment.	Volatile matter.	Carbon.	Earthy matter.
1·337	83·3 lbs.	54·3 lbs.	12·67	74·53	10·34

The water and loss on the analysis appear to have been 2·46 per cent., and the proportions of the ingredients in the earthy matter is not stated.

No average increase of volume can be taken, in the present state of our information, to be of any practical utility; for, 1st, the result depends so much upon the methods employed; and, 2d, it is not the aggregate of the volatile matters which determines the expansion, but chiefly the proportion of oxygen and hydrogen to one another, and also to the earthy matters present. In regard to the first point, Berthier has shown the proportions of volatile matters existing in coke prepared on a large scale for blast-furnaces, to vary from $2\frac{7}{10}$ to 18 per cent.; in regard to the last, while analysis alone could satisfactorily determine it, yet for the practical purposes of the manufacturer it may be borne in mind that in general great lustre, but deficient hardness and elasticity, indicate the presence of hydrogen, (the element promoting fusibility,) while great lustre, with an intensely black color and much hardness, show a predominance of oxygen, associated with a large proportion of carbon. These last-mentioned indications, assuming the earthy matter in constant proportion, characterize the class of *dry* coals, which may be, with more or less advantage, employed *raw* in the smelting of iron. In general, it may be added, that coals containing more than 20 per cent. of volatile matter cannot be expected, *prima facie*, to be advantageously used in the furnace, either hot or cold blast, without coking.

From what has been said, it is obvious that the final efficiency of any coke must depend on its ultimate constitution. Thus the coke of Luxemburg, just now mentioned, with its 18 per cent. of volatile matter, is substantially but *dry* coals. The average composition of good coke may be represented as of

Carbon	82	per cent
Earthy matters	15	do.
Volatile matters	3	do

It is also obvious that the earthy matters in coke answer no useful purpose in smelting—they are only absorbents of heat. In proportion to their occurrence, therefore, they embarrass the operations of the furnace. It is difficult to fix a limit to which there will not be individual exceptions; but in general, coke containing more than 15 per cent. of ashes is not fit for the iron-master's use. Karsten places the excluding proportion far lower than this.

The absolute or relative efficiency of coke, then, can only be determined upon analysis; and external characters by no means give a conclusive result, though they are often valuable as an approximation. Good coke may be inferred from its not having undergone great alteration of *volume*, or change of *shape*; from its *color*, an iron-gray, or more nearly that of graphite; from its *lustre*, more *silky* than metallic, from much *hardness, elasticity*, and *resistance to impact*; from a uniform *fracture*; from a *texture* more fibrous than compact, and which imparts a peculiar *sonorousness* to a mass when struck; and, finally from a specific gravity which should, if any thing, somewhat exceed that of water.

These details upon fuel may be concluded with the following table, showing the probable consumption of fuel per 100 of crude iron produced with ores of different sorts

Denomination.	Per centage of Metal in Ore.	Per centage of Fuel consumed.	
		Charcoal.	Coke.
Fusible ores, (Class 4, in part, and 5,)	25 @ 30	66 @ 90	110 @ 150
do.	30 " 35	90 " 110	150 " 180
do.	35 " 40	110 " 130	180 " 220
Ores of mean fusibility, (mixed mines,)	30 " 40	110 " 140	180 " 240
do. do.	40 " 50	140 " 180	240 " 300
do. do.	50 " 60	180 " 210	300 " 360
Refractory ores, (Class 2, 3, and part of 4,)	30 " 40	160 " 200	275 " 350
do. do.	40 " 50	200 " 250	350 " 400
do. do.	50 " 60	250 " 300	400 " 500

Anthracite has been omitted in the discussion of fuels, mainly to save room, and also because, in one aspect, it may be considered as coming under the category of coals capable of being used *raw* in furnaces; whose employment, (whether bituminous or anthracite,) however interesting to particular districts, has not yet received actual extension enough to be treated on the ground of uniform or average experience. In another aspect, it may be regarded as belonging to the class of *hard-coked coals*, whose constitution its own very much resembles, as will appear from the following average, viz.:

Carbon	88·7	per cent.
Earthy matters	7·4	"
Volatile matters	3·9	"

It is on the respective proportions of the ingredients in these earthy and volatile matters that its treatment and behavior depend; the principles of calculation must be precisely the same as those which govern in the case of average coke, and the results accordant.

2. *Ores, and their preparation.*—The methods of *extraction*, or *mining*, practised for different ores, according to differing circumstances of position and association; of *picking*, (Fr. *triage*,) *washing*, and *stamping*,—processes used according to circumstances for separating the ore proper from a more or less indurated gangue, and cleaning it,—will not be considered here; according to the distribution practised in extensive iron-works, at least, the ores do not come properly under the hand of the furnace-manager until the last of these processes is achieved; and they belong, therefore, to the article MINING, which see.

The *roasting* of the ore is the beginning of the furnace processes. The objects of this are to diminish the aggregation of the mass, and thus leave more room for other chemical affinities to act, and for new combinations to take place; to drive off such impurities and admixtures (water, carbonic acid, and sulphur, principally) as can be volatilized at a red heat; and, as some suppose, to present the mine in a higher state of oxidation. The methods followed should be in subordination to these aims.

In point of fact, all of them are partly answered with many ores by continued exposure to the atmosphere, under which a spontaneous disintegration takes place, together with a partial absorption of impurities and a peroxidation. But with some ores, these effects are not manifested till after a long period, (as, for example, with magnetic and specular oxides,) and with all they are vastly accelerated by a due application of heat. It may even be said that all ores are the better for being roasted and then exposed for as long a time as convenient to the macerating influence of the atmosphere. The *red hematites* of Lancashire are hardly an exception to this; for, though used habitually raw, it is only for intermixture with other ores, and in small quantity; while the custom, in some districts, of only *weathering* the sparry carbonates, which are afterwards used unmixed, arises only from the difficulty of so managing the heat as to roast and not fuse them.

This management of temperature is more or less necessary with all ores. Thus, magnetic and red oxides, quartzose sparry carbonates, argillaceous carbonates containing a suitable proportion of silica, and generally all the silicated ores, are easily vitrifiable. As a general rule, the roasting should be as prolonged and at as low a temperature as possible, with free access of air and moisture.

The roasting may be done in *kilns*, or *clamps*, or *ovens*. The first is the most simple of all and the most extensively practised. The shape of the kiln is indifferent; it is sometimes conical, sometimes a square or rectangular pyramid. Its size is equally indifferent. The whole method consists in interstratifying the ore and fuel, (in an average proportion of about five of the former to one of the latter,) from the base, where there is a sufficient accumulation of combustible, and certain rudely made flues or prolonged cavities, to insure the fire taking throughout. The smaller pieces of ore are put outside as a cover, and ashes and cinders, coal, coke, or charcoal dust, or loam, used afterwards, where necessary, as a stopper or damper of the fire. After piling and starting the fire, it is, in good weather, only looked at from time to time. In most of the English, Welch, and Scottish furnaces, as well as at many in America, they appear to overlook the importance of keeping a large stock of roasted mine ahead, so as to give it the further benefit of atmospheric exposure.

Clamps are, in principle, very much the same with those already described for making charcoal. Three sides of a parallelogram, of width and length indefinite, are built round with a dry wall in stone, having draught-holes left at intervals of five or six feet in the base, and carried up to about three feet in height. Chimneys are built loosely, of brick or stone, along the middle of the clamp, and corresponding with each one (or, sometimes, two) of the flues. The fuel is laid, in the beginning, at the bottom, and is more or less interstratified with the pile of ore according to the greater or less presumed fusibility of this last. Sometimes there is no interstratification at all, but fuel is supplied as wanted to the draught-holes in the base.

The *ovens* used are of almost infinite variety in shape and dimensions. Their general types are a cylinder, an inverted cone, or a combination of an inverted and a right cone, and a truncated ellipsoid; they vary from 6 to 18 feet in height, with an average diameter of 3 feet at the grate and of 5 to 10 feet at the trundle-head. They are like *lime-kilns*, either perpetual or periodic; and, in fact, the description of a lime-kiln is also that of a roasting oven. The temperature to be maintained in the last is lower than in the other. *Reverberatory* ovens have been tried, but unsatisfactorily, for the roasting of ores.

It is to be supposed that the larger the oven, the more regular and economical will be the work. For refractory ores, the oval shape is, perhaps, the best; while the more simple cone or cylinder is better suited to fusible ores. Ores generally pass, with but short (if any) interval, (and in so far disadvantageously,) from the ovens to the top-house, where they are *broken up*, and immediately charged into the furnace.

This *breaking* is effected upon a stone or (better) a cast-iron floor, sometimes with a beetle, one or two handed; sometimes with iron-shod stampers, moved by machinery; sometimes the mine is crushed between fluted cylinders made to revolve. But the best of all methods is to break by hand with an ordinary stone-hammer.

The size to which the mines should be reduced before charging ought to vary directly with the hardness of the ore and the height of the furnace. From one to three inches, average diameter, inside, will be the limits. Larger than the one, they leave too much to be done in the furnace; smaller than the other, they embarrass the blast.

3. *Fluxes.*—The reducing effect of the carbon of the fuel upon the metallic oxides in the high-furnace has been already spoken of, as well as that of the potassa and soda contained in the earthy matter of charcoal; but these are rarely sufficient, with most mines, to cause at once fusion and reduction; and it becomes necessary, then, to add other matters, sterile in metal, to promote fusion: these are known as *fluxes*. *Silica*, indeed, which is a constant association in all ores of iron, is, of itself, a sufficient flux in some cases; but, even in those, it is more apt to be in excess, when it both embarrasses the working of the furnace and impairs the quality of the metal. It would be proper, then, to neutralize this excess by the addition of some other substance; and such addition becomes still more proper when (the practical problem in the furnace being *to effect fusion at the lowest possible temperature*) both theory and experiment show that it not only cures such excess, but also promotes fusibility. In fact, we know that while of each of the earthy bases most ordinarily accessible, viz., silica, lime, magnesia, and alumina, is almost (and one of them entirely) infusible, *per se*, yet in combination, two and two, three and three, and, still more, four and four, they melt readily at easily attainable temperatures. The addition, then, of suitable proportions of these sterile matters, is the means to economical fusion of the materials in the furnace.

Without dwelling, however, upon the theory of their action, (which has been explored more or less profoundly by a host of chemists and metallurgists, and has been experimentally examined by Achard, Alexander, Berthier, Descotils, and Lampadius,) and regarding only the practical maxims that fit the question, it may be said that in addition to the silica and alumina, always present in the ores and fuel, and to the lime, magnesia, manganese, and potassa, sometimes present, too, the positive flux most usually added is *lime*, in the form of marine shells, limestone, or chalk. The proportion of this addition varies in almost every case; but, at a mean, it may be taken, for charcoal furnaces, at one-fourteenth of the other solid materials by weight; and at one-eighth, for coke furnaces.

Although lime is the flux thus almost universally employed, it is not always the one that best suits the case. With an excess of silica, it is the proper one. But when the ores are themselves *calcareous* in any considerable degree, the best addition is of aluminous or magnesian earth, or both. In some cases, where the ores and fuel are highly aluminous, the addition required (though with great caution) is *silica*, in the shape of quartz, &c. In such cases, the best avail has been taken of *siliceous* matter containing also a low proportion of iron. It is thus that amphibole, basalt, and garnet have been applied. This is, in fact, the use of a *poor* material instead of one utterly sterile.

In general, it may be estimated, that of the whole solid materials introduced into the furnace, (the *metallic iron* excepted,) the

Silica	may range from	45 to 60	per 100.
Lime	"	20 to 35	"
Alumina	"	12 to 15	"
Magnesia	"	12 to 25	"
Oxide of manganese		15 to 20	"

If all four first named are present together at once, the most fusible proportions in which they can exist (without regard to the fluxing action of metallic oxides that may be there too) are,

Silica	35·2 per 100.	Lime........................	19·1 per 100.
Alumina........................	31·7 "	Magnesia	14·0 "

The solid material of the fluxes should be, like the ores, broken up into fragments of similar and uniform size. When oyster-shells are used, it is not necessary to treat them further than by a slight previous calcination. They do not always receive that.

The artificial fluxes, (such as *salt*, *potash*, *saltpetre*, &c.,) either singly or in combination with alkaline earths, which have been suggested at various times in the last twenty years, do not appear to have met with as much practical success as the theories of those who recommended them seemed to warrant. It is probable that this will be always the result; owing not so much to mistake in the principle as to a difficulty, inherent in the blast-furnace, of applying these highly fusible and reducing agents just at the point where they are wanted.

4. *Gaseous material—atmospheric air.*—The remaining material in blast furnaces, besides those that have been considered, is the *atmospheric air*, which is regularly blown in to keep up the combustion

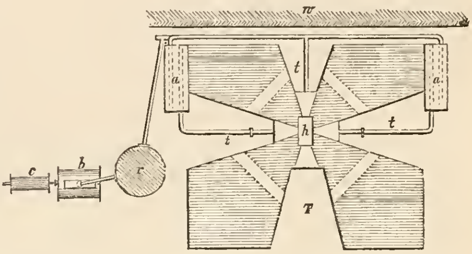
It is, therefore, in this aspect, one of the most important to be duly managed; and when the enormous quantities of it that are required are taken into view, its probable influence and collateral effect can be still better appreciated. The following average statement may be derived from the practice in this particular.

	Charcoal Furnaces.		Coke Furnaces.	
	Solid.	Gaseous.	Solid.	Gaseous.
Volume of materials, in cubic feet, per minute	0·295	900·	1·06	3000.
do. proportionate	1·	3050·	1·	2830·
Weight of materials, in lbs., per minute	24·82	75·	102·12	269·
do. proportionate	1·	3·022	1·	2·634.

Taking the mean of the proportional quantities, it appears that, in round numbers, the *volume* of the air injected is 3000 times larger than that of all the solid materials in any given time; while its *weight* is three times greater than theirs. The elements used above would show also that on the average there is consumed nineteen tons of *air* for one ton of *iron* made.

In order to illustrate the means of managing this vast supply, Fig. 2365 (a sketch, with more attention to distinctness than proportion of parts) shows the arrangements suitable for a furnace of the first class. The power used is assumed to be *steam;* though the method of its procurement and application is not carried further back here than to the steam-cylinder *c*, worked horizontally by the same piston-rod that goes through and works the cylindrical bellows *b*. It is obvious that other sources of power, or other methods of geering, may, under suitable circumstances, be resorted to. From *b*, the bellows, the air is driven into *r*, the *regulator*, whence it passes into *a a*, the furnaces for heating it, and then transmitting it along *t t* into *h*, the hearth or crucible. T indicates the tymp-arch as before; W a retaining wall against the hill-side, and connected by an arched bridge above with the stack; while the blanks left in the piers show the passage-ways before spoken of, left for more convenient access between the tuyère and tymp-arches. Such being the general arrangements, the parts and their requisites will be spoken of briefly in order.

2365.

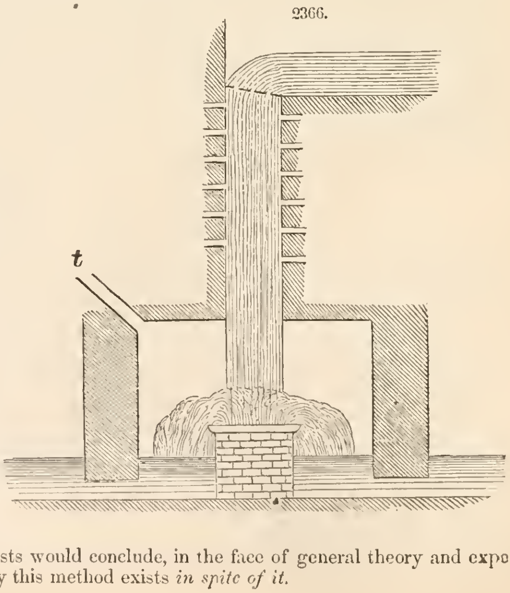


Bellows, or *blowing machines*, have been constructed of *leather*, of *wood*, of *stone*, and of *cast-iron*. The first material, on account of its expensiveness and the narrow limits which it imposed upon both the volume and density of the blast, is no longer used except for smiths' fires. The second, whether made with hinges or (as afterwards) worked with a piston, left much to be desired. The use of the third, in an instance or two, can only be justified by necessity, or applauded as a conquest over circumstances: while the last, in the shape of a double-acting cylinder, furnishes the only satisfactory and sound means to the end.

Before describing these, however, mention must be made of a method on a totally different principle, which, under variously modified forms, is still employed in parts of Italy and the districts of the Pyrenees. This is the *trompe* or *water-blast*, of which Fig. 2366 shows the principle.

In this, a vertical tube of wood or iron, cylindrical or prismatic, of length and diameter suited to the fall and quantity of water intended to be used, connects with a cistern below, made air-tight except for the opening *t*, to connect with the tuyère. Through this tube a stream of water is allowed to fall, drawing in the air as it descends through openings that are indicated by broken lines in the sides of the column, and breaking upon an altar below. The air thus carried into the cistern has no means of escape except the tuyère *t*, and its quantity and pressure delivered through that depends upon the absolute size of the column of water, and the proportions of the various parts. Venturi has already satisfactorily investigated the relations of this machine; which will not be dwelt on in that aspect further here than to say, that although very cheap and convenient in its construction, it uses more water for a given effect than a water-wheel would do, and that its effectiveness is quite limited. Karsten refuses to admit that the *dampness* of the blast it affords, injures the quality of the iron; although it is probable that most metallurgists would conclude, in the face of general theory and experience, that the good quality of iron made by this method exists *in spite of it.*

2366.

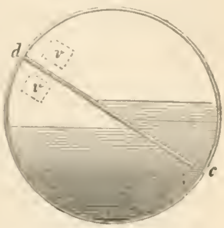


The *chain-blower* of Henschel is an improvement upon this machine. In it, a more complete separation of the air and water is effected, by means of an endless chain of floats or pistons, worked by the descending water itself; but its effect is not such as to take it out of the general category of objections.

The *hydraulic bellows* of Baader is, in fact, but a single-acting piston air-pump, in which the surface of a reservoir of water is made to take the place of the otherwise solid end of the pump. It cannot be made to furnish blast either of large volume or much density, and is mentioned here only because it is actually used with satisfactory effect in suitable cases; but it can only be recommended in districts where water is plenty and the labor of the artisan dear.

The *oscillating cylinders* of D'Aubuisson are an extremely ingenious blowing-machine, cheap to construct, and worked with little power and at small expense. Although not giving a blast of sufficient amount or density for the smallest high-furnace, except with the most fusible materials, they answer very well for chafery and finery fires. Fig. 2367, which is a section of one of the cylinders, will afford an illustration of their action. A diaphragm, central, through the entire length and nearly the whole diameter, is shown at *c d*; *v v* are two valves, alternately aspiring and expiring. In its normal position *d d* is vertical; the barrel is filled half full of water, through a bung, and is then set in oscillation, through an arc of 90 or 100 degrees, by a connecting-rod and crank geered on near *c*. It is manifest, that in different angular positions of the diaphragm the content of water in the two semi-cylinders will come to be unequal, as shown by the shaded lines; and the air will be respectively rarefied and condensed accordingly.

2367.



All these methods, however, imply more or less contact of the air with water, and the consequent immission of more or less moisture with the blast; which is objectionable. But this oscillating method leads to speak of a *rotary* method for delivering dry air—at least, air of the ordinary atmospheric humidity only. This last is the *fan-blast*, in which fans, radiating from an axis, are caused to revolve rapidly in an appropriate disk, receiving the air at the centre of rotation, and delivering it on the circumference into a chest, with or without a valve. The volume of air furnished by this means is not, without considerable expense in construction and power, sufficient for a high-furnace of the first, or even of the second class; but the density that can be obtained leaves nothing to desire. For cupolas, refineries, &c., it is very convenient and appropriate. It is, in practice, of two kinds: one acting *impulsively*, in which the air is aspired and at once diffused in a common chamber, whence it is driven out by the fan-wheel; the other *centrifugally*, in which the fan itself is a hollow wheel, receiving the air at openings near its axis, discharging it first, at openings in its circumference, into the chamber or casing, and then driving it out from said chamber by fans fixed upon its own periphery. The chamber of the outer casing is kept from communicating with the external air, as it is inspired, by a portion of the internal revolving disk, which is made to work air-tight as possible in the outer casing. Here is exactly the embarrassment of the arrangement, which imposes a higher cost upon the apparatus in the beginning, and is difficult of maintenance. When it fails of being maintained, however, the machine does not, on that account, lose its value—it merely passes over into the other class.

2368.

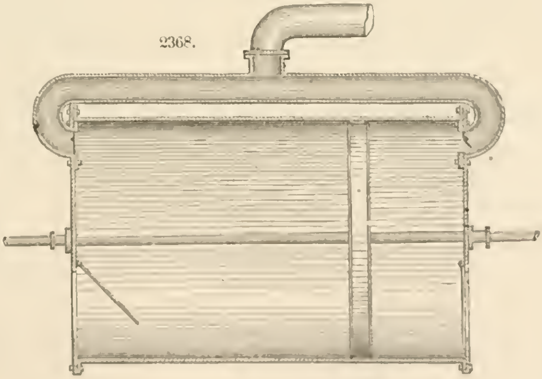


Fig. 2368 is a section of a horizontal, double-acting, blowing-cylinder, in cast-iron; which may be taken as the type of a class that fulfils all desirable conditions. The details, it is supposed, sufficiently explain themselves. There are some advantages in a horizontal cylinder rather than a vertical one, principally, it can more readily secure a good foundation, with less waste room from valves, which, in the others, are more or less necessarily in the sides. By carrying the piston rod through both heads, the weight of the piston is equalized upon the collars, and there is left but little risk of the cylinder's wearing out of shape.

The *size of the blowing cylinder* depends upon the volume of blast wanted. As the length of the stroke is generally somewhat limited by the conditions of the other machinery which supplies the moving power to the piston, and as the maximum speed of the stroke, or number of revolutions in a given time, is, in like manner, determined by general mechanical considerations, it has been found necessary, in practice to give these cylinders a large diameter, disproportionate to the length of stroke

The blowing-cylinder at Dowlais, for instance, (which is the most extreme case that could be cited,) has a stroke of 10 feet and a diameter of 12 feet.

To determine the volume of blast, and, consequently, the size of cylinder, the best rule is, when the constitution of the materials to be used is known, to allow air enough to *peroxidate all the materials* in the furnace at any one moment. This will be the outside limit. In ordinary practice, the machinery will be worked at a slower speed; and in emergencies, there will be still a margin to go upon. In calculating the supply of air, it is to be remembered that the best-executed blowing machines do not deliver into the furnace more than $\frac{4}{5}$ of their theoretical capacity: it would be even safer to take, as an average, $\frac{2}{3}$ of such capacity for the actual supply.

If the constitution of the materials is not known, but the size of the furnace is, and thence the number of charges that it ought to bear in a turn, we have another rule: *One-fifth of the weight in pounds of fuel* (either charcoal or coke) *charged during one turn of twelve hours, is the number of cubic feet of air, under the pressure of the atmosphere, to be furnished in one minute.*

This allows for the average discount on the working of the machine, leakage of pipes, &c.; and gives, therefore, at once the capacity of the cylinder.

Regulators are of two general classes: 1st, of *variable* capacity; and, 2d, of *constant* capacity. Those of the first class are either *dry*, or *wet*, or (as these last are called) *water-regulators*. *Dry regulators* are merely cylindrical air-chambers, in which a piston works air-tight, which is loaded to the pressure desired at any time. These cylinders have, of course, an inlet and an outlet pipe for the air, neither of which needs valves: the valves shown in the air-chest above the cylinder, in Fig. 2368, answer all the purpose of isolating the air in the regulator from that under the piston, on the one hand, while, on the other, the blast-pipes and tuyères are regarded but as continuations of the regulator. In fact, in every case, long and large blast-pipes (although density is lost in proportion to length) serve, in a measure, to assist in uniformity of blast. The *capacity* of these *dry regulators* should be, in theory, *twice* the capacity of the blowing-cylinder; in practice, they will answer to be *one and a half* times as large.

Water-regulators are oblong chests without a bottom, or *receivers*, let down in a tank containing water, and balanced after the manner of gasometers. The weight of the chest, and the additional load put upon it, cause it to sink; the influx of the air, and its elasticity, cause it to rise. As the air beneath the piston is under much greater pressure than in the regulator, and thus every stroke of the piston causes a slight fluctuation, the capacity of these regulators (whose minimum is the same as in the former kind) is generally governed by other considerations, and made as great as convenient. The adjutages and pipes for receiving and discharging the blast are, in practice, very much varied in position, &c.; but the general principles of their arrangement are too obvious to require description here. Very convenient and suitable in most regards, this kind of regulators is liable to all the objections accruing from access of moisture.

The second great class comprehends air-chambers of *constant capacity*. These, which long ago were built under or above ground in masonry, or for which even subterranean caverns, sedulously rendered air-tight, were resorted to, have, in the most modern times, come up again, (as in Wales,) only in a material more suitable and manageable. Sheet-iron is now most generally resorted to; strengthened, when thought necessary, with ties. Their form is generally cylindrical or spherical; one of the latter shape exists with the enormous diameter of $25\frac{1}{3}$ feet. The most convenient form appears to be that of a right cylinder, of thin sheet-iron; with a base solidly supported, and a head, either of cast-iron or sheet-iron, stiffened with wood, carrying a safety-valve, (which acts here also as an equalizer of pressure,) and admitting of an aperture, large enough for the entrance of a workman, and capable of being closed air-tight.

Of course, the larger such a chamber is, the less will it feel the pulsations of the piston; but there must be an economical limit in this respect. In practice, the regulator is made from nine to fifteen times as large as the blowing-cylinder; in theory, its least capacity, to furnish a uniform discharge, should be in the same proportion to the blowing-cylinder as the pressure of one atmosphere is to the pressure desired to be maintained. Thus, if the pressure be assumed at 2 lbs. per square inch, the regulator must be at least $\frac{15}{2}$ or $7\frac{1}{2}$ times the size of the blowing-cylinder.

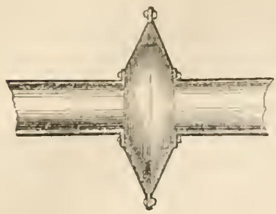
From the regulator the blast-pipes were traced, in Fig. 2365, to *the hot-air furnaces;* but the considerations belonging to these will be postponed for a moment, and the furnace considered as working (as all did, in fact, until 1827, the epoch of Mr. Neilson's improvement, and as many prefer to do still) with *cold-blast.* What remains to be spoken of in advance is the *blast-pipes* and *nozzles;* the water-tuyères, which are indispensable with hot air, and advantageous with cold-blast, have been already mentioned.

Blast-pipes are made of sheet or cast iron; for first-class furnaces, where the pressure is required to be considerable, generally of the last-named material. As they cannot be made in one piece, they are jointed either by flanges or by a muff, (what is called the *faucet and spigot* joint,) as in gas and water pipes. When cold air is employed, the packing of the joints is *lead;* with hot air, an iron cement must be used. This cement is made of 99 parts of iron filings, sifted fine, and 1 part of powdered sal ammoniac, intimately mixed, dry. When used, as much water is added as will make a stiff paste. Flowers of sulphur, sometimes recommended, in no way contributes to the efficiency of the mixture, but rather to the contrary.

The pipes are sometimes laid under ground and covered over; but this mode is not to be recommended; they should be always accessible. If hot air is ever expected to be used, provision should be made in the laying for expansion and contraction by resting them upon rollers, (short pieces of three-inch iron pipe answer very well,) on a smooth foundation. It is impossible, in the conditions of application, to avoid flexures; but these flexures should, of course, to save friction, be made as gentle as possible.

When the straight lengths are so great that there appears to be danger that the pipe will break, a

2371.



compensation-joint is inserted; this frequently consists of an end of a pipe movable in a stuffing box. The plan represented in fig. 2371 is preferable to it. This is a compensation-joint, consisting of two round dishes of sheet-iron, or copper, 20 or 30 inches in diameter, according to the size of the pipe, riveted air-tight at their periphery, and screwed to the two flanges of joining pipes. The sheet iron may be from $\frac{1}{8}$ to $\frac{3}{16}$ of an inch thick. The large diameter and flexibility of the sheet-iron allow the two pipes which are joined to it, to move longitudinally, independent of each other. Wooden blast pipes are sometimes used, but are useless where a dense blast is to be conducted.

The capacity of the pipes, *i. e.* their *diameter*, should, other things being equal, be as large as possible. But, as other things (to wit, the expense) are not equal, they should be proportioned to the quantity of blast to be delivered. A reasonable unit may be taken, in allowing a nine-inch pipe to 1000 cubic feet of blast per minute. Then, as the quantities vary with the squares of the diameters, 4000 cubic feet per minute will be accommodated by pipes of eighteen inches.

Whether the pipes are laid under or on the ground, the level of the tuyère will still be above them; two elbows, therefore, are necessary to bring the nozzle into the tuyère. The junction of these elbow-pieces should be always with a ball and socket joint for giving play to the nozzle. With cold-blast, this play can be, and frequently is, attained upon fixed elbows, by connecting the nozzle and the blast pipe proper with a leather hose or bag; with hot-blast, the leather is inadmissible.

Various forms, of more or less complexity, are used in and about the termination of the pipes for shutting off the blast entirely (as has to be done at every run-out) or partially, measuring its intensity, &c. Fig. 2372 shows one of the most simple and satisfactory. The ball and socket and fixed elbow

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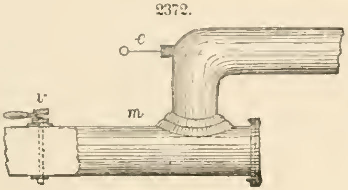

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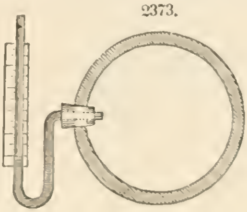


joints are both seen. At *v* is a trundle-valve of sheet-iron, elliptical in shape, with alternately bevelled edges, and worked by the winch above. When this winch is parallel with the axis of the pipe, the valve presents nothing but its thickness to the blast; when it is at right angles to the axis, it shuts up the pipe entirely, and with a tightness proportionate to the accuracy of its fitting. It can be made (so to speak) perfectly tight. Some furnace-managers have a plate-collar fastened beneath the winch, divided angularly on its circumference, and read by an index that moves with the winch, to show either the absolute or relative quantities of blast in the different positions of the winch-handle. At *c* is an *eyelet*, closed ordinarily with a conical iron plug, as shown. When this plug is out it allows the founder to look into the hearth and observe the aspect of the tuyère. With hot air, this has to be used discreetly. Between the valve and the elbow, somewhere about *m*, is placed (with cold-blast) the *manometer* or *pressure*-meter of the blast. Fig. 2373 shows a section of the pipe with the apparatus attached; which is only a glass tube, $\frac{3}{8}$ inch bore, containing a few inches of quicksilver, and open at both ends. When there is no pressure from within, as when the blowing-machine is at rest or the blast shut off, the mercury stands, of course, at the same level in the two branches of the tube; when there is pressure, the column in the long arm rises, at the rate of 1 inch in height for every $\frac{1}{4}$ lb. of pressure. The best scale to put on it is a piece of card, divided in equal parts, sliding up and down by friction, and capable at any moment, by shutting of the valve, of proper adjustment. With *hot-blast*, the manometer has to be placed in the regulator. Otherwise the actual density of the air is more accurately measured as near as possible to the *nozzle*.

These *nozzles* or adjutages are conical sheet-iron tubes, made to fit as tight as possible upon the cylindrical blast-pipe, and tapering off to an orifice from 1 to 5 inches in diameter. Furnace-managers do not generally trouble themselves much about the laws of pneumatics, and hence we find a great variety in the shape and proportions of these utensils. Several of them are provided of larger and smaller orifices, to be used as circumstances require. Ordinarily they are in two joints, of which the one fitted to the blast-pipe is the more permanent. The elliptical shape of the orifice sometimes found, is a disadvantage, as well as the great length of the cone; both lessen the discharge that would follow a shorter and more acute cone. The following table (which is strictly accurate under the conditions for which it was calculated) is sufficiently so to be relied on for giving the discharge of blast into a furnace in any case likely to occur, the pressure being that in the regulator, and the diameter of nozzle being measured at the extreme point of discharge.

A table like this is indispensable to a furnace-manager who wishes to be cognizant of what is going on in the furnace, in connection with changes, accidental or designed, in the blast. Its application in the present shape is both direct and inverse, and in either method is very simple. Thus, having ascertained the actual pressure of the blast to be, say $1\frac{1}{2}$ lbs., while we are using a nozzle of 2 inches; if we wish to know directly what is the quantity actually going into the furnace, we enter the table, under the first column, and opposite to that we find 122·61 cubic feet, which is the quantity that would pass through a 1 inch nozzle. Then, as the areas of circles are as the squares of their diameters, the quantity passing through a 2-inch nozzle will be four times as great as through a 1-inch; therefore the quantity in question will be 122·61 $\times$ 4 = 490·44 cubic feet per minute, through one tuyère. If the furnace has *two* tuyères with the same sized nozzle, the whole quantity discharged in one minute will be, then, 980·88 cubic feet. We have, then, as a general rule, to *enter the first column of the table for the given pressure, ranging with which, in the second, is a number that, multiplied by the square of the diameter of nozzle used, will give the actual quantity blown in by the single tuyère.*

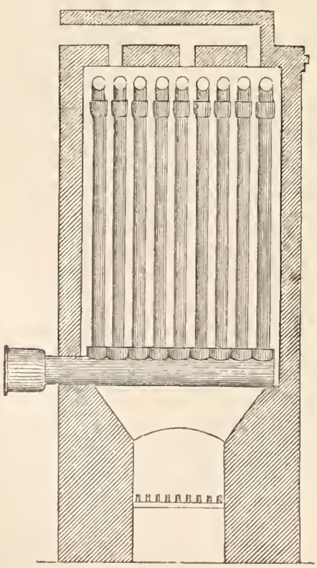
It may be applied, again, *inversely*, to find the diameter of nozzle that will discharge any required quantity per minute under a given pressure. Thus, if the question be, what diameter of nozzle will keep up a pressure of 1 lb. on a discharge of 800 cubic feet per minute through one tuyère?—we have only to divide 800 by the number (101·66) standing in the second column opposite the given pressure; the square root of the quotient $\left(\sqrt{\frac{800}{101{\cdot}66}}\right)$ or $2\frac{3}{10}$ inches is the diameter sought.

TABLE *showing the Volume and Weight of Blast discharged under various Pressures and at ordinary Temperatures.*

Pressure per square inch.	Quantity in cubic feet per minute, through a 1-inch nozzle.	Weight in lbs. per minute.	Pressure per square inch.	Quantity in cubic feet per minute, through a 1-inch nozzle.	Weight in lbs. per minute.
½ oz. av'd.	18·54	1·43	2 lbs. avd.	139·48	12.14
1 " "	26·20	2·02	2¼ "	146·86	12·97
2 " "	36·97	2·86	2½ "	153·70	13·77
4 " "	52·07	4·07	2¾ "	160·06	14·55
6 " "	63·51	5·	3 "	166·01	15·30
8 "or ½ lb.	73·04	5·80	3¼ "	171·61	16·03
10 " av'd.	81·33	6·51	3½ "	176.88	16·75
12 " "	88·74	7·16	3¾ "	181·86	17·46
14 " "	95·47	7·76	4 "	186·58	18·15
1 lb. "	101·66	8·33	4¼ "	191·07	18·83
1¼ " "	112·78	9·38	4½ "	195·35	19·50
1½ " "	122·61	10·36	4¾ "	199·43	20·17
1¾ " "	131·44	11·27	5 "	203·32	20·82

If, instead of measuring the discharge by *volume*, we have occasion to know the *weight* of the blast, the third column, treated in the same manner, gives that element.

2374.



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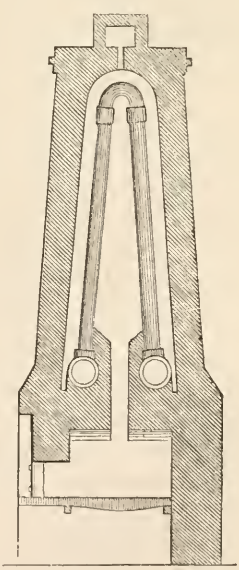


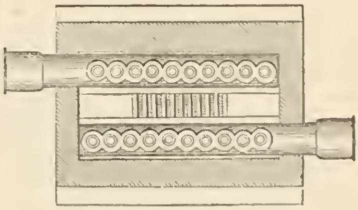
The effects of a more or less dense blast, i. e. of more or less pressure, appear to take place in two ways principally. First, *mechanically* upon the quantity of discharge in the same time; and, secondly, *chemically* upon its constitution, and upon the materials in the furnace. The air, at the instant of expiring, is of the density it had in the blast-pipe, although it very shortly afterwards assumes its normal volume. But as far as the melted materials in the hearth are concerned, it is, at the moment of entry richer in oxygen in proportion to its density. Thus, under

Pressure of	Volume of air.		Weight in oxygen.
1 lb.	100 cubic feet give		1·88 lbs.
2 "	do.	do.	2· "
3 "	do.	do.	2·12 "

By increasing the *pressure*, then, we support combustion more readily, and generate a *more intense degree* of heat. By augmenting *volume*, we support combustion more extensively, and produce a *greater quantity* of heat. These considerations apply to and solve the question often mooted among founders, as to whether the best effect is obtained by increasing *the pillar of blast*, (as they term it,) or using larger nozzles, and thus furnishing more air under a constant pressure. With fusible materials, sufficient air should be furnished under low pressure; with refractory ones, it is better to increase pressure rather than volume.

The apparatus used for *heating the blast* is very varied and multiform, the aim being in all to furnish the utmost extent of heating surface with the greatest economy. Instead of mentioning all the modifications that have been suggested, or figuring the contortions that hot-air pipes have been made to exhibit, Figs. 2374 and 2375 give vertical sections, transverse and longitudinal, and Fig. 2376 a horizontal section of the most convenient and best arrangement, either for separate furnaces near the tuyères, or for ovens on the trundle-head. In the latter case, the horizontal flue shown in Fig. 2376 (which communicates with a vertical one in the stack itself, or back-wall) is replaced by a short chimney. So far as outlay is concerned, to heat the air at the trundle-head is the cheapest, for there is no extra fuel required. But to realize all the benefits of the system and the greatest absolute economy, separate furnaces below are much preferable.

2376.



For the *dimensions* to be given, in either case, iron-masters are yet without any rule, not so much from any difficulty in investigating the principles that should govern, as from want of actual experimental knowledge on the rate of cooling, &c., which prevents any general formula from being applied. Calculations made upon the quantities and velocities of blast under pressures between the ordinary limits, (of 1¼ to 2½ pounds per square inch,) result in 18 and 28 square inches respectively of heating surface for every cubic foot of air per minute. The mean of these, or the 1-6th of a square foot, may be taken as a safe allowance (if the pressure does not exceed 2½ pounds) for raising the temperature of the air, at the instant of leaving the oven, to *half* that of the pipes. What will be its temperature at the nozzle depends upon the distance it has to go, the thickness and size of pipes, &c. With a higher pressure than 2½ pounds, the heating surface ought to be enlarged directly in proportion, at least; for in the very fact of being heated the air acquires a great increase of velocity, and therefore is exposed so much shorter time in the heated pipes.

There are a number of interesting points, chemical and mechanical, in the employment of hot-blast, for which there is no room here. All that can be said is, that, in general, with hot-blast the furnace works easier, carries a greater burden, with, of course, a higher yield, and reduces materials too refractory for cold air. A notable economy of *fuel* and *flux* follows. With regard to the former, the saving of fuel, upon an extensive comparison of results, may be stated for

Coke-furnaces	at 32 per cent.,	from an average	temperature of		330° F.
Charcoal	do. 20	do.	do.	do.	390° F.

Besides this, certain *raw* coals that would not be admissible with cold-blast, are capable of being used with hot.

As to the *quality* of metal made, it is generally *gray foundry-iron*, with a more uniformly cubic crystalline form than cold-blast foundry. There is a general prejudice against it, as being less strong, but this opinion is more exaggerated than actual experiments warrant. The following table shows the proportionate strength in various aspects, from numerous trials:—

	Resistance to				
	Stretching strain.	Crushing strain.	Transverse or oblique strains.	Impact.	Stiffness.
Cold-blast iron	1000	1000	1000	1000	1000
Hot-blast iron	913	1033	963	1005	935

These statements upon the quality of metal lead naturally to the next class of considerations, which must be taken up, viz., upon the *products* of the blast-furnace.

These *products* are, like the materials, both solid and gaseous. To the former belong the crude iron and the *furnace-cinder*, as the melted slag of earthy matters is termed; to the other the various elementary and compound gases which arise from combustion and decomposition, and pass off at the trundle-head.

The first solid product, the crude iron, has been already sufficiently treated of; the other, the *cinder*, is reciprocal with it, and is one of the important tests which the founder has in judging of the progress of his work and of the issue that he may reasonably expect.

Furnace-cinder, chemically, is chiefly a *silicate of lime* in various proportions. In charcoal works it is a bisilicate, in coke furnaces a single silicate. This appears from the following statement, which represents the average of good cinder, i. e., when the furnace is doing good work:—

	Charcoal cinder.	Coke cinder.
Silica	53	43
Lime	22	35
Alumina	16	14
Magnesia	5	4
Protoxide of iron	4	4

The charcoal cinder is, in its proportions, a more fusible compound than the other; but abstract *fusibility* is not so much to be considered as *fusibility at the temperature employed.* Coke-furnaces, having a higher temperature, require a more refractory material, in order that the cinder may answer its proper uses.

These *uses*, in general, are to assist in fusion and reduction; with very fusible ores, to retard fusion until the deoxidation of the metal has occurred; and after reduction, to protect the metal in the hearth from contact with the blast. In this last aspect, especially, the *degree of fusibility* of the cinder is of great practical importance. If it be too thick and pasty, it embarrasses the separation of the metal; if it be too thin and liquid, the iron is exposed naked to the blast. These properties, as they may exist within the furnace, are judged of by the *consistency* of the cinder during its flow. If liquid enough to flow readily over the dam-plate, and *slowly cooling* afterwards, it is of the proper character; but whatever its liquidity may be, if it tends to cool *rapidly*, the presence of metallic associations is to be inferred. Such association, as far as iron is concerned, may be inferred also from its *color*, which, with an admixture of iron in notable proportions, is always brownish or black. The most satisfactory color for the mass, on a fresh fracture, is whitish gray. Blue and bluish-green shades and streaks are almost always to be met with. The proper way to judge of color, however, is only upon a pulverized specimen. The *fracture* of cinder is always conchoidal, and its specific gravity, at a mean, 2·6. The aspect of good cinder, from charcoal works, is *glassy;* from coke-furnaces, it is more *lithoid*, or stone-like. When cinder becomes *earthy*-looking, it argues deficiency of heat; and if the furnace on the preceding cast has given gray iron, more blast may be put on without fear,—if white iron, the blast should be augmented cautiously. A *cavernous* or honeycombed cinder appears to originate in the same defect of heat; while one like *enamel*, although by many founders attributed to the same cause, arises more from elements in the materials—chiefly *phosphate of lime.*

The *gaseous products* of the furnace may be taken to consist, on an average, of

Nitrogen	56	Carburetted hydrogen	2
Carbonic acid	19	Vapor of water	7
Carbonic oxide	16		

The watery vapor most likely arises from the moisture of the materials freshly put in, and is, therefore, hardly a *product.* If the fuel had all been fully consumed, the sole products would be nitrogen and carbonic acid. But this full combustion has not been, and, with the methods followed, cannot be attained.

These gases, as they are, pass off at the trundle-head at a high temperature; so high, that the oxy and hydro carbon combine there with the oxygen of the atmosphere and inflame. This flame furnishes, among other things, a sign to the founder of the state of the furnace. If it is small and weak, it is presumable that the blast does not pass through sufficiently; and the materials, which from the moment of charging ought to be undergoing a preparation for fusion, are in fact descending more or less raw. The remedy for this is not always to increase the blast; on the contrary, a discreet founder will first take into consideration the nature of the materials, their friability, and liability to become *packed* in the cuvette. Too little slope to the boshes, too, is always more or less involved in the result, where the materials are constant.

If the flame is, as sometimes, on one side, it is a sign that the charges are not descending equally. If this is permanent, there is reason to suppose that the in-walls or boshes, or both, have degraded out of shape. If occasional, it is rather to be attributed to an accidental choking of the furnace, caused either by a bad state of materials, or, what is more common, bad filling. Of course, the flaring from atmospheric causes must not be confounded with this phenomenon. In a well-going furnace and a calm atmosphere the flame should rise cylindrically, with life, and with a certain whistling cry the founder likes to hear.

A *flame at the tymp* is a sign that the blast is not going in the right direction; in this case, it is better to alter the charges, by putting on less mine, than to change the blast.

The high temperature at which the gases pass off at the trundle-head is an unavoidable consequence of the process; it is, nevertheless, *waste-heat.* This waste-heat has been turned to account, as already mentioned, in the case of *hot-blast.* It has also been used for burning lime, for carbonizing wood, for coking, and for generating steam. For all these purposes, except the first and last, it is rarely convenient to apply the inflamed gases; and as, in leading off to a distance what is only inflammable air there is more or less loss of heat, these applications have been limited. For roasting ores, it is a perfectly appropriate means.

M. Faber du Faure, as far back as 1837, conceived and very ingeniously executed a very brilliant idea of leading off the gases, without contact of air at first, to suitable points where, by mixing it with highly heated atmospheric air, it could be burnt, and the heat thus produced applied not only to the generation of steam, but also to other processes (refining, puddling, and reheating) in the manufacture of the crude iron yielded from the blast-furnace. The progress of his experiments led to investigations upon the actual constitution of the gases at different points of the stack; and to the conclusion that the oxide of carbon existed as a maximum at a level below the trundle-head, about one-third of the height of the stack. About this level, therefore, one or more flues are made in the stack, through which the gas ascends into a reservoir around the trundle-head, whence conduits of masonry or metal take it off into an air-chest; from which, after mixture with a hot-blast, it issues through a suitable number of nozzles or burners into the hearth where it is destined to be burned.

This discovery and application excited a good deal of attention shortly after it was made public—in this country, about 1840, and large expectations were formed as to the revolution it was destined to cause in the manufacture of iron. But, either from some intrinsic difficulties, not at first apparent, or from bad management, its subsequent development has not been so extensive.

Faber's method, if confined to gases existing at or very near the trundle-head, would be perfectly unexceptionable; when, however, they are drawn too low down from the body of the materials, there is reason to apprehend that the train of the furnace will be disadvantageously embarrassed. At least, such seems to be the conclusion of those most practically conversant with smelting. This *train* is, as we know, very easily, and sometimes unaccountably, deranged; and there are few processes in the arts, where large masses are in action at once, so liable to the influence of apparently slight causes, and so much under the domain of what may be called the *working*. Before leaving the subject of smelting, then, some particulars must be mentioned in regard to the *working of the furnace*.

For working a single coke-furnace of the first class, the following statement may be taken of the hands usually found necessary, with their respective occupations: viz., *two* keepers, who take turn and turn about, every twelve hours, in the tymp-arch and below; two fillers, who are engaged in a similar manner about the trundle-head and top-house above, each with a boy to help; two cinder-fillers, in turn, to clear away cinder below; one cinder-hauler; one engineer and helper at the blast-engine; one weigher of pigs: all these (together, 9 men and 3 boys) are engaged, day and night, in and about the stack. Besides these, for ore-roasting are required one man and two boys; for coking, two men and eight boys; for breaking limestone, two boys; for hauling material from the yard, (which is done on a rail-track,) a man, a boy, and a horse. These 4 men and 13 boys are occupied in the yards adjacent, where, and about the stack, &c., there is always miscellaneous work enough for four laboring hands by day. This enumeration excludes the furnace-manager or founder, and underground agent; for the first can superintend the smelting, as the other can the mining, for several furnaces as well as for one.

Of course, where the furnace is smaller, as it is where charcoal is the fuel, there is not so much work to be done, and, in proportion, fewer hands can do it; where wages are high, more work might perhaps be got out of each hand, or it may be satisfactory if done in a less perfect manner; but the statement above is from establishments where ultimate economy has been a principal object.

None of the work that has been mentioned can advantageously be done by *contract;* the fuel and mine should always be prepared under the supervision of the furnace-manager. But a plan used in all large works to a greater or less extent, is to have a tariff of wages for all the hands named; which is rated and paid per ton of metal made, according to its quality. It becomes, thus, the direct interest of all hands that the furnace should yield the most possible of the best iron.

The number of hands given above may seem large, but in reality, there is a good deal of work to be done, and that of a sort at intervals so hard, and under such variations of temperature, that workmen about furnaces are generally short-lived. Thus, the duty of the keeper, for instance, besides moulding the pig-bed, which is done at spare times, and watching the tuyères, &c., which is a frequent duty, is to do the heavy work sometimes required for breaking into the furnace either at the fore-hearth or at the tuyères, putting in grates, &c. These, which are extraordinary demands, are done under the direction of the founder; who also himself bears a hand when necessary, or calls down the filler too. The *tapping*, which, when the furnace is in regular train, occurs twice in the twenty-four hours, (and, from old habit, at 6 A. M. and 6 P. M.,) is generally done by the founder, except in extensive works of several furnaces.

As a general principle, a furnace works best when most let alone; care having been taken in the selection and proportion of the materials and blast. But, in the best managed, accidents will not unfrequently happen, the repairing of which is a serious task upon the physical energies of the workmen.

The *filler*, with less demand upon his reasoning faculties, has not less labor to perform; and its proper execution is one of the most important items about the furnace. Upon regular and suitable filling depends more than is often supposed. Various methods have been proposed and tried, in this respect, to promote a mechanical accuracy; some very plausible, but none unexceptionable. The old, and most habitual method, is to fill by hand; the fuel, if coke, being upset from two wheelbarrows—if charcoal, thrown in from baskets. Ore and flux are generally filled from sheet-iron trays. Later, a more judicious practice has grown up of *weighing* all charges instead of *measuring*, for which the barrows, baskets, &c., served. Sometimes, after being weighed, the materials are kept separate; sometimes they are mixed and charged together. This last, if well done, is undoubtedly the best.

When furnaces are built on a plane, with the yards around their base, the labor of the filler is sometimes much increased. With such furnaces there is often an inclined plane, along which a separate engine generally winds up the trucks containing the charges; or the blast-engine is geered for the same purpose. In both cases, the different diameters of the fore and hind wheels keep the platform of the truck horizontal. The filler takes passage along with his freight. Sometimes a vertically elevating machinery is employed; as the equilibratro water system of Staffordshire, where the counterpoise to the charges ascending is a bucket filled, *pro hac vice*, with water, and discharging itself when it strikes the ground. Empty, it is overbalanced by the platform for the baskets; which, upon being cast off, again descend to be filled, &c.

The number of charges per turn, of twelve hours, varies with the work that the furnace is doing from 20 to 48. As soon as made, each one is scored by the filler upon a board for the inspection of the founder; who thus sees at a glance what the furnace is bearing, and can direct accordingly.

The business of keeping the tymp-arch clear of cinder is, with a first-class coke furnace, no little occupation of itself. It is dragged off with long hooks, in large masses, to a suitable place in the moulding house; where, if necessary, it is quenched and broken up in order to being loaded on a cart. Mixed with broken stone, or even by itself, it forms one of the best materials known for road metal.

The breaking off, weighing, and piling the pigs, sows, and runners, (as the different moulds in a pig bed are called,) is another task in a large furnace. The number of pieces in a day will amount to about 400, from 50 to 60 lbs. each.

The moulding, &c., of castings, which are not unfrequently made at the blast-furnace, belong more properly to the next division of the subject, that of *founding*.

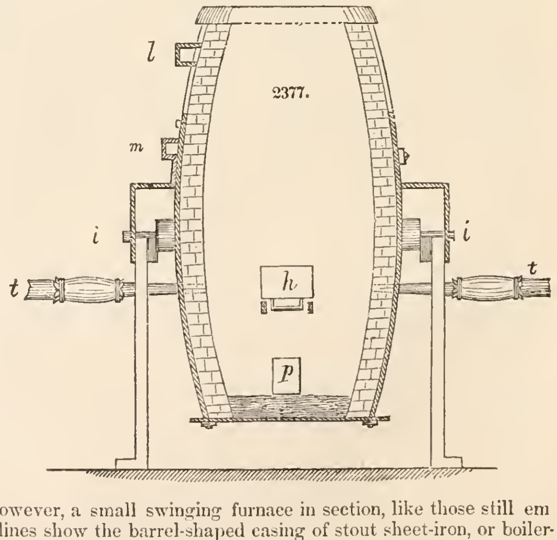
II. *Founding*, or casting crude iron in fusion into hollow moulds, no doubt followed, historically, the working of the metal in a more or less malleable state; but, in the chronological sequence of processes, it comes, as here, directly after the production of the crude iron itself. Indeed, for some objects, this crude iron answers very well itself, without a second fusion; but, in the general business of casting particular qualities of metal are required for particular objects, and certain characters are attainable only by a mixture of different sorts of metal at once. It is obvious that these conditions are not attained with a single or even several blast-furnaces. Further, in the casting, care has to be taken to have the metal entering the moulds of a suitable temperature; this would be more difficult in metal that is *run out*, as generally it has to be, from blast-furnaces, than in that which is first received in a ladle, where it is kept till of a supposed suitable temperature to be poured. Finally, it is often necessary (as for blowing-cylinders, &c.) to have a greater weight of metal than the hearth of even a large blast-furnace contains; resort must be had, in such case, to several separate furnaces, whose united contents may suffice. But wherever *rough* castings, as they may be termed, viz., tram-rails, railroad chairs, hollow-ware, &c., are to be made in quantity, where the shape and dimensions of the moulds will allow uniform cooling, and where the highest quality of metal need not be possessed, or at least such quality as is attained by mixtures, it is the best economy to put the blast-furnace upon a proper train for the purpose, and to cast at once, either by run-outs or pourings, from it.

There are general principles about moulding and casting which govern in all metals and alloys. These should have come under a special article, Founding; but, in default of that, will be found under Metallurgy. All that will be given here, will be such principles, precautions, and practice, as belong particularly to iron-founding.

In general, the metal suitable for castings is *gray* crude iron; for certain cases where the surface is of no great consequence, (i. e., the perfection of the casting,) and where the resistance is to a crushing force, *white* iron may be used. The effect of a remelting is to consume the carbon, both free and combined, to a greater or less degree; and the aim is to produce a metal which shall contain the least quantity of free carbon, and at the same time retain the octahedral crystalline structure that characterizes gray iron. This structure, other things being the same, appears to be chiefly affected by the capacity of the metal for heat, its radiation, and the circumstances under which it cools.

Iron may be melted either, 1st, in *crucibles* or *pots;* 2d, in cupolas; or, 3d, in reverberatory furnaces. The first are made of sand, as the Hessian crucibles, or of black-lead, like the blue-pots of commerce. They are of various size; but the largest will not hold more than 35 lbs., beyond which they become unmanageable. They are set upon some refractory stand or shelf, in a suitable oven. Not in contact with air directly, the loss in remelting ought not to be more than five per cent. In fact, however, it is much greater; and experience seems to dictate, as the best economy, rather to burn away a portion of the iron than to use a vitrifiable flux. Where the temperature is not at command, it is better to use a flux, both as an economy of fuel and of metal. It is obvious that the application of this method is limited to small articles. The advantage of it, in such cases, is the beauty and finish of surface it affords.

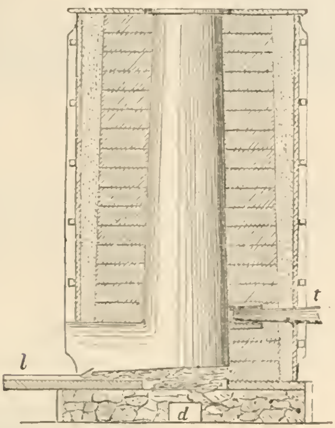
In the second method, that of *cupolas*, the metal is in contact with air, fuel, and flux. There is, therefore, both a greater loss and an inferior result. This loss may be rated, on the average, at 8 per cent. The introduction of cupolas followed upon the use of the pots; and they have grown from the little portable furnaces of France (about the year 1700)—say two feet in height, in parts—into miniature blast-furnaces, 10 and even 15 feet in height. To show that this is no limit in economy, although it is, perhaps, in the labor, may be adduced a case in Prussia, some years ago, where a blast-furnace 34 feet high, which worked in hollow-ware, had become so encumbered with scraps, that it became a serious matter to disembarrass the establishment. For this, they built inside of the stack somewhat in section like a fluss-ofen before described, narrowing it to 22 inches at the trundle-head; 4 feet at the boshes, which received a slope of 45°; with a hearth 15 inches in diameter at top, and twelve inches below. With this was remelted, in 21 weeks, very nearly 240 tons of metal; the fuel (charcoal) was 34 per cent. of the yield, and the loss of metal was 8 per cent.



The little furnaces of 1½ to 2½ feet are, except for special purposes, very much out of use. Fig. 2377 shows, however, a small swinging furnace in section, like those still employed in Sweden. The dark parallel lines show the barrel-shaped casing of stout sheet-iron, or boiler-plate, inside of which the fire-brick are laid. The whole concern rests, and can be made to swing, on its journals, *i i*, which work in an appropriate gallows-frame, seen below At *l m* are staples, in which iron levers can be thrust to tilt the furnace over and pour through the tap-hole *h*, which is furnished with projections on which a clay *lip*, or runner, can be moulded. This tilting is still further helped by placing the centre of motion an inch or two below the centre of gravity when the hearth is full. The ash-hole, for cleaning out, is shown at *p*, and *t t* represent the two tuyères used. Over the throat is fixed a hood, or mantle, connected with a chimney-flue. These cupolas are about 8 feet high; the tuyere, from 14 to 16 inches above the hearth, which, as shown, is made of fire-clay, well packed and beaten on the iron bottom. The diameter at the bottom is 18 inches; across at the tuyères, 30 inches; at the throat, about 2 feet: on the average containing about 1000 lbs. of metal.

Figs. 2378 and 2379 show a section and ground-plan of a neat and convenient form of cupola. The exterior is of cast-iron plates, with flanges that bolt together; the in-walls of fire-brick; the space between the casing and in-walls filled with coke, dust, or ashes. The bottom is an annular plate, upon

2378.



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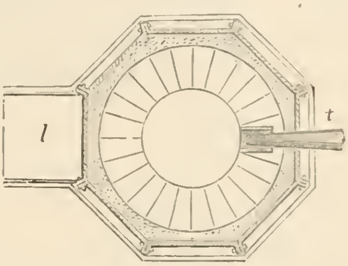


foundation of masonry, which should be well drained, as shown at *d*. The hearth itself is made of fire-clay, sloping outwards to the lip in order to make a clean run-out. The height of such a cupola is from 8 to 10 feet; the *tymp*, as it may be called, (i. e., the *tap*,) is 12 by 16 inches high. (This is made large purposely, in order to get at the hearth for cleaning it, and, when the cupola is working, is stopped up.) The tuyere can be varied from 16 to 20 inches above the hearth.

The hearth in this figure is represented as very large—the object being to save metal and repairs, rather than fuel. In general, a narrow hearth saves fuel; but it is at the expense of metals oxidated and in-walls worn. The comparison for ultimate economy must be made in each case; and the result will differ according to the locality. Where fuel is dear, the hearth may be narrowed to advantage.

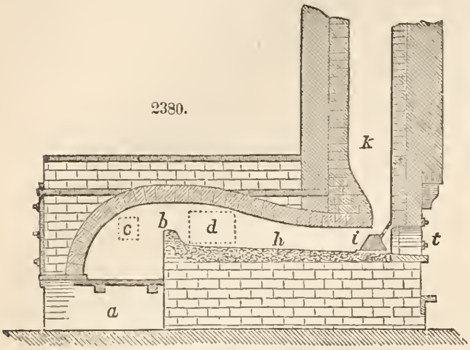
The internal shape of cupolas does not appear to have been much studied, if one may judge from their variety. These rules, however, may be safely taken; that, with charcoal, the height should be greater than with coke, on account of the greater friability of the material, and the greater tendency of the crude iron to descend too soon. A cupola for coke ought not to be less than 6 feet in any case; nor, with charcoal, less than 9 feet. The English cupolas for coke are ordinarily 8 feet high, and about 3 feet wide, holding between 3 and 4 tons. The best form for economy is that of a small blast-furnace, proportioned as for refractory materials.

According to the size, the quantity of blast, under a mean pressure of $1\frac{1}{2}$ lbs., will be from 250 to 550 cubic feet per minute. The fuel consumed under a good train will be, with the best coke, about 30 per cent.; with coke of inferior quality, 50 per cent.; and with charcoal, 75 per cent. of the yield, which, in the best cupolas, is about one ton per hour. If the pigs are not very clean, no flux need be used; if scraps are to be worked up, limestone (chalk is preferred in England) or oyster-shells must be added in small quantities. If the average loss of metal, in remelting, is more than 8 per cent., it must generally be attributed to some error in the building, or in the management.

When a cupola is connected with a high-furnace, the blast is generally taken off from the blowing-engine. Otherwise, the fan-blast, already described, is the most convenient. It is also well, in cupolas for large work, to have three or four tuyere holes at different elevations, to which the nozzles can be successively applied as the hearth fills.

The third method of remelting is by *reverberatory* furnaces, where the metal, not in contact with fuel, is fused by the heat of the flame that, from the peculiar shape of the roof, is reflected and *reverberated* down upon the bottom, or sole. With a reverberatory furnace proper, there is no blast or impulsion of air—it is all *aspiration*—and the necessary draught is created by the height of the chimney. Figs. 2380 and 2381 show a vertical and horizontal section of one of the best forms of reverberatory furnaces; in which *a* indicates the ash-pit, with the grate-bars over it; *c c* the charging door for fuel; *b b* the bridge dividing the fuel from the metal to be melted; *d d* the charging-door for the metal; (both *c* and *d* are balance-doors, that slide vertically, shut tightly, and, when the fire is to be most intensely urged, must be luted;) *h h* the hearth, or sole, on the upper part of which, near the bridge, the metal is charged, and along whose inclined surface it, when melted, runs; *i i* the dam, whose function is as well to narrow the chimney throat, as to retain the fused metal; *k* the chimney; and *t t* the tap, where the metal is run out through the dam, and which is stopped with clay till needed. This tap is sometimes placed in the side, but disadvantageously. The inner parts of this furnace and chimney are built with fire-brick; the sole, which needs frequent repair, laid of fire-clay, resting either on massive or arched

2380.



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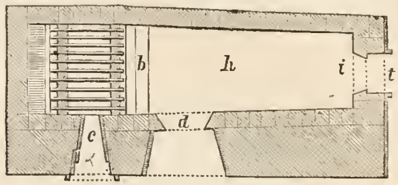
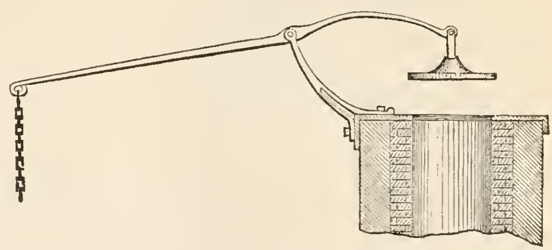


masonry, or on castings; the external parts of common brick, well tied with iron bolts and plates; the chimney, which, in the figure, is represented fragmentary, should be, at a minimum, 40 feet in height, and is terminated with a damper, as shown in Fig. 2382. The flue in this figure appears cylindrical, which is the best for the draught, although it is generally made square. In no case ought its section to be less than a square foot. The damper, which is worked with a light chain or wire, as shown, should always be provided with a register-scale below, calculated for different degrees of opening and draught.

2382.



The dimensions of such furnaces are at discretion: some hold hardly a ton, others three and four tons. But the *proportions* of the principal parts—viz., the fire-grate, the hearth, and the chimney—must be subject to the laws of Pneumatics and Heat, and are, therefore, not arbitrary. The following rules, which are far from having the generality and exactitude that would flow from a fully explored theory, may be taken as in accordance with the best practice:

1. The higher the chimney, the better and more manageable the draught, other things being equal. If the section of the chimney be too narrow, the draught will be choked; if too wide, it will be weakened. When one stack is built for several furnaces, each one, then, should have its separate flue.

2. The sections, respectively, of the narrowest part of the throat (about *i*, Fig. 2380) and the widest part of the shaft, (near *k*,) may vary between the limits of 2½ : 1 and 3 : 1. This variation can be made from time to time, according to the nature of the fuel and of the metal to be melted, by packing more or less sand upon the dam.

3. With a given capacity of hearth and given fuel, the areas of the throat and fire-grate must be in constant proportion. This is easily ascertained by observing how the furnace works. If fusion takes place the soonest near the *bridge*, it may certainly be concluded that the area of the throat is too small; if fusion occurs sooner near the *dam*, the throat is too large. The numerical ratio will vary according to the strength of the coal and the length of the hearth: it may be assumed, as a mean, that the aggregate of the open spaces between the bars should be 3½ times the area of the throat.

4. The absolute capacity of the furnace is, of course, determined in advance by the work it is intended to do. Its relative capacity should be such as that it goes on continually contracting itself the further from the grate; so that there should be an equal degree and quantity of heat in every part.

5. The length and width of the hearth, two of the elements of the capacity, should vary according to the fuel. On an average, the length may be *twice* the width. With coal that gives much flame, it may be 2½ times the width; with a dry coal, and especially anthracite, it should not be more than 1½ times the width.

6. The area of the hearth should not be more than 3½ times the area of the grate, bars and all.

7. The height and width of the hearth should be such as that a vertical section through its widest part, near the bridge, should be ¾ the horizontal section of the grate.

8. The slope of the hearth need not be more than ⅓ inch to the foot, which allows the iron to run out freely. If the inclination be great, there is no chance for yet solid fragments to be soaked (as it were) in already melted metal, and thus be facilitated in their fusion; while there is also a greater liability to decarbonization, and consequent formation of *carcase*.

9. The height of the bridge above the hearth depends upon the fusibility of the iron to be melted. If easily fusible, it may be from 8 to 10 inches in height; if refractory, not more than 4 or 5 inches.

10. The section of the grate has been given already in terms of the other parts. The space between

the bars may vary from 0·5 to 0·75 inch, according to the size of coal. The depth of ash-pit may be lessened in proportion to the inflammability of the coal; but it should always be considerable enough to avoid having the air heated by transmission over fallen cinders and ashes.

Theoretically, it would hardly appear that a large reverberatory furnace should give a less intense heat than a small one; practically, however, this is found to be the case, which may arise from this—that in proportioning the size of chimney, beyond a certain limit there occurs the phenomenon of ascending and descending currents.

The foregoing rules apply to furnaces worked with *coal*, which is by far the most economical fuel for these arrangements. When wood is used, which contains less carbon and more oxygen, there has to be a material alteration in the proportions. In a successful example, the area of the grate was two-thirds that of the hearth, four times the widest section beyond the bridge, and ten times that of the throat.

Every time iron is fused it becomes more refractory, especially after reverberatory fusion. Metal of the first and second fusion should not, therefore, be mixed together; and, as far as possible, only those of the same or nearly equal fusibility. So also the fragments ought to be of the same size. If any difference is allowed, then the larger pieces ought to be charged nearest the bridge.

In charging, it is well to get the heat of the furnace well up first, and afterwards the aim should be to raise it to the full height as quickly as possible. A low temperature is only at the expense of fuel and metal. After the iron is liquefied, every care must be taken to keep out cold air; the fuel must be charged quickly, frequently, and in quantities that will just maintain a continued and active combustion. If too much is thrown on at once, the temperature fluctuates; if too little, it falls. From one-half to three-quarters of a bushel of coal, every ten minutes, will keep a grate of average size (say nine square feet) sufficiently supplied. The best test is the flame at the top of the chimney: if it does not appear there, even with a chimney of sixty feet, there is a waste of metal; if, on the contrary, it shoots out much above, there is a waste of fuel.

The average *consumption* of coal is about 60 per cent. of the yield; the waste of metal about 7 per cent., with a good train. The average effect, under equal volumes of coal to wood, is very nearly seven to one. Upon the experience in Russia, it takes, by weight, of seasoned wood, 150 per cent. upon the yield.

The *time* taken to melt down a charge is very variable, according to the fusibility of the metal, the strength of the coal, the proportions of the furnace, and the management. The average power of fusion may be rated as equivalent to one ton per hour, and the furnace can be tapped, according to circumstances, (size, &c.,) every two to four hours.

If the scope and practical appliance of these three methods of founding be compared, it may be said that,

1. The employment of crucibles, very costly in materials, though not in construction, is limited to small objects, whose price bears no comparison to the weight of metal out of which they are made.

2. Cupolas, which are rather the most expensive in construction and maintenance, are yet worked more regularly with a less proportionate expense for wages, and are the most universally applicable for all objects of ordinary demand; and,

3. Reverberatory furnaces are especially required for castings of the heaviest sort, where the maximum resistance of the metal is demanded.

In all, the same general principles apply in the management of the metal before and after fusion. Thus, the *mixture* or charge of different kinds of crude iron is a point of great importance, both as regards fusibility, and the properties of the cast-iron run out. Castings will hardly ever be made from one sort of pig only; at least two, and often six or eight sorts are charged together. This is a matter dependent upon the practical experience and judgment of the founder, for which no written rules serve.

So also the *pouring* of the iron, or conveying the melted metal to the flasks, is independent of the kind of furnace in which it may have been fused, and is determined by the quantity required to be poured at once, and the character of the casting, whether it is to be *open*, or in *close* moulds. Very large objects, with plane surfaces, (such as girders, plates, &c.,) are generally cast open in sand-moulds, and the metal runs through a gutter (frequently itself of iron) lined with sand, after the same fashion with the sow and pig casts from the high-furnace. But when the surfaces are curved or re-entering, (as cylinders, &c.,) it is best to pour from ladles. These ladles vary in size, and, of course, in management, according to their purpose. A hand-ladle, which is wielded by one man, will contain from 50 to 60 pounds; a double hand-ladle, or *shank*, managed by three or four men, carries from 200 to 400 pounds; ladles holding four or five tons travel in a crane. The handles or pivots of all these are placed a little above the centre of gravity of the ladle when charged, so that they may be easily tilted. With the smaller ladles, accidents, either to the workmen or the contents, are rare; the largest are now so improved with tangent-screws, worm-wheels, and skimmers, as to render their management even easier than that of the smaller ones.

The whole business of making patterns and moulds is the same in principle for all metals, and belongs to the article Moulding. Only such particulars will be summarily mentioned here in which the casting of iron differs more or less from the founding of other metals.

The *patterns* for iron castings, besides being made so as to draw readily from the mould, are made larger than the intended casting, by an average scale of ⅛th inch per foot. This is to allow for the contraction of the metal in cooling. In strictness, every particular mixture has its own proportionate contraction, and when a foundry is running upon the same mixture and article, the pattern is dressed to suit; but the proportion which is given is the one generally adopted. The pattern maker, in getting the proportion, simply uses a *contraction rule*, whose divisions of feet and inches are everywhere 1-96th longer than the true measurement. In this way he works directly from the measurements given, without any trouble of calculation. In making a pattern of wood from which to cast an iron pattern, to be used afterwards, a double shrinkage is to be allowed for, and a double contraction rule, with divisions 1-48th in excess everywhere, is employed.

Patterns for iron-castings require to be more carefully designed as to symmetry and equality of parts, and distribution of material, than for any other metal, partly because of the heavier stress upon the objects in use, and partly because of the peculiar behavior of the metal itself in cooling. It is easy tc see that a small external stress, coming upon a material already strained by its own shrinkage, will cause it to give way. Inattention to these considerations is the frequent cause of breakages in the wheels for railroad cars. In planning a pattern other than for simple prismatic figures, regard should always be paid as to which parts are to endure extension, and which compression. The latter may be made thin, and be allowed to chill; but the parts to resist extension should be, as far as possible, compressed in the mould, and escape chilling. For instance, a T-shaped cast-iron joint is a bad shape at best for strength, but its resistance is still less when the vertical leg is downwards. In general, patterns for castings, if at all complicated, should be regarded as systems of *framing;* and in combining the several parts, it should be remembered that the strength of the whole can never exceed the weakness of the weakest part.

In taking impressions from these patterns, or *moulding* the object desired to be produced in metal, the processes are the same for iron as for other metals, regard being had to the heavier masses required of the former, and also to its different affection by heat. In this last particular, moulds for cast-iron need not be so dry as for other metals. The sand employed is also coarser, and less adhesive. Sand for partings in the mould is generally that which is scraped off from former castings, and which, having been once exposed to a full red-heat, and mechanically triturated in the rough processes of scraping, has become less sharp. The best facing-sand is charcoal and coal-dust in equal parts, ground fine, and intimately mixed. For small articles of luxury, the best facing is graphite.

Cores, which are prismatic or cylindrical pieces inserted in the mould, to produce the *holes* and openings in the casting, and in general intercept the flow of the metal, may be made of any material which does not alter its shape or volume materially when exposed to heat. The best for iron-castings are made of sand, horse-dung, and a little loam. After being shaped they are dried, and then put in a crucible and burned for ten or twelve hours, in order to consume all the vegetable matter, and leave them in a proper porous condition, both for their own permanence, and also the escape of air.

Castings of ordinary objects are made in iron moulds or in sand; very heavy objects, such as cylinders, &c., are moulded in loam. Of the use of *iron moulds,* the running of bullets is a familiar, but perhaps the best illustration, though it is ordinarily exemplified with other metal than iron. This kind of mould is applied advantageously to the casting of heavy shot and shells, (which will be treated of more particularly under the title PROJECTILES,) to tram-plates and chairs for railway bars, and to railway wheels. In these last the outer rim only is often made of iron, and the nave and spokes cast in sand upon an iron-core, the object here being chiefly to chill the tire of the wheel. Another object, *ploughshares,* are advantageously cast in iron moulds, so also are cylinders for rolling metal, forge-hammers, ore-stampers, &c., and in general all objects which have a sufficient mass of matter to resist impact or compression, and require in use the hardest and least wearing surface.

Sand-mouldings (we do not speak here of those objects, plates, joists, &c., which may be run *open*) are made in *flasks,* which, for iron-founders' use, are best made themselves of iron, but in other respects like the wooden ones used in foundries generally. The bottom flask or *drag* has generally plain, flat cross-ribs, to serve instead of a bottom-board; the top flask has deep cross-ribs cutting it up into compartments five or six inches wide and twenty to thirty inches long, with little fillets on their sides to lock in the sand more effectually; middle flasks have no such compartments at all. Of these middle flasks the iron-founder makes frequent use. They constitute the three or four part flasks, which are much more convenient for many objects than two-part flasks only, which might have to be of excessive depth. The *cottering,* or fastening these parts together, is easily effected by transverse wedges in the steady-pins of the flasks, and the internal mass of sand is retained firmly, or *gagged,* by means of *lifters,* or T-shaped pieces of iron, with wedge-shaped tail, and set head downwards. These *gaggers* are placed in various parts of the flask, according to the objects to be moulded, and the discretion of the founder.

The following figures, showing the pattern and mould for the top of a sliding-rest for a lathe, will illustrate the application of a three-part flask.

The pattern, Fig. 2383, might be moulded in a two-part flask of sufficient depth by making the parting along the dotted line *a a*; and indeed there are several ways in which it might be cast, but the one shown will be seen to be the most convenient. The chamfer at *c* might also be cast, either by moulding square at first, and then filling in sand and working it to a gage, or by means of a core whose print is shown in the dotted lines terminating at *b*; but the most usual and the best way is to

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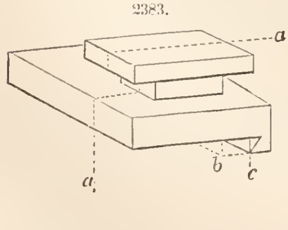

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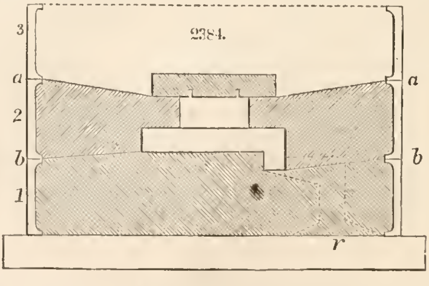

cast it square, and plane it to the required bevel afterwards. That being the case, Fig. 2384 shows the flasks 1, 2, 3, after they are put together. In working them, 1 and 2 are first set, nearly filled with sand, and the pattern knocked in as shown, the whole well rammed, and the parting made along *a a*. The flask 3 is then added, filled and rammed, levelled, covered with a board, and all three turned over, so that 1 becomes the top, which is now taken off, a parting made along the line *b b*, and the runner-stick put in to make the runner or in-gate, as shown by the dotted lines near *r*. To prepare for casting the runner-stick is taken out, flask 1 is lifted off, and the part of the pattern (shown white) is taken out from the middle flask; the middle flask is then removed, and the shaded part of the pattern (which has been fitted by pins or lugs, as shown) is taken out from flask 3 or the *drag*. The flasks are then united, and the pouring made through *r*. It is manifest that the same system would be pursued with a flask having a greater number of parts.

The iron-founder has, from the vast variety of works which he is called on to execute, greater occasion than others to use a variety of methods of *coring*. The following figures will illustrate some of these, and will indicate how others, more complicated still, are met and accomplished. Thus, Fig 85 shows the finished casting which is desired to be produced, and Fig. 2386 the pattern, with its core-prints for producing it. The horizontal print *a* delivers itself, but one made like the left-hand vertical one *b*, would tear up the sand in the attempt to remove the pattern from the mould. The right-hand print *d*, therefore, shows the proper shape and length, reaching down to the bed of the pattern. The circular opening has, in the same manner, a tapering print of the same length. These prints, if we suppose the pattern inverted, will leave a recess, as shown at *d* in Fig. 2387. Upon being drawn, the cores are inserted as in Fig. 2388, (a section through *d*,) the upper part of the recess is made good with sand to the general surface, and the mould is ready for casting.

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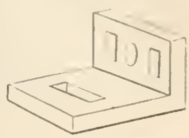

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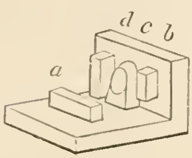

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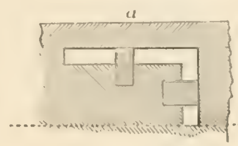

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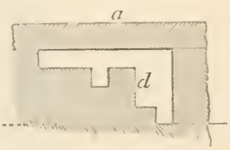

By observation and practice moulders become exceedingly expert in managing their patterns, &c., and often display remarkable ingenuity in the shifts and contrivances to which they resort for eking out or stopping off patterns, or for moulding additional parts for which there is no pattern. Indeed, as one of the heavy items of expense in a foundry is for a stock of patterns, it is not unusual, for avoiding this, to see many common articles of simple form, (grates, parts of stove-plates, &c.,) which are made upon written orders, built up with core-prints or slips of wood, and moulded almost entirely by hand. Wherever accuracy is required, however, well-made patterns are indispensable.

The objects which are moulded in sand and cast in flasks are too numerous to be mentioned. They comprehend nearly all the articles of cast-iron in ordinary or domestic use. Before leaving this branch, another illustration of flask-casting of the last-mentioned class of articles may be of interest to some readers, viz., the manufacture of *iron pots*. Fig. 2389 will give an idea of the implements in this process. The pattern for the pot (which is of metal, for wood could not be turned down well to the thinness of these vessels) exists in two hemispheres, which fit and are fastened together in the oblique dotted curve shown in the figure. The moulder takes these and places them together, mouth downwards, upon a board which has a bevel-rim just fitting the mouth of the pot. On the same board, he places symmetrically over the pattern the flask *a*, which is in two pieces, as shown. Sand is rammed down round the pattern till the flask is full, when a parting is made even with its top, and flask *b* is placed on and fastened. This is filled in like manner, prints for the feet and a runner-stick having been put in at the proper levels. The top of *b* is levelled off, a board placed on it, and the whole concern inverted. The board that originally served as the drag, and upon which *a* and *b* have been built, is removed, the interior of the pot is seen, and the flask *c* is set around its mouth upon *a*. The pot is then filled with sand and rammed to the edge of *c*, when it is all *strickled*, (i. e., levelled off,) a drag-board placed on it, and the whole reverted to its former position, as seen in the cut. In drawing the pattern, *b* comes off first, out of which the core prints are also taken; *a* takes apart and leaves the pattern exposed, which comes out in halves. The convex and concave moulds are then dressed with tools and facing-sand, the flasks replaced, the runner-stick taken out, and the whole is ready for casting. In spite of the apparent complexity of all this, it is by no means among the costlier or more difficult works of the foundry.

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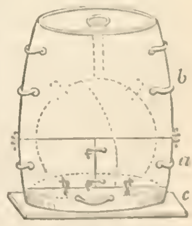
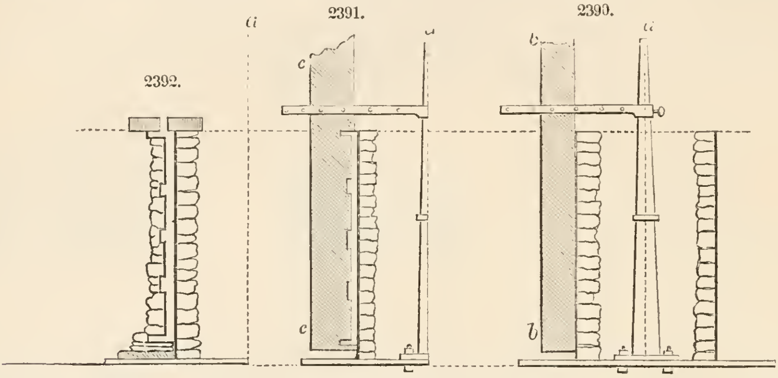


Articles that are heavy or large have to be *moulded in loam*, as it is termed; and as such things are generally required to be cast vertically, while the quantity of metal is too great to be ladled, it is more convenient to dig a pit for the mould to which the metal may be led by gutters, than to raise the furnace foundations high enough to have all the work above ground. Indeed, as works have sometimes to be executed fifteen and even twenty feet high, this last arrangement would be well nigh absurd. So far as resistance is concerned, pit moulding is advantageous; and if due provision be made for the escape of elastic gases, it is not more objectionable on the score of danger than large flasks above ground. The great merit of this method is, however, in dispensing with a solid pattern, which, for such cylinders, for instance, as are used in Cornish engines, of eight feet diameter and fifteen feet stroke, would be al enormous expense. The following figures will serve to explain the general process of loam-moulding. Fig. 2390 shows the first stage of the mould for a steam or blast cylinder. The lowest lines represent the bed of the loam-plate, upon which the inner wall is built. This inner wall, for small works, such as pipes, is called the *core*, for large cylinders it is termed the *nowel*. The loam-plate is of iron, cast rough, and with projecting ears for lifting it. Sometimes these plates are raised from the ground, to allow of a fire for drying the loam to be made up beneath; or if the work be not too large, it is set upon a wheeled truck, by which it may be rolled into the loam-stove. Upon this truck, or on the loam-plate, or in any convenient and steady manner, a spindle *a* is fixed, which carries the templet *b b*, whose distance from the centre is adjusted exactly to the internal radius of the intended cylinder. An inner wall of brick-work is then built, whose face is plastered with soft loam, which loam is shaped and turned by the motion of the templet. When smooth it is thoroughly dried, and then brushed over with black-wash of charcoal and coal-dust, to be dried again, and serve as a parting to prevent the adherence of fresh loam. This finishes the mould for the inside of the cylinder.

The templet *b b* is then dismounted, and another *c c*, Fig. 2391, cut in profile to the external form of the cylinder, with flanges, and bosses, &c., is attached to the spindle at a distance from the centre exactly corresponding to the radius of the cylinder, *plus* its intended thickness. Fresh loam is then thrown on the nowel-mould, in order to form the thickness, which is shaped on the outside by the revolutions of the templet, carefully smoothed, dried, and black-washed as the other.



When this is finished, a loam-plate or ring is laid down to carry the outer case or *cope*, as shown in Fig. 2392. This cope is built up of brick and loam, with an inner facing of loam worked carefully to the turned thickness; it is then thoroughly dried, and lifted off carefully from the nowel. This is done by means of a crane. The *thickness* comes off with the cope, generally broken, but it has now answered its purpose. Any accidental damage to either of the moulds is repaired, the faces are black-washed and dried again, and the mould is ready to be put together, the position of the cope having been determined at first either by studs, or by marks upon the nowel-plate.

Ports at the ends of the cylinder (or short flanged tubes for attaching the steam or blast pipes) are made by working the patterns into the cope; the cores are supported either by *grains* (which are little plates of sheet-iron staid by wire, and as wide as the thickness of the metal at the port) or by sand-bearings, the holes left by which are afterwards plugged up. From the precariousness of the union of the melted metal with that of the wire and sheets, the use of grains is, when possible, to be avoided. Other passages for steam or air, either in the side or around the cylinder, can be worked in a similar manner upon the thickness, and be covered in by the cope.

When all is ready the mould is put together in the pit, the two plates bolted together, and the external space in the pit rammed hard, to resist the outward pressure of the melted metal. In very large works there are iron rings, larger than the cope, piled one on another to hold the sand; these rings are steadied by numerous stays going to the sides of the pit, which is sometimes itself walled up with brick, or even cased with iron. In such works the core too has to be strengthened by iron stays laid in diameters, and entering the brick-work of the nowel.

The metal, in pouring, is led in various ways to the mould, according to circumstances, from the sow or main runner. Sometimes there is a circular trough round the top of the mould, and the feeding is through holes in the loam-cake; sometimes the runners are sunk, and enter the mould at about one-third of the height from the bottom and tangent to the circumference. This is supposed to be a good way to keep the metal in circulation, and clear of the scoriæ or *sullage*. Sometimes, to supply hydrostatic pressure for condensation, or shrinkage in cooling, iron rings are piled up to inclose a lofty runner. In the largest works several such reservoirs or *feeds* are made in addition to the runners, purposely to provide for shrinkage. Sometimes a piston has been applied in the runners, when they are not numerous; and a still better-intended process has been proposed—that of exhausting the air from the mould, and supplying the feed from below.

Both of these methods—which have never come into general use—aim at accomplishing perfectly what the founders ordinarily obviate by other contrivances, viz., the expulsion of the air from the mould. If the air or vapor in small quantities gets entangled in the metal, it produces, of course, a bad casting, leaving cavities in the mass such as we very often see. If large quantities, especially of steam, are caught, the consequence is a greater or less explosion, sometimes attended with very disastrous consequences. The Thorncliffe accident in 1820 is still remembered in the annals of founding as one of the saddest of such catastrophes. Upwards of 100 persons were in the cast-house at the time, to witness the pouring of a tilt-shaft of about five tons in a vertical mould. The cast was nearly finished when the explosion took place, and some four tons of melted iron shot out as from a petard, killing and wounding terribly about one-fourth of those present. There happened to be a thunder-storm at the time, and as no one knew of any mistake committed in any of the arrangements, the accident was attributed to that indefinite agent, *electricity*. It more likely arose from a sudden and explosive combination of carburetted hydrogen, a gas which is always formed in the moulds. The workmen are very well aware of this, and in casting, for example, the thick cylinders for a hydrostatic press, which are set mouth downwards generally, the air-tube or tubes which are made to come up from the core underneath to the surface are ignited for greater safety, and burn like perfect gas-torches. In small works this is not so manifest, and in these, by making openings similar to and corresponding with the runners, the metal flows *through* the mould, and drives out the greater quantity of the air and gas before it. In larger works the air-chamber is generally provided below, underneath the nowel-plate, by laying there a mass of hay-bands, with which air-tubes, leading to the surface, immediately communicate. But the use of this combustible matter cannot be recommended on the score of security.

The *temperature* proper for pouring is slightly different for every mixture; it can be judged of only by experience: at least it cannot be defined by any written rules of universal application. The *rate* of pouring, too, is in the same category. In general, *bad* castings (i. e., *blown* and spongy) are apt to be made by quick pouring of hot metal, and *imperfect* ones by slow pouring.

The necessity of providing sufficient resistance to all sides of the mould during pouring has been already spoken of. After pouring, however, the condition becomes inverted, for the metal is then shrinking into itself. The pressure from without is generally nothing; but that from within must be removed, that the cylinder be not strained, or *scored*. So, in two or three hours, according to the size of the work, the iron stays within the core are knocked away, and the workmen go down to break away the brick-work. The excessive heat renders this the most dreadful of their duties.

Loam-casting, suitably modified, is applied to all large works with curved surfaces, such as cylinders of all sorts, large pans, guns, pipes for water, gas, &c., &c. Guns have been cast with a core, like cylinders, but their imperfections are such as to make it more advantageous, in spite of the waste of metal, to run them solid and bore them out afterwards. The cores for pipes are usually made upon an iron tube pierced with holes, wound round with hay-bands, and revolved, while the loam is being applied, by a winch at the end, upon two iron trestles. A scraper, fixed parallel to the axis, turns off the loam, and brings the core to its true cylindric shape. This arrangement, which is susceptible of more accuracy, is the *founder's lathe.* These cores are dried and blackwashed; the thickness is laid on in loam, and also dried and blackwashed; and the object is then moulded in sand in an iron box parting in half. The core is then taken out, the thickness removed, and the core replaced, and held in place, if necessary, with grains. In establishments where pipes are cast in large quantities, it is usual to mould from wooden patterns in halves.

Within a short period, a method has been tried of casting pipes inside of an iron pattern, which is laid with a slight slope, and caused to revolve while the metal is fed. Its revolutions inspire a centrifugal tendency to the melted metal, which is restrained and shaped, as it cools, by the pattern. The precariousness of result, however, or some other cause, appears to have restricted the economical use of this method.

The scope of the iron-founder's art is exceedingly comprehensive, both as to the forms he produces, and the weight of metal he has to deal with. Thus, castings are sometimes required of 20 and even 30 tons in one piece, requiring the conjoint operation of three or four furnaces tapped at one time. On the other hand, the beautiful Berlin ornaments are cast in pieces of a few grains weight. The art of casting these ornaments was first developed in Prussia, and is supposed to depend, in some degree, upon the quality of the iron and of the sand employed. The latter, as well as the ores (bog-ores) out of which the former is reduced, is not only fossiliferous, but appears to be constituted entirely of the remains of animalculæ. But there are examples of successful castings of the smallest size with materials where this infusorial influence could not be suspected of operating.

The following figures exhibit one of these Berlin chains entirely of castings (many of those on sale will be found to have been connected with iron wire): its length is 4 feet 10 inches, and its whole weight 730 grains; a large and small link together weigh a little over 8 grains. Fig. 2393 shows the

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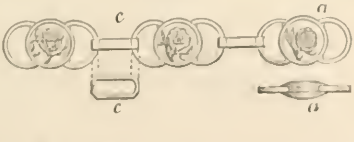

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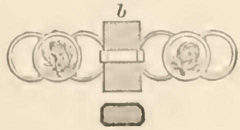

chain itself; Fig. 2394 is intended to explain the way it was worked. The large links *a a* (Fig. 2393) were first cast separately. Then a pattern of the chain with core-prints *b* (Fig. 2394) was moulded. The links *a*, smoked to prevent adhesion of the metal, were laid in the mould, and then the sand cores, *b*. The actual mould was about 8 inches long, and a separate runner was made to every one of the small links *c c*. Such things are even greater wonders of art than the larger works.

When castings are set and cooled, the next thing is to remove them from the moulds; the runners are snapped off, and all the loose sand scraped from the casting, and the seams of partings smoothed. For common castings, very rough implements serve; for the finer kinds more appropriate tools are required. To these, the skin left from a sand mould is very destructive; and therefore, if they are intended to be wrought, they are generally first *pickled* with dilute sulphuric acid—by immersion if they are small, and aspersion if large. The acid attacks the metal underneath; and the crust that is left after a day or two is easily removed.

The skin of castings from sand-moulds is always harder than from loam. This is not so much from the siliceous matter taken up in the surface, as from the effect of a different conduction of heat, and a change of crystallization at and near the surface, which is known as *chilling*. These chilled castings have been already mentioned: it only remains to speak of the *malleable* iron castings which are produced at a few establishments.

The *malleability*, which is in some respects the reverse of chilling, in general follows the abstraction of carbon, and is proportionate to it; but the metal so produced has none of the *fibre* which is caused by forging and laminating. Like chilling, the change is external, and penetrates but a small way; the methods, therefore, are applicable only to light and thin articles. There are many such (brads, bridle-bits, coach-makers' fastenings and furniture, locks, snuffers, stirrup-irons, &c., and various vessels in domestic use) which can be cast more cheaply and conveniently than forged: to all these the method applies.

It reposes both upon the character of the crude iron and upon processes subsequent to casting. Gray crude iron produced from refractory ores, which never can be chilled, is the suitable quality; and articles cast from this, which are at first brittle, are enclosed in iron boxes, in contact with powdered oxides of iron, (either mineral, as red hematite, or artificial, as forge-cinder,) with lime, or with any absorbents of carbon. The cases, well closed and luted, are placed in an oven, and left there, at a high temperature, for a period varying from three days to a week. The temperature is then allowed to subside, and the matters to cool gradually in the ovens. When pieces of these castings are fractured, the alteration of structure is very apparent.

III. Refining, Forging, &c., of Malleable Iron.—The mention of malleable iron castings leads naturally to the account of those processes by which a malleability is imparted, higher both in kind and degree. These processes apply, 1st, to the production of iron which can be wrought directly from suitable ores; as well as, 2d, to the refining and working of crude iron which has been otherwise produced. The fagoting of scrap-iron is not sufficiently distinctive, either chemically or mechanically, to constitute a third class of processes.

1. *Of malleable iron directly from ores.*—This product undoubtedly preceded any other manufacture of iron. All the workings of antiquity were of this sort, there is reason to believe; and what has been already said in this article serves to show the gradual advance of the modern epoch of *crude iron*. The improvement in this epoch has been the utilization of many ores which, under the old process, were unavailable. Only rich and fusible mines—magnetic oxides, and some of the sparry carbonates and red hematites, and the like—admit of this treatment. This restriction will be justified in considering the general theoretical aim of the process, which, in so far different from that of the high-furnace, embraces a double task, and recurring decompositions and recompositions. In the high-furnace, our object is to drive off the oxygen from the ores; which is effected by preventing carbon in excess at a high temperature, while that portion of excessive carbon that combines with the iron after reduction is gotten rid of by subsequent separate treatment. But in the *forge-fire*, one treatment must answer both ends; carbon at the lowest temperature that will answer must be prevented to effect an *imperfect reduction* at first, till the mass consists, in fact, of a mixture of oxides and carburets of iron; and while this mixture is reacting internally on itself, additional oxygen from a current of air must be afforded to assist in the neutralization of the carbon.

To this aim, the character of the furnaces employed must conform; they must be low, so that the reduction may not take place too soon and fusion be checked; they must be wide, that the melting carburets may offer a large surface to the action of the air. Where exactly the fusion is maintained, is not of so much moment: if above the tuyère, the furnace is properly a *stück-ofen*, which has been already described; if below the tuyère, it is to be termed a *forge-fire*, of which the so-called *Catalan forge* may be taken as the type. Whether one or the other form be used, there is in either another characteristic diversity from the processes of the high-furnace, which should not be omitted. In the latter, the result depends upon the chemical action of the materials; i. e., upon the proportions of fuel and mine, and the temperature which is kept up; in the former, the chemical reactions are chiefly dependent upon the mechanical agency of the workman, whose business it is to expose successively the imperfectly reduced masses to the influence of the air. Thus the reduction and the refining are both, in a measure, mechanically effected; the formation of too much crude iron at once is checked by immediate admixture of oxide, and by a judicious management of the blast; and the result depends upon the skill with which this is done, just as in the case mentioned in a preceding part, where, to produce crude metal of a particular quality, doses of suitable materials are injected into the crucible of a high-furnace.

So much has been already said upon the *stück-ofen*, that its application need not be insisted on here, further than to remark, that their product is never entirely *malleable iron*, and requires a fresh reheating and fusion of a part. This subsequent process results in the formation of part malleable iron and part *steel*.

The furnaces used in Sweden and Norway for this purpose are also properly stück-ofen, and the result similar. In some places of these countries, they treat a roasted ore with wood in inverted cone-like furnaces, from 4 to 7 feet high, and from 2½ to 5 feet diameter at the top.

The old German method was also so far like that of the stück-ofen, in requiring actual fusion; but the shape of the hearth was different, resembling the Catalan forge-fire, and the original, apparently, of the modern *bloomery-fires* of Pennsylvania. There was also another method used still in Gallicia, of interstratifying the ores with the fuel which is broken fine and kept almost in a pasty state. The reduced metal filtering slowly through this paste is refined by the current of air directed downwards towards the bottom of the hearth.

The methods, &c., which have been applied from time immemorial in the Pyrenees, and are called the *Catalan method*, will convey a sufficient idea of all the others, which are but modifications. This appellation comprehends, in reality, the whole arrangement of water-blasts, tilt-hammers, &c.; but the exposition will be confined for the moment only to the chemical part of the process, or the production of metal ready to be forged. The ores are generally roasted in furnaces or ovens; but in some instances a compact brown hematite has been used raw. The results, compared with roasted mine, do not appear advantageous. When the ores are tolerably pure, they are usually charged in the furnace within a month after roasting; but pyritous or phosphated mines are macerated, *i. e.*, exposed to the air, and frequently stirred and moistened with water for a twelvemonth. Before charging, they are broken up into fragments, like small nuts; red hematites are even used in powder. According to the character of the ore, earthy matter, argillaceous or calcareous, is added, to serve as a flux. Throughout the Pyrenees, the general machinery for the blast is the *trompe* that has been already described; small forge-fires are sometimes blown with leasher bellows. In this last case, to maintain a continuous blast and furnish a suitable quantity, two tuyères are required.

The following figures indicate the construction of these Catalan forges. Fig. 2395 is a ground plan on a scale of 1-40th of the actual size of the forge-fires used in the Lower Pyrenees. Such are properly called Navarrese furnaces; and while the general structure is the same for all, are intermediate in dimensions between the Spanish Catalan, which are smaller, and the Biscayan forges.

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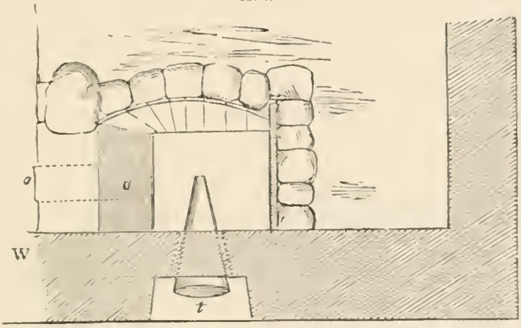

Fig. 2396 is a vertical section through the axis of the tuyère; and Fig. 2397 another section at right angles to the former. In Fig. 2395, W W represents the wall separating the forge-fire from the blast machinery, and in which is the embrasure for the tuyère. The hearth is usually lined with cast plates, and the *counter*, or side opposite the tuyère, of flat bars. Sometimes the lining of these is only a refractory sandstone; but the cinder slope (on the side *o* of the tuyère) on which the workman rests his ringers and bars, is always of cast-iron. The aperture *o* is for the discharge of cinder into the embrasure beneath; the tuyère *t* is a truncated half-cone of copper, with the orifice or *eye* circular, from 1¾ to 2 inches in diameter. The pressure of the blast varies from ½ lb. to 1½ lb. per inch.

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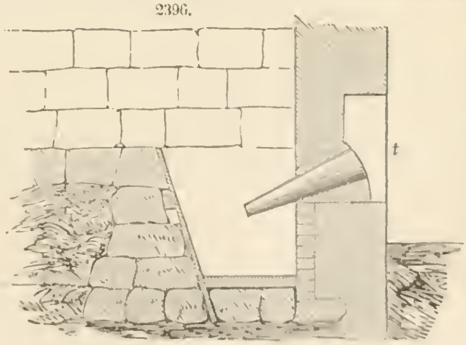

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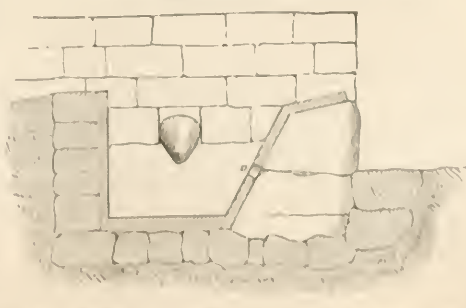

The fewest men to work one of these fires, not counting the hammer-man, is three; the greatest number employed in the largest and most active, is eight. In beginning to work, the hearth has first to be heated by keeping it two-thirds full of ignited charcoal for 4 or 5 hours. The fuel is then thrown up against the tuyere and beaten down into an inclined plane towards the counter. Upon this is thrown at once from one half to three-fourths of the charge of mine; the hearth is heaped up with charcoal; the cinder tap *o* stopped with clay; and the blast gradually let on, till, in about two hours, it attains its maximum. The founder, during the process, frequently wets the charcoal on top to prevent its burning too fast, and to concentrate the heat; throws on, from time to time, the smaller fragments remaining of the charge, near the tuyère; feels with a crow bar at the bottom of the hearth for the cinder and metal; gradually brings the charge nearer the tuyère; keeps the tuyère free; and about every quarter hour after cinder has commenced to show itself, taps and lets it off. This tapping, after the whole blast is on, has to be done more frequently: sometimes every five minutes; the other part of the work too, goes on with more activity. In three hours the whole charge is melted; a bar is thrust through the charcoal in many places to clear the metal which is thus gathered up on the bottom of the hearth, and worked and pressed with ringers into a sort of ball or loop. This takes the greater part of an hour; when the heat is done, the charcoal is raked over against the counter; and the loop thus cleared is lifted by the bar to which it adheres, and, if necessary, with tongs, and carried to the shingling-hammer to be forged. In the Catalan forges, the weight of these loops (or *marsets*) is from 100 to 150 lbs.; in the Navarrese, from 180 to 250 lbs.; in the Biscayan, from 280 to 350 lbs.; and in some of the forges among the Eastern Pyrenees, as much as 425 lbs. The tilt-hammers employed weigh from 600 to 700 lbs., generally of cast-iron, sometimes of wrought; the helve and fixtures mostly of wood. Besides these are used smaller lift-hammers, for working smaller bars, called *martinets*. When the loop is placed under the hammer, it is struck at first slowly to condense it and drive out the cinder; it is then forged more rapidly into the shape of a prism, 12 to 18 inches long, and 6 to 8 inches square. This is cut in two by a chisel under the hammer; the pieces carried back to the same fire as a special chafery, there heated and successively forged again. When smaller bars are wanted, these pieces are again cut, reheated, and forged under the martinet.

The charge of roasted mine for each heat is, with the Catalan fire, from 325 to 450 lbs.; with the Navarrese, from 550 to 650 lbs.; with the Biscayan, from 750 to 900 lbs.; and with the largest fires of the Eastern Pyrenees, an average of 1250 lbs. But the economical result in metal is, as might be expected, against the large charges. The smaller fires allow six and sometimes seven heats in the 24 hours, and give about 90 per cent. of the metal found by assay in the ore: the larger ones never more than four heats in the same time, yielding about 85 per cent. of the metal. In fuel, there is less consumption with the large charges. In the smallest fires, the fuel used is, on an average, *five* for one of mine; in the larger it is about *three*.

The fuel used is universally *charcoal*. Frequent experiments have been made looking to the substitution of *coke*, both with cold and hot blast, but hitherto, and probably of necessity, always without success.

2. *Of malleable iron from pig or crude iron*—produced (*a*) with charcoal in open forge-fires, bloomeries, &c.; (*b*) with coal in reverberatory or *puddling* furnaces; (*c*) with coke or coal in a special furnace, termed a *finery*, or run-out fire, and then in a puddling-furnace. The object is the same in all these, viz., the decarburation of the metal, (as to driving off other impurities, that will be spoken of specially hereafter;) and the methods may be distinguished into two classes—first, where the metal is refined in contact with carbon, as in mode *a*; and, secondly, where it is only in contact with heated air and inflamed gases, as in the reverberatory furnaces of modes *b* and *c*. In theory, the latter method should be the best, so far as quality of metal and economy of material are concerned; but in practice, the former, though at a greater loss and expense, is the most successful in yielding a good article.

In regard to the quality of crude iron most advantageous for refining, different metallurgists have expressed different opinions. As this is no place for a lengthened discussion of principles, only such statements will be briefly made as seem to accord the best with experience.

Gray iron demands a higher temperature for fusion than white, becomes more liquid, and requires more blast and a longer time for conversion. White iron coagulates more readily, and passes sooner to the malleable state. Whether these differences arise solely or chiefly from the presence of the free carbon in the former, is not the question: it is certain, however, that some kinds of gray iron cannot be refined at all without having been first whitened by a special process. This is especially the case with coke iron; and the finery of the English method is an expedient for meeting this very difficulty. The best qualities for easy refining are white iron, produced in the high-furnace by heavy burden, gray pig, which is loose in its texture and cavernous, and broken castings from a cupola or crucible. Next come the mottled pig, the lamellar and loosely crystallized white iron, and close-grained gray coke iron Last of all to be employed, are the compact crystallized gray pigs, especially those made with coke or coal.

No *flux*, properly so called, is employed in the fusion of refineries; but several substances are occasionally introduced, besides the air and charcoal, to act as chemical reagents. These are, for instance the rich finery-cinder, the forge-cinder, oxides of iron and manganese, sand, and water. Of the finery cinder, only that is useful which is formed after fusion is perfect, and while, in fact, the loop is about to be drawn. This cinder falls to the lower part of the hearth: rich as they are, containing from 80 to 90 per cent. of magnetic oxide, they are not displaced by the iron, and may be left in the hearth after the loop is removed. If drawn, which need only be when they have accumulated to a great degree, they must be tapped for very low down; when tapped, they run and solidify slowly, and take, of course, all forms readily. Their formation in the hearth is indicated by the silvery sparks in which they are thrown out by the blast; and they are recognizable afterwards by their weight and semi-metallic lustre. These present to the refiner the best reagent for coagulating the melted metal and bringing it *to nature*. A part of these, also, are apt to adhere to the loop, from which they are broken off and driven out by the hammer, and are very apt to be found mixed with the forge-cinder.

The oxides of iron and manganese are used mainly to save the metal which is otherwise supplied from the pig under treatment to form cinders. Sand is used sometimes (and acting then like a flux) to retain the metal in fusion; but this is bad economy, both for quantity and quality. And *water*, although its principal effect may be in saving fuel, as mentioned a while ago, yet acts as an oxidating agent too.

When the pig contains sulphur or phosphorus in any appreciable proportions, (which give red-short and cold-short iron respectively,) *carbonate of lime*, as pure as possible, may be added; and the more comminuted, the better. It should be applied when fusion is commencing, and not afterwards. In the Pomeranian forges at Torgelow, about ten per cent. of limestone is added after fusion is complete, in three different operations, each of which implies a stoppage of the blast and a stirring of the pig. It is very successful in one respect—that the phosphorus, which exists in the pig at an average of 4¼ per cent., is reduced, in the malleable metal, to ¾ per cent.; but it is at a considerable waste of iron and fuel. Other alkalies have been tried, such as the carbonates of soda and of potash, with and without lime, but without much encouragement. In theory, carbonate of magnesia would be the best corrective.

(*a*.) The modes which are introduced under this method are, in some minute respects, almost as numerous as the localities where it is applied. Karsten has enumerated and described *sixteen* different processes, of which *eleven* are effected by a single fusion, and *five* by a double fusion. But the general type of all is the so-called *German method*, which is spread over the whole of North Germany, widely used in France, and, in many respects, exemplified in the bloomeries of the United States, especially in Pennsylvania. The hearths used for this method, except the large chimneys under which they are set, and which must, of course, have suitable foundations, so much resemble the Catalan forges, as not to need a figure. Only some of the processes followed will be spoken of.

To work advantageously, the workman must know the pig-metal he is using, for so much is dependent on management. Generally, a mixture is better than any one kind. Forge-pigs ought to be run slender, both that they may be broken easier, and that they may be proportioned more exactly. The fragments should not be too large, to waste fuel, nor too small, to run too quick. The quantity for one heat will, of course, depend upon the particular case: as an average, it may be taken from 250 to 350 lbs. The best charcoal is that from *soft* woods, (for instance, the *pinus alba*, *larix*, *strobus*, &c.,) and it should not be broken into pieces smaller than one's fist. The quantity of blast varies with the quality of metal and weight of fuel and charge, and also at different times of the operation. This last variation, unlike the high-furnace, must be under the constant vigilance and control of the workman. It is usual to put more pressure on with white than gray iron; a practice which does not arise so much from the chemical condition requisite as from the habitual mechanical arrangement—of placing gray iron nearer the tuyère. With an average charge, there will be required, while the *melting* is taking place, about 150 cubic feet of air per minute; while stirring, about 225 cubic feet; and while making the loop, as much as 275 cubic feet per minute. In cases where the loop is made by *attachment*, as it is termed, as much as 400 cubic feet is used per minute.

This word, *loop*, has been already used here frequently: it is only the French *loupe*, (a *wen*, a *lump*,) applicable to the shape of the mass. The Germans call it *blume*, (a *flower*—because it resembles the unopened corol of a campanulate flower,) from which we get our English word *bloom*—applied, in our language more particularly, to what has been under the hammer and has been forged. The term *loop* is more appropriate before forging. The French word *renardière*, by which these forge-fires are called, means, literally, a *blind ditch* through which water escapes; and the analogy may be supposed with the filtering and disappearance of the melted metal. The name has no relation to that of the animal (the *fox*) whose kennel, or earth, it also is applied to signify.

To prevent the charge from attaching itself, in fusion, to the cast-iron sides, and especially the bottom of the hearth, an arrangement is usually made by which water can be applied to the outside of these to cool them. This should be judiciously resorted to, when necessary; particularly in the case of the bottom-plate, to avoid breaking it—which would result not only in its own loss, but likewise in that of the charge for that heat. It is better to dispense with water after the fusion is complete.

The slope of the sides and inclination of the bottom, varying in different forges, and strongly insisted on by some metallurgists, appear chemically of absolute indifference. There is a mechanical advantage, only, in the ease of working and lifting the loop. But in the direction and pressure of the blast, and the size of the tuyère, (or *tue-iron*, as the American workmen call it,) the chemical results, both as to quantity and quality, are largely bound up. In former times, there were used two different tuyères, i. e., the blast was admitted through more than one orifice: a more correct observation has reduced them, almost universally, to one tuyère. The nozzle of the tuyère is frequently of cast or wrought iron, which can be easily fitted on the copper pipe. It is usually semicircular—sometimes round, or oval; and its area will not surpass 1½ square inches. The inclination of the tuyère varies from 5 to 10 degrees downwards from the horizon. Were it horizontal, it would burn away more fuel, and a part of the blast would be lost. The more depressed the tuyère, the longer the metal remains liquid; the more horizontal it is, the sooner the metal passes to the malleable state. White iron, then, which has this last tendency in itself, requires a more depressed tuyère than gray iron—although some metallurgists assert the contrary. The depth of the hearth—i. e., the distance between the bottom-plate and the upper edge of the tuyère—is manifestly correlative with the depression of the latter; and they should work together. A hearth should not be shallower than 7 inches, nor exceed 10 inches. When the proportions are established, the tuyère is fixed, by cramps or otherwise built in as firmly as the sides of the hearth, to prevent derangements that would be sure to accrue upon its accidental dislocation.

After covering the hearth with fuel, (leaving there, or not, the cinder of a former heat,) and getting up a good heat, the pigs are pushed in the hearth to about 6 or 8 inches of the tuyère, (the grayer the iron, the nearer it is placed,) covered with charcoal, the blast put on, and every thing done to promote fusion. When they have begun to melt, the workman sounds with his bar to feel the consistency of the fused mass; and he judges by that whether cinder requires to be let off, and what is the state of crudity of the metal. When the latter begins to be stiff and pasty, he draws the mass towards the counter, and, clearing away the charcoal and cinder to expose its surface, lifts it out upon his ringer. It generally breaks into several pieces, which he draws from the fire, supplies fresh fuel, and then replaces the pieces in the inverse order of their conversion; i. e., the most crude nearest the tuyère. They are fused again as before, again worked and lifted. This time, generally, they remain coherent, and the metal is sufficiently refined. Sometimes, however, a third fusion is necessary. The liftings which have been made hitherto, have only been up to, or a little above, the surface of the melted cinder; according as the workman judges it necessary to have the strongly oxidating influence of the blast, or the more gentle reaction of the scoriæ. But in making up the loop, it is lifted quite above the tuyère, so that the air may pass under and around it; it is turned upside down, and end for end, to expose every part of it, and then redeposited in the hearth, where the cinder is drawn to one side. It is covered with fresh fuel, the blast is strongly urged, and the loop is kept at a temperature almost of fusion, completely to decarburate and purify it. This result is judged of by plunging a ringer into the loop after the blast has been gradually diminished: if the thimble, which comes out upon the ringer, is easily detached after cooling, the metal is refined, and the loop is then taken out to be shingled.

The number of workmen required is generally *five*, including the hammer-man; the time taken to finish a loop from 3 to 4 hours. But there is always extra time lost in preparations, &c.; so that a better calculation would be to say that in the week of six days, an average forge will turn out from 4 to 5 tons of large merchant-bars, say 2 inches square; or about 3 tons of inch-square bars. The average waste will be about 27 per cent. of the crude iron; and the fuel used will be, at a mean, about 180 for 100 of bar-iron.

This process is, perhaps, the best for the quality of the bars produced; in respect to quantity, however, waste and fuel, it is among the least economical. In this last regard, of all the existing European processes, that of Sregen appears the most advantageous, the quantity of bar (of large size, to be sure) amounting to 9 and 10 tons per week, the average waste about 20 per cent., and the fuel, weight for weight of bar produced.

(*b.*) This, which is the method used in Champagne, and extensively in America, substitutes a reverberatory or air-furnace for an open forge-fire, urged by a direct blast; and, in fact, leaves the workman to do by manual labor what was done partly in the preceding method by chemical reagents. From a supposed analogy between the manipulations here, the behavior of the material, &c., and what was familiar in the preparation of *clay* to prevent the passage of water to foundations, &c., the process received the name of *puddling;* as the other method is sometimes called *boiling.* As in this a higher temperature is necessary, (heated air being the only reagent,) a fuel giving more heat is required, and therefore coal is used. The metal, however, was at first, and is largely still, charcoal iron; prepared in advance, both in form and substance, for the final refining it has to undergo. This preparation is a conversion into *white iron;* which is done either at the high-furnace or by a second fusion. If the first is relied on, the crude iron should be run into *plates*, or very flat pigs, to whiten it thoroughly. The Styrian method for this purpose is a curious one. The crude iron is run at once into an oval pit, or basin, in sand; the cinder is cleared off, and water is sprinkled over the yet liquid metal to chill it. In this way, plate after plate, weighing from 25 to 50 lbs. each, is formed in intervals of hardly a minute. Only gray iron, from fusible materials, will chill in this way. The plates thus made are roasted, *i. e.*, exposed for 10 or 12 hours to a red-heat, either in an appropriate oven or in an open pile; by which they are slowly decarburated. If this operation of roasting were in any case well performed, a great deal of the carbon should be got rid of; but the expense of fuel is very considerable.

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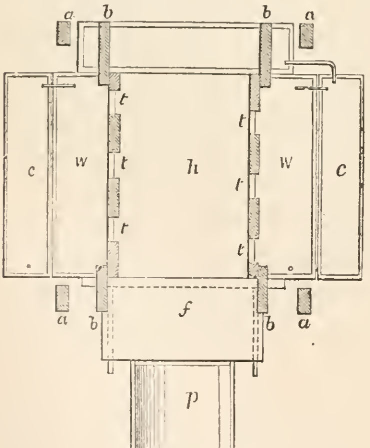
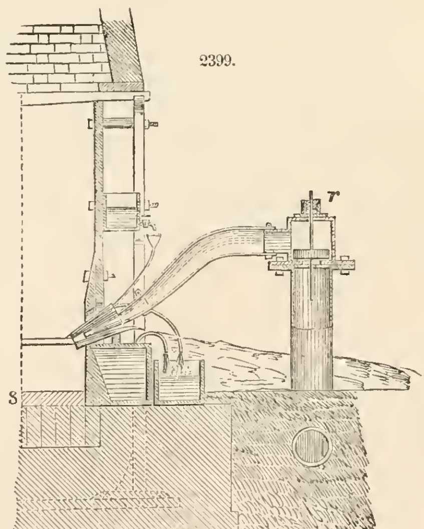


2399.



The second fusion to whiten iron, is what the French term *mazéage*, and the English *running out* or *fining.* This is very much such a process and in such a furnace as has been described under the former method of refining, only it is not carried so far, and the metal, instead of being lifted and looped, is run into plates. The waste in this operation is from 5 to 7 per cent. on the crude iron: *mazéage*, proper, is done with charcoal.

The reverberatory furnace used is similar in form to what has been already figured under a former section.

(*c.*) The constant combination of a *finery*, where the plate-metal is produced with coke, and a *reverberatory furnace*, where it is puddled with coal, constitutes the method practised in England; and there, as elsewhere, is more or less appropriate and even necessary, whenever iron is to be produced in great quantity, and fossil fuel is of course to be relied on.

Fig. 2398 is a ground plan, on a scale of 1-25th of the actual size, of an English finery, blown with six tuyères. In this *a a a a* indicate the places of the cast-iron columns on which the chimney rests; *b b* &c., are the side-plates of the forge; *h* is the hearth formed by the water-backs *w w w*; *f* is the front plate, and *p* the mould in which the plates are run; *c c* are troughs where the bars are cooled.

Fig. 2399 is a half vertical section of the same plan, drawn to the same scale, and serving to explain it. This last figure also shows the attachment of the blast, which, to save room, was left off from the other; as well as, by the dotted lines in the hatched space beneath, the mode of securing the sustaining columns in a mass of masonry. The right half-section would be a counterpart of this.

2400.

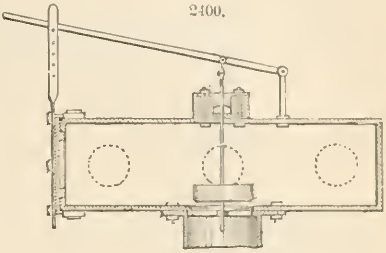
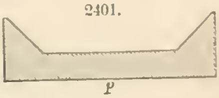


Fig. 2400 is a longitudinal section of the air-box *r*; and the dotted circles on its face are the ports by which the blast is conducted to the several tuyères. The lever-valve allows the blast (which in these establishments comes generally from the great blowing-engines of the high-furnaces) to be regulated by the workman.

Fig. 2401 is a section, still upon the same scale, of the plate-mould *p*. The earlier fineries were blown only on one side, and with three tuyères; the modern ones, almost universally, are blown with four or six tuyères, with a cross blast. The crude iron intended for the finery should, like that for the fires already spoken of, be run into small pigs. They very frequently, however, are employed weighing from 100 to 120 lbs.

The kind of coke to be preferred varies with the quality of the metal. When this last is refractory the coke should be heavy and compact. A friable coke, and one containing much earthy matter, as well as oven coke generally, are objectionable.

2401.



p

The *sole* or bottom of the hearth is indicated on Fig. 2399 by the letter *s*, and by a different species of hachures. This reposes upon fire-brick or refractory sandstone; and is best made of a layer, 4 or 5 inches thick, of broken quartz, well rammed. At the first heat, this layer is partially melted and percolated by the metal, forming a bottom exceedingly hard and refractory. This property, in expediting the work, compensates fully the waste of metal in the beginning. From time to time, however, it requires replacement. The most convenient way to get it out (for it weighs often a couple of tons) is, upon the conclusion of the week's work, and after the last heat, to throw water upon it while yet red-hot. This cracks it up and renders it easy to be taken out; the water-backs may then be reset, and the bottom laid anew. The old bottom, which contains a good deal of half-refined iron, can be used up, little by little, as *scrap*.

As the object of this process is to fuse the metal, the tools and working are only fitted to that end. It is rare that any flux or reagents are added. Hard metal is heated sometimes with forge-cinder or finery-cinder. These, as well as any thing else that may be used, act in nearly the same manner as in refineries with charcoal.

The plate-mould, which can be added to, from its construction, at pleasure, should be so long in proportion to the charge, (which, for a large hearth, will be, on an average, 1½ tons,) that the plates are left not more than 1½ or 2 inches thick. After the metal is in the mould, water is thrown copiously upon the cinder which has run out with and covers it, and which, by this, is easily separated. The plate itself, after being chilled with water, is broken up for the next process.

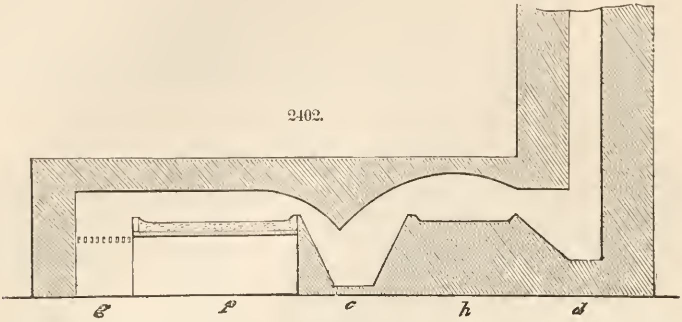
Care must be taken, in this, to strike a proper medium between doing too much and doing too little. If the metal in the run-out sparkles little, and, after being cool, preserves its compacity, it has not been fined enough, and the puddling will be hard and long. If in the run-out it disengages, on the contrary, a multitude of faint sparks, so confluent as to become a sort of flame, and emits a white vapor, it will probably be found converted partly into malleable iron; and the puddling, in this case, will be more difficult and wasteful than in the other.

These results depend, in a measure, upon the supply of blast—which should vary according to the quality of iron, and also according to the character of the fuel with which it has been produced in the high-furnace. With charcoal iron, each tuyère should furnish from 200 to 250 cubic feet per minute, under a pressure of 2 lbs. per square inch. With coke iron, the quantity may advantageously be raised to 300 cubic feet, and the pressure to 2½ lbs.

With this supply, a finery such as described will run out rather more than a ton per hour; and ten heats may be made a turn of twelve hours. The waste should not be more than 12 per cent. of crude iron; and the coke used, about 30 per cent. of the weight of metal charged.

From the finery, the metal is ready to be passed to the *puddling furnace.* This resembles so much, in shape and detail, the reverberatory furnaces before given, as not to require a figure. Sometimes it is used with a charging-door on each side, when it is said to be a *double furnace.* In some cases, the two doors have been placed on the same side; but, as they could not be worked exactly together, their alternations tended to produce irregularities and waste. There is a furnace of this kind, however, though with a different aim, which is affirmed to be very convenient and economical. It is a *two-hearthed* arrangement, which will be made sufficiently clear by the sketch, in longitudinal section, (Fig. 2402,) where *g* is opposite to the grate, *p* to the hearth for puddling, *c* to the cinder pit, *h* to the hearth for heating, and *d* to the smoke flue. On the hearth *h*, the metal undergoes a roasting and partial refining before it is removed to *p*. The external fixtures, the pulleys and counterpoises for the doors, the travelling stirrup for shifting the charge, &c., can be very easily imagined. That this furnace would save fuel is quite probable, but, in respect to other conditions, its efficiency is more problematical.

These conditions for puddling would seem to be, 1st, that a sufficient heat be obtainable to melt the metal entirely; 2d, that the heat, in whatever degree availed of, should be uniformly distributed over the hearth; 3d, that there should be no carbon unconsumed in the flame, in contact or to be combined



with the metal, which contains enough of that impurity already; and, 4th, that the metal (and this is more important for *fine metal*) should not be exposed to a too oxidating effect of the air which is aspersed through the grate.

As yet, bituminous coal is the best fuel that can be applied in a puddling-furnace. Anthracite is also used in America, with better results than have been experienced in Europe. Charcoal and wood also have been tried, but do not appear to diminish the waste or improve the quality of the metal, while the cost of fuel is enhanced. The hearths are supposed, also, to be more difficult to maintain with these last.

This maintenance is one of the points of trouble and expense; and various methods are resorted to for the purpose in constructing the hearth. It is sometimes made of cast-iron; in which case it is covered with a layer of cinder 1½ to 2 inches thick, well pounded, and melted down before the metal is charged. Others prefer to make it of sand, or broken quartz, from 6 to 8 inches thick, well rammed, and covered then with a thin coating (less than an inch) of powdered cinder, which is melted and smoothed before charging. This method is ordinarily productive of more waste, for the silica takes up portions of the oxide which is formed: with impure metal, (containing phosphorus, for instance,) the silica aids in refining it. Others, again, use cinder entirely for the hearth; stratifying it in small fragments to a depth of 5 or 6 inches, and then fusing it and smoothing down. In working only fine metal of good quality, the tendency of the hearth is to thicken itself and change shape upwards; when it is of bad quality, (and still more when crude iron is puddled by the first operation,) the hearth becomes burnt out, as it were, and hollowed downwards. Either change of shape renders repair necessary. Old hearths in sand or cinder, which have been melted out or broken up, can be used advantageously in making new ones. Limestone hearths have also been tried, to the improvement of certain kinds of metal, but to the speedy destruction of the in-walls.

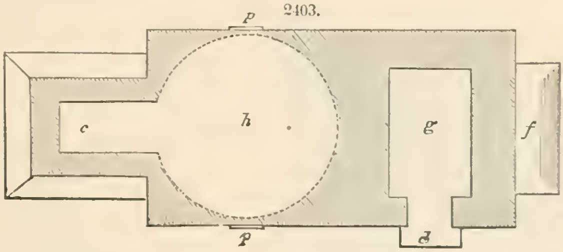
Before charging the furnace, a full red heat is got up inside, principally to save the waste that would follow the oxidation by a slower fusion. Then the fine metal, broken up into pieces, which should not exceed 28 lbs. apiece, and the smaller the better, is charged—hot from the smaller hearth, if the furnace, Fig. 2402, is used—otherwise cold. Ordinarily, the whole charge is about 400 lbs. The register is then raised, and the heat urged for about a quarter of an hour, when the mass becomes pasty, as the workman can judge by feeling it with his bar. If the metal is charged hot, this ordinarily occurs in 10 minutes; longer, if it was put in cold. If it gets too liquid in that period, water is injected to cool it. The register is let down when it is at a proper viscidity; and the workman, introducing his ringer, works the pasty mass continually, to disengage the carbon. As this passes off, the metal becomes more stiff, but it still must be worked, as before, to present the oxidated portions to those that may yet be carburetted, and to prevent too great oxidation, or, as the workmen accurately term it, *burning*. Sometimes it becomes so thick as to be incapable of being worked and divided: in such case, the external air must be shut off, the register lifted, and its consistence destroyed again by fresh urgency of heat. If this misfortune does not happen, the thickened condition is followed shortly by an apparent boiling, more or less marked, and an escape of oxide of carbon, burning with a blue flame. These appearances gradually cease, and another epoch occurs, in the metal's becoming easier to work—in fact, *short*, or tending to break apart in small lumps. The departure of the last remaining portions of carbon is generally indicated by a more lively lustre, which is taken as an indication of its having become malleable iron, or *come to nature*. A continued puddling for four or five minutes more increases its shortness, and it becomes pulverulent almost—the particles of pure iron falling apart, because there is not heat enough to weld them.

To afford this heat is the next step. The temperature, which, from the first pastiness the metal assumed, has been kept as constant as possible, is urged intensely; and the puddler judges, by his own experience, of the proper moment to commence rolling the matter into balls. If begun too soon, it would not be sufficiently welded; if postponed too long, the little fragments would have become independent, and would refuse to weld at all. Taking the proper moment, and beginning with the matter the nearest the fire, the puddler works it all up into five or six balls, (or even more, if the charge is very large,) which he draws over towards the bridge. While making the last, he rolls it all over the hearth to pick up all stray metal. This balling is done sometimes by parting the mass into as many equal parts as it may be intended to make balls, and working each separately; or, by taking a small portion at once, and augmenting by *attachment*, (i. e., as one would roll a snow-ball,) like one of the modes spoken of before in refining with a forge-fire. The result in either case must be the same; and the care to have the balls well rounded and uniformly compact must be equal. The balls, when finished, are taken out with suitable tongs and carried to be shingled.

The operation of puddling crude iron directly does not differ materially, except in time and in the occasional addition of cinder, from puddling fine metal. The latter, if charged cold, will be balled in about $1\frac{1}{4}$ hours; if hot, in 10 or 15 minutes sooner. The former, cold, will require nearer 2 hours. Ordinarily, six heats will be made in a turn of 8 hours with fine metal, and four heats with pig. There is, of course, more waste, in proportion, with pig than with fine metal. The exact loss cannot be conveniently known, because the balls go directly to the hammer, or roughing-rolls, and a part of the measured waste occurs there. This last, however, will be tolerably constant; and a fair estimate of the waste of pig may be made at 15 per 100. With gray iron, it would be, probably, nearly 20 per 100. The loss on fine metal should not exceed 10 per 100. The weight of fuel consumed is about equal to that of fine metal puddled, and about $1\frac{1}{2}$ to 1 of pig puddled. But to compare the absolute economy of the two processes in this respect, allowance must be made for the coke used in the fineries. This was before stated at rather less than one-third of a ton of coke for one ton of pig fined—equivalent to half a ton of raw coal. Allowing, besides, the waste, &c., in making this coke, we should probably conclude that, in the item of fuel, puddling direct from the pig is cheaper than from fine metal. In all other respects, however, it is dearer; and the puddled iron made is rarely of such good quality.

The use of *anthracite* as a fuel for puddling was mentioned just now. In point of fact, the furnaces in which it is applicable hardly belong to the present class of reverberatory, or *aspiring;* since, to maintain a sufficient combustion, a fan-blast, resembling what has been before described, has to be resorted to. Fig. 2403 is a horizontal projection of the principal features of one of these anthracite

2403.



puddling-furnaces; in which *f* indicates the situation of the blast; *g* the fire-grate, with *d* its filling-door; *h* the hearth, with *p p* its charging-doors, constituting a *double* furnace; and *c* the flue into the smoke-stack. The remaining details, fastenings, &c., are analogous to other puddling-furnaces, and can easily be imagined. The ash-pit is, of course, closed up, and the blast passes into it by one or two orifices. The grate is made to be about twice as deep as for bituminous coal—say 20 inches; and, for a double furnace, is about five feet long. The hearth is about six feet in diameter; and the flue, to reach the base of the chimney, pitches very much downwards. The height of the chimney, which, for bituminous coal air-furnaces, is about 40 feet, is, in these, almost immaterial, since the draught is regulated by the fans.

Among the modifications that have been proposed in the details of puddling-furnaces, may be mentioned one (a double one) planned by Mr. Overman, the author of one of the most recent treatises on the manufacture of iron; and designed principally for economy of maintenance and repair, in cases where fusible reagents should be used for improving the iron. In this, the hearth, lozenge-shaped, is enclosed by water-backs; the sole is cast-iron, supported on pedestals, and allowing free circulation of air underneath. It is said by its expert author to have worked "exceedingly well in all cases in which inferior hot or cold short iron, from heavy burden, is puddled...... But for gray metal of small burden, particularly for all coke, stone-coal, or hot-blast iron, it is of questionable utility. For white metal it is perfectly useless." The candor of this account is an additional guaranty of its correctness.

With the puddling ends all the strictly chemical metallurgy of iron. The remaining processes of *forging*, (whether they be effected by impact, or under the hammer—by pressure, as in the squeezer, or by lamination, as in the roughing-rolls,) although necessary, to expel the remains of oxides and earthy matters admixed with the metal, and essential to the production of fibrous wrought iron, are yet only mechanical.

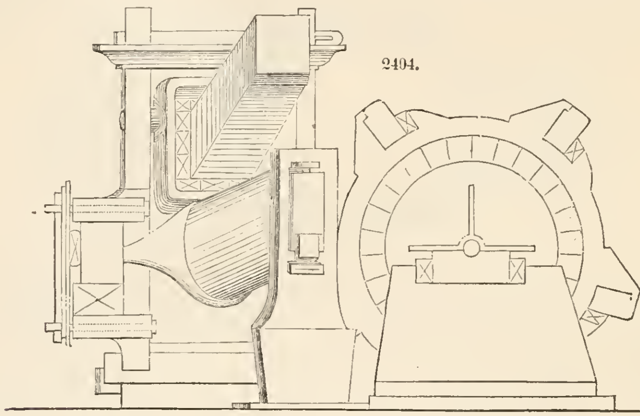
The *hammers* used at the Catalan forge-fires are yet of primitive construction. A head of cast or wrought iron, or both, weighing from 600 to 800 lbs., is fixed, as well as may be, upon a helve of beech or oak. This helve, or log, is 12 or 15 feet long, and 12 to 15 inches in diameter; not squared or dressed, further than to stub off the projecting knots; and fitted with trunnions in a stout and solid wooden frame, to allow of movement up and down. This is effected by tilting the end downwards with cams placed upon the circumference of a water wheel, usually 10 or 12 feet in diameter, but only about one foot wide. This wheel makes from 25 to 30 revolutions a minute; and, there being usually but four cams upon it, the strokes of the hammer, at a maximum, will be not more than 120. The lower face of the hammer works upon an anvil of the same surface and same material, and weighing from 450 to 550 lbs. The anvil is so inclined that the striking faces shall be parallel when in normal position. These heavier hammers are used for shingling the loops, and even for drawing down a large-sized bar. For smaller work, and for finishing, lighter hammers are used, arranged in the same manner, but weighing from 150 to 180 lbs., with an anvil of 120 to 150 lbs., and worked by a smaller wheel, of 6 to 8 feet, making 30 to 35 revolutions per minute, with, ordinarily, 6 cams, so that the strokes amount to 180 or even 200 in a minute. The skill of the hammer-man is shown by so managing the powerful implement at his disposal as to condense the bloom uniformly; and his art, in finishing the bar to a uniform surface.

The hammers of the German forges were set with wood, in a wooden frame, like the Catalan; only they are almost universally *trip* or *lift* hammers—i. e., the cam is applied between the centre of motion and the anvil. This position has the awkwardness of sometimes embarrassing the hammer-man, and makes it necessary that the helve be set obliquely in the framing. At the present day, more or less of the framing is made of cast-iron. The weight of these hammers is from 400 to 450 lbs. only; the lift, i. e., the vertical fall of the face, from 24 to 28 inches; the wheel generally has 5 cams; and the number of strokes is from 90 to 100 per minute.

In the French forges the arrangement is the same, except that the heads are habitually heavier, weighing from 650 to 750 lbs.; the lift is not more than 20 inches; and the stroke is slower, being from 75 to 80 per minute.

In the forges of both countries, the *finishing-hammers* are *tilted*, both for convenience of access and speed. These are of different sizes, according to the work to be done and the quality of the iron. The larger ones weigh from 200 to 300 lbs., and make from 120 to 150 strokes per minute, with a fall of 18 or 20 inches; the smaller range from 60 to 100 lbs. in weight, and make from 250 to 300 strokes in a minute, with a fall of not more than 12 inches. To get up this speed, the water-wheel is furnished with more cams, sometimes as many as 32 in number. All, the largest and smallest, work against a sort of wooden spring, which checks their upward motion and imparts more momentum to the downward fall.

Fig. 2404 is a projection, upon a scale of one-thirtieth, parallel to the plane of the water-wheel, of one of the modern German hammers, in an iron frame. The faces of the head and anvil are, in this, a

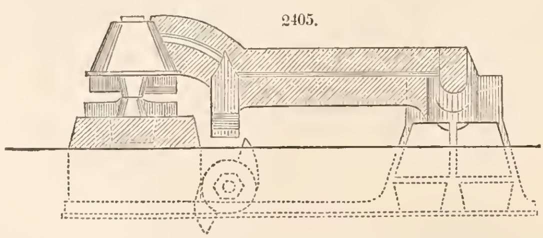


2404.

uniform plane; but often, and especially for finishing hammers, the face is like the letter **T** in relief or else a full cross.

This modification is borrowed from the English fashion, whose hammers, besides, are altogether more powerful and substantial. Made of iron throughout, the hammer-head and helve weigh from 4 to 7 tons. The lift is effected to a height of about 15 inches, by cams, which seize a projecting lip in advance of the very head, and constitute a *trip*-hammer proper; sometimes by an eccentric, which works against the helve between the head and the centre of motion. The number of strokes is about 80 or 90 per minute. The power is taken off from a steam-engine, and a heavy fly-wheel is necessary to equalize the motion. The anvil weighs ordinarily from 4 to 5 tons. Fig. 2405 is a sketch of one of these

2405.



hammers; the dotted lines showing that part of the arrangement which is below the floor-line and rests upon the foundations. There are also lighter hammers, for special work, in the English forges, which weigh altogether not more than two tons, and make from 140 to 180 strokes a minute.

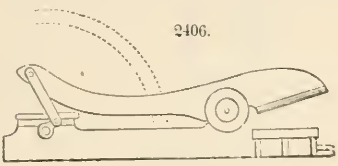
With their heavy fly-wheels, these hammers cannot be stopped in the same way as the lighter ones The usual mode is by thrusting a *jack*, or piece of iron, under the helve when it is at its highest. In starting again, a piece of wood is dexterously placed to be caught by the cam, and the jack is released

Overman has suggested a permanent jack, (or jack-ketch,) to be worked by a piece of wire, which is undoubtedly better.

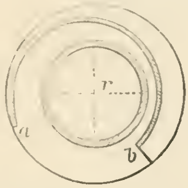
A very ingenious and useful application of steam directly to a vertical hammer has been executed by Mr. Nasmyth. Its behavior is not unlike that of a pile-driver; only, it can be worked with great rapidity, and thus, in some cases, dispenses with the number of reheatings necessary in finishing a bar. As this machine is applicable to other purposes than the forging of iron, its description will be given under a special article, STEAM-HAMMER.

The *squeezers*, which are extensively found in English iron-works, are employed for the same purpose as the heavy shingling-hammers, viz., condensing the puddle-balls into slabs: they act, as might be supposed by the name, by steady pressure instead of impact. They are supposed by some metallurgists to answer the end of expelling the cinder, &c., as well as hammers; but this is very doubtful. As applied to finishing bars, their use would not be economical. The most numerous class is of *tilt-squeezers*—i. e., the trunnions are between the power and the squeezing-jaws. The power is variously applied, by an eccentric or by cranks. Fig. 2406 shows the chief features of one of the last kind, upon a scale of one-fortieth of the actual size. The whole apparatus, which is of cast-iron, requires to be strongly bolted down to a solid foundation. The dotted circle indicates the position of the fly-wheel, by which the power is equalized on the crank; and the shaded lines show the jaws, which are separate plates of wrought or cast iron, bolted on the frame, and renewed when necessary. Such a machine, making from 80 to 90 revolutions per minute, can squeeze about 100 tons per week. Its theoretical deficiency is the want of parallel movement; its practical one, the enormous strain (especially if the loop should be too cold) upon all the blocks and journals.

2406.



2407.



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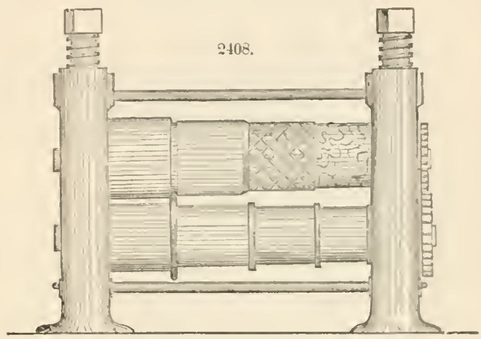


A different apparatus from this, and free from some of its defects, is Burden's patent eccentric rotary squeezer—the mode of whose action will be apparent from the projection in Fig. 2407, where r shows a cylinder with a roughened or serrated surface, revolving vertically in an eccentric drum which is permanent. The ball goes in at a, and is dragged round with it, more and more compressed in its narrowing path, until it comes out at b. The bottom is a solid plate; the top admits of a slight adjustment.

This machine has brought us round to the method, much older, and still practised in many English establishments, of squeezing and condensing between horizontal cylinders, or *roughing-rolls.* A sufficiently indicative sketch of these is given in Fig. 2408, about one-fiftieth of the actual size. The securings and couplings, &c., are omitted. The first of the upper train on the right is moriscoed or roughened, to catch and drag the ball. The next one is channelled for the same purpose. The surface-adhesion is enough to that end in the other two. The collars on the lower train are for up-setting or keeping the slab in shape laterally.

What are called roughing-rolls in America are used, not instead of, but subsequently to, the hammer or squeezer; and serve to forge the bloom into shape, rather than perfect its malleability. Instead, therefore, of being flat, the cylinders have corresponding grooves of large size, making a square or lozenge-like section. In other respects, in housing, geering, &c., they are the same with the English.

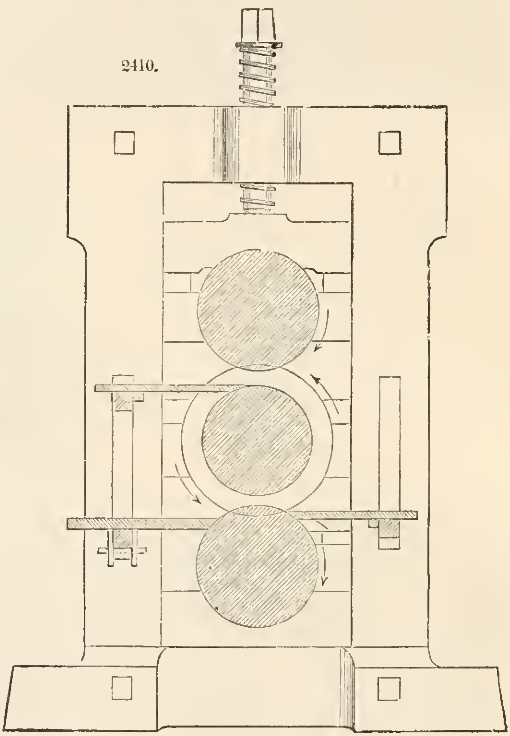
In proportion as the bloom or slab becomes drawn out by any of the condensing or flatting processes which have been mentioned, it becomes necessary to shear it up into shorter lengths, which are reheated separately or in piles, to be treated as before. The Catalan forges use a chisel under the hammer for this purpose. But rough-bar is much better severed by heavy shears, worked either by a water-wheel or steam-engine. Small bar can be cut with hand-shears. In general arrangement, the heavy shears resemble the squeezers—cutting-edges being substituted for the flatting planes; and, like the latter, they are worked with a crank at the end of a straight or bent shank, or with an eccentric that tilts the edges. The shank and shear-block are all of cast iron; and the leverage, from the trunnions to the crank, will vary from 4 to 10 feet, according to the work intended. The cutting-edges are of steel, bolted on to the block, and lie either in the same plane with the shank, or parallel with the trunnions. The last mode has been devised, as obviating the defect belonging to all scissors arrangement—viz, the varying angle of the cutting planes. As suitable for thin work to be cut evenly, a sketch of this arrangement is given in Fig. 2409. The blades, which are shown by the vertically shaded lines, may be of any length—15, or even 24 inches—

2409.

suited to the character of the work to be cut. The defect in these, as in all existing shears, is the want of horizontal slide as they come down vertically—a modification easier to imagine than execute.

The *reheating* or *piling furnaces*, which have been just now mentioned as necessary for restoring the temperature to the slabs or bars, and enabling them to be further worked on and finished, are, in the most complete establishments, separate fires. In the more primitive methods, this reheating (which is required twice or thrice) is done in the forge-fires themselves; sometimes it is done in the puddling-fire, or at the end of the puddling-furnace. In general character, these reheating ovens resemble the ordinary puddling-furnace; but they require some modifications to yield their best effect. The aim of these is to produce a welding-heat uniformly over the hearth; and, at the same time, at the expense of as little metal oxidated as possible. The last end is answered by making the grate larger in proportion to the hearth, and charging more fuel in proportion to the chimney, so that the air may be more completely deoxidized by the excess of carbon. The former is sought to be satisfied by lowering the bridge and bringing down the arch nearer to the ramp, to which, also, the hearth proper inclines a little. Wood may be used in one of these furnaces, but with a larger grate and a lower arch.

2410.



The remaining machinery to be spoken of is the cylinders or rolls for finishing the bars—flat, square, round, or in any fancy section. The housing and coupling these trains can be understood from the roughing-rolls just now given, without a special figure. All are arranged upon the same principles; only, the lighter the work the longer may be the trains, and more rollers in a train. The frames or housing for the rolls are made of cast-iron, as seen in section on Fig. 2410, which shows, on a scale of one-twelfth, an assemblage of three cylinders in a train, suitable for finishing light bars. This section also serves to illustrate Fig. 2408. These frames should, of course, be set as solidly as possible; for instance, upon a cast-iron bed-plate, bolted to a timber foundation built in with masonry. This seems better than masonry alone, because of a certain elasticity in wood. If slots are left in the bed-plate, the frames will be found of easier adjustment. The bed-plate should be open in the middle, leaving a trench that may catch the cinder that comes off from the bars, as well as the water that drips on, and that may serve as a cellar to the foundations.

For rolling flat bars, the cylinders are grooved alternately and work reciprocally in each other; for round or square bars, however, half their section is turned out of each cylinder. The diameter in the one case, and a diagonal in the other, correspond with the normal surface of the cylinders before being turned out. In turning out grooves, &c., for fancy patterns, a good deal of ingenuity is sometimes exercised, as will be seen in the descriptions and figures under the article Railroad Bars.

The reciprocal fitting of the grooves for flat bars renders a longitudinal dislocation of the rolls impossible. With the others, such dislocation is ordinarily sought to be guarded against by strong screws in the frames; but it is much better to have a groove and collar turned in one or both extremities of all cylinders. Vertical displacement is prevented by the head-screw seen in the figure; and a lateral adjustment is, in some cases, given by horizontal screws working through the trussing against the plumber-blocks. There is usually a play of about a quarter of an inch allowed in the blocks and couplings, to obviate immediate fracture in case of slight derangement; and also to throw the breakage, if an accident does occur, upon these parts rather than on the cylinders, which are the costly parts of the machinery. It is easy to see that upon the truth of all the movements depend freedom from accident, and excellence and economy of work. It is, therefore, cheapest to have every thing made of the best material and in the best manner.

In rolls for flat iron, the diameter of the cylinders is usually the same; for round and square iron, the upper cylinder is often a little (say half an inch) larger than the lower. If there are more than two cylinders, the same practice is found, in some places, of making their diameters regularly decrease (by say a quarter of an inch) from the upper to the lower. In others, and perhaps in the generality of cases, the middle of the three is the largest. Some metallurgists, on the contrary, object entirely to this difference of diameter, as causing increased friction in the machinery, and straining the iron. This objection is theoretically correct. The aim of the contrivance is to prevent the bar, as it passes through the rolls, from curling around the upper cylinder; if this last be larger, it will continue to bear on the bar after the resistance of the lower roll has ceased, and will, of course, tend to force it down upon the apron. But this tendency to curl is best corrected by having *guards* to each groove—i. e., wedges of wrought-iron, which catch the bar as it comes out.

The diameter of the cylinders, and their bearing, vary according to the purpose for which they are intended. Roughing-rolls for puddle-balls are from 18 to 20 inches diameter, and 5 to 6 feet long; for piled iron or rough bars, from 12 to 14 inches diameter, and 5 feet long. Finishing-rolls for heavy bar will be of the same diameter with the last, but from 12 to 18 inches shorter; while for small rods their diameter need not be more than 8 to 10 inches, and their bearing about 2½ feet. The weight of a pair of roughing-rolls is from 4 to 5 tons, and of finishing-rolls from 1½ to 2 tons.

In geering up the rolls, the lower one is the driver, when there are only two; in a train of three rolls, the middle one drives. The velocity of rotation varies according to size and purpose, and even according to the state and quality of metal. Roughing-rolls should work slow: for puddle-balls 16 to 18 revolutions, and for piled iron 22 to 24 revolutions per minute, are sufficiently rapid. For finishing-rolls, this may be increased to 70 or 80 revolutions; while small rods are rolled with 120, 150, and sometimes even 200 revolutions per minute. But these high speeds are liable to frequent accidents.

The friction of the machine, and the initial temperature of the material to be rolled, heat the journals and cylinders very much. To abate this a wooden trough is laid above the train, from which water may drip on the machinery and metal under treatment. The effect is, to keep both the cylinders and metal clean.

The size of the grooves, and their proportionate spacing, varies in different countries; and the last particular even in different establishments. The methods for it are purely geometrical, and present nothing peculiar in the manufacture of iron. The constant rule prevails here, as in all lamination, viz., to place the largest grooves and the heaviest work nearest to the end at which the power is applied.

With a single pair of cylinders the bar always enters on the same side. As it comes out on the other, it is caught by a second workman, who, with the aid of a travelling-stirrup, hands it over the rolls to the first. When the cylinders are triple, the rods enter alternately first on one side and then on the other. The process with the single pair is time-consuming, but it does not seem likely to be bettered, unless by having two trains parallel to each other, which would admit of the alternation of entry as in the triple rolls. Such an arrangement would increase the first cost of machinery, but the work would be done cheaper and better.

Such are the particulars which belong to the finishing of ordinary merchant-bars. The processes by which iron is further prepared for special uses will be detailed more appropriately under separate heads. Thus, the rolling of iron for railroads—an enormous branch of trade—will be treated under RAILROAD BARS; the lamination of plates and sheets, together with the further preparations for several purposes that these undergo in the mill, will come under SHEET-IRON; the cutting up of these in making nails, hoops, &c., will be grouped under the head SLITTING-MILL; the extensive and remarkable apparatus by which this reluctant metal is shaped with chisel and drill, as if it were only wood, will be described under the articles LATHE PLANING-MACHINE, and TURNING (OF IRON;) and as far as relates to the boring of cannon, under ORDNANCE; the methods followed in drawing it out into WIRE, will be explained under that title; and, finally, under SMITH-WORK will be contained all that class of operations before indicated, which comprehend all the processes of hand-forging and welding, (as for anchors, chains, horse-shoes, &c.,) and of steeling and tempering, (as for cutlery, &c.,) practised in an art whose exercise has originated the most extensive and well-known family name in the world.

History.—There is room here only for the indication of epochs signalized by inventions that have given fresh impulses or new directions to the manufacture. From the earliest times till at least 800 A. D., the processes were either primitive, or, with unimportant modifications, gave only a more or less malleable metal direct from the ores, which were necessarily those that fused readily. The fuel, originally *wood*, had been changed, during this period, to *charcoal*—though by whose ingenuity, or when, there is no record. Some writers place about the termination of this era, which is that of Charlemagne, the introduction of crude iron. This seems an antedating by at least four centuries.

A. D. 1340. Earliest epoch of crude or cast-iron; employed as ordnance by the Duke of Normandy, afterwards John II. of France.

1490. Usual epoch of foundries.
1550. Epoch of wooden blowing-machines.
1612–19. Fossil-fuel (pit-coal) first used for reducing iron in England.
1640. Invention of *trampes*, or water-blasts.
1645–56. Epoch of foundries in America.
1740. Pit-coal and coke used in high furnaces.
1749. Invention of rotary or fan-blasts.
1760. First cast-iron cylinder blowing-machine.
1780. Epoch of the puddling-furnace.
1784. Epoch of the rolling-mill.
1829. Discovery of the application of hot blast.
1836. Application of the waste gases from the high-furnace.
1837. Anthracite used as a fuel with hot blast.

During the intervals between these dates, and since the last, divers improvements, both in theory and practice, have been suggested and executed, but none of them of palmary importance.

Statistics.—The following table, covering the last 10 years, contains what is known or can be estimated in regard to Great Britain and the United States—the two principal producers and consumers in the world:

Years.	Great Britain Manufacture.	United States.		
		Manufacture.	Imported from Great Britain.	
			Crude Iron.	Bar Iron.
1840	1,396,000 tons.	286,000 tons.	5,516 tons.	32,829 tons.
1841	1,200,000 "	250,000 "	12,268 "	63,056 "
1842	1,088,000 "	215,000 "	18,694 "	61,599 "
1843	1,215,000 "	350,000 "	3,873 "	15,758 "
1844	1,210,000 "	490,000 "	14,944 "	37,891 "
1845	1,513,000 "	625,000 "	27,510 "	51,189 "
1846	1,675,000 "	765,000 "	24,188 "	24,109 "
1847	1,840,000 "	800,000 "	23,377 "	32,085 "
1848	1,999,000 "	750,000 "	51,632 "	81,589 "
1849	2,150,000 "	600,000 "	105,632 "	173,457 "

The following table may be of interest as showing the range and relation of value and price in the two countries for the same period:

Years.	Average Valuation in U. S. Custom-Houses.	Average Price of Scotch Pig in Glasgow.	Average Valuation in U. S. Custom-Houses.	Price, at beginning of Year, of Bar-Iron in Liverpool.
1840	$21 per ton.	$19 per ton.	$52 per ton.	$43 per ton.
1841	18 "	16 "	35 "	37 "
1842	16 "	13 "	33 "	31 "
1843	12 "	10 "	32 "	25 "
1844	13 "	13 "	28 "	24 "
1845	18 "	21 "	33 "	31 "
1846	20 "	17 "	47 "	43 "
1847	20 "	16 "	53 "	46 "
1848	16 "	11 "	45 "	36 "
1849	13 "	10 "	35 "	28 "

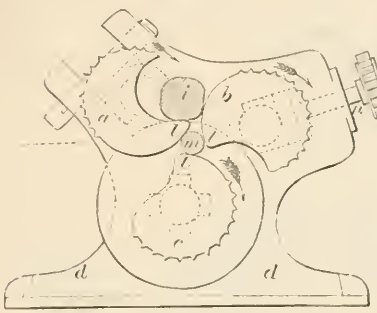
Sterling money is here converted, purposely, only to the nearest dollar.

Within the past ten years, of other countries only Belgium, France, Italy, and Prussia have extended their manufacture of iron; but the statistics of these which are accessible do not warrant a continuous statement. It may be safely assumed, however, that the aggregate production of the world in 1849 did not fall short of *four millions of tons*—an increase of 60 per cent. over 1839. Such, and so growing, is the importance of this metal.

Bibliography.—Among ancient authors need be mentioned only Aristotle, *Meteorolog., lib.* iv., and *De mirab. Auseultat., lib.;* Diodore of Sicily, *Histor., lib.* v.; Strabo, *Geograph., libb.* iv. v. x.; of the Greek writers: and of Latin, the elder Pliny, Hist. Natur., lib. xxxiv. In connection should be taken Hausmann, de arte Ferri conficiendi veterum, 1820. In modern times, Agricola, *de re Metallica*, 1546; Reaumur, *L'art d'adoucir le fer fondu*, etc., 1722; Swedenborg, *Regnum Subterran.*, 1734; Bergman de Analysi Ferri, 1781; and the Swede Rinman, *Forsök till jernets-historie*, 1785, (Researches into the History of Iron, and translated into German by Karsten,)—compose a class who needed only a truer chemical theory to direct and bind up their observations. Such a theory—begun to be exemplified in the memoir of Berthollet, Vandermonde, and Monge, upon the different states of iron, *Hist. de l'Acad. des Sciences*, 1786—was more elaborated in the four quartos of Hassenfratz, *La Siderotechnie*, 1812; and underwent a final establishment in Karsten's *Handbuch der Eisenhütten Kunde*, first published in 1816, translated from a second German edition under the title of *Metallurgie de Fer*, by Culman, in 1830, and republished in a third German edition in 1844. Use has been made, in both of the last editions, of the same author's *Metallurg. Reise durch Baiern, etc.*, 1821. Other writers who since then have contributed facts or explanations, will be mentioned chronologically: for instance, Berzelius, in his *Afhandlingar i Fysik, Kemi, &c.*, (a periodical begun in 1806,) where there are several important announcements, which were subsequently collected and translated by Hervé under the title of *Chimie de Fer*, 1826; the same Berzelius in Manual of Chemistry, (*Traité de Chimie*, vol. iii.,) translated into French by Jourdan; Manson, *Traité de Fer et de l'Acier*, 1826; Pelouze, *l'Art du Maître de Forges*, 1827; Landrin, *Manuel Complet du Maître de Forges*, 1829; Berthier, *Essais par la Voie Sèche, tom.* ii., 1834; Holland, *Manufactures in Metal, vols.* i. ii., 1834; Gnenyvean, *Nouveaux Procedés pour fabriquer la Fonte et le Fer*, 1835; Dufrênoy, De Beaumont, Coste, and Perionnet, *Voyage Metallurgique en Angleterre*, (2d edition,) 1837; Le Blanc and Walter, *Metallurgie Pratique du Fer*, 1835–38; Scrivenor, *History of the Iron Trade*, 1839–41; Mushet, Papers on Iron and Steel, (being a collection and revision of papers published many years before in Tillock's Philos. Mag.,) 1840; Johnson, *Anthracite Iron*, 1841; Alexander, *Progress and Present State of the Manufacture of Iron*, 1841, and an edition of Rogers's *Letters on Iron-Making*, 1844; Flachat, Barrault, and Petiet, *Traité de la Fabrication de la Fonte et du Fer*, 1846; and Overman, *The Manufacture of Iron in all its various Branches*, 1850. Authors who have treated of the mechanical resistance of this metal are, Duleau, *sur la Resistance du Fer forgé*, 1820; Tredgold, *Essay on Cast-Iron, &c.*, (2d edition, enlarged,) 1824, and with additions by Hodgkinson, 1842–46; Turnbull, *on Cast-Iron*, 1832; Navier, *Mémoire sur les Ponts Suspendus*, 1830, and *Resumé des Leçons, &c.*, (2d edition,) 1833—in the first volume of which there is a copious collection of the results of preceding experimenters. Besides these, there are to be consulted upon the theory and practice, upon the minerals, material, and manufacture of iron, papers in various scientific journals which can only be generally indicated: for example, in the *Ann. de Chimie et de Physique* of Guyton-Morveau, Arago, Berthier, Thenard, &c.; in the *Journal des Mines* of Collet Descotils, Vauquelin, &c.; in the *Annale des Mines* of D'Aubuisson, Bunsen, Ebelmen, Thirria, &c.; in the *Annalen of Poggendorff*, of Mosander, Rose, and Seebeck; in the *Archiv. für Bergbau of Karsten*, of Berzelius, and Karsten; in the *Phil. Transact.*, and in the *L. and E. Philosoph. Mag.* of Rennie and Daniell, &c.: many of which would require examination and discussion in a complete modern treatise on iron.

Improved Machines for the Manufacture of Iron.—Various machines have been contrived for the squeezing out the cinder from the puddle ball; the best is probably the hammer, and it is generally used in the manufacture of the best iron. A common form of squeezers called the *alligator* is shown

2411.



2412.

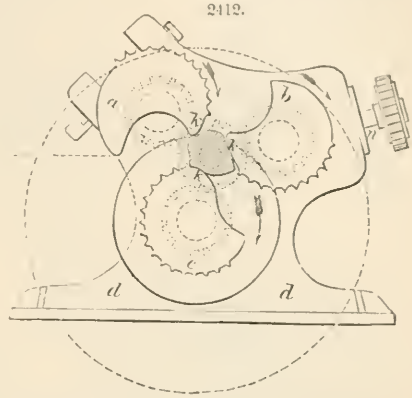
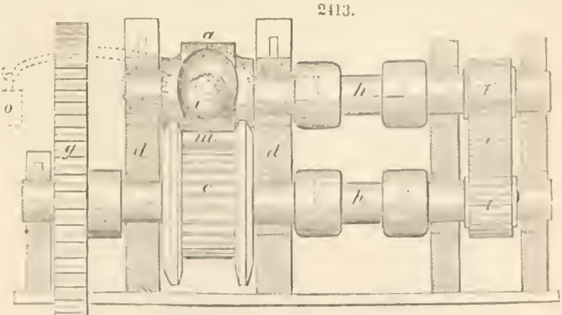


fig. 2406, an improvement over the "Burden's Patent Eccentric Rotatory Squeezers," illustrated in fig. 2407. A machine somewhat similar in its action, will be found under the head of PUDDLER'S BALLS.

Figs. 2411, 2412, and 2413, illustrate an English machine, patented by Mr. Jeremiah Brown, and intended to serve the same purpose. The machine consists of three large eccentric rollers *a*, *b*, *c*, placed horizontally in the strong holsters *d d*, the centres of the rollers being arranged in a triangular position and the bottom roller *c*, nearly central between the two top rollers *a*, *b*: these rollers rotate in the same direction as shown by the arrows, and are driven by a centre pinion *e*, working into three pinions of equal size *f f f*, fixed on the roller spindles. In the present machine, the driving power is applied direct to the bottom roller, by means of the large wheel *g*, for the convenience of carrying the main shaft under the floor, but it could be applied to the centre pinion if preferred. The rollers are cast solid, with their journals like ordinany rollers, and are driven in the usual manner by coupling boxes and spindles *h h*. The roller faces are sixteen inches long, and the bottom roller has strong flanges at each end 8 inches deep, between which the two upper rollers work; the object of these flanges is to upset or compress the ends of the bloom, as the iron in the operation is elongated, and the ends are forced against the flanges which make them square and sound. The top roller *a* has a large hollow, in which the puddled ball *i* is placed by the puddler; and this roller carries the ball round, and drops it into the space between the three rollers, as shown in fig. 2412, this space being at that moment at its largest capacity. The three projecting points *k k k*, of the rollers immediately impinge upon the ball, and compress it forcibly on the three sides, and, giving a rotating motion to the ball at the same time, they have a very powerful kneading action upon the iron, squeezing out the cinder very effectually, which flows freely away, down each side of the bottom roller. The space between the rollers gradually contracts, from the eccentric or spiral form of the rollers, thereby maintaining an increasing compression on the iron on all sides and the ends, until it is liberated by the points *l l l* simultaneously passing the bloom *m*, which falls down in the direction of the arrow and is discharged from the machine at the same moment that another ball is dropped in at the top of the machine. The projecting teeth on the surface of the rollers assist this action, by seizing hold of the iron and kneading into it as it rotates; and these teeth gradually diminish in projection, the last portion of each roller being plain, and the bloom is consequently turned out in a smooth compact form. The space between the flanges of the bottom roller is

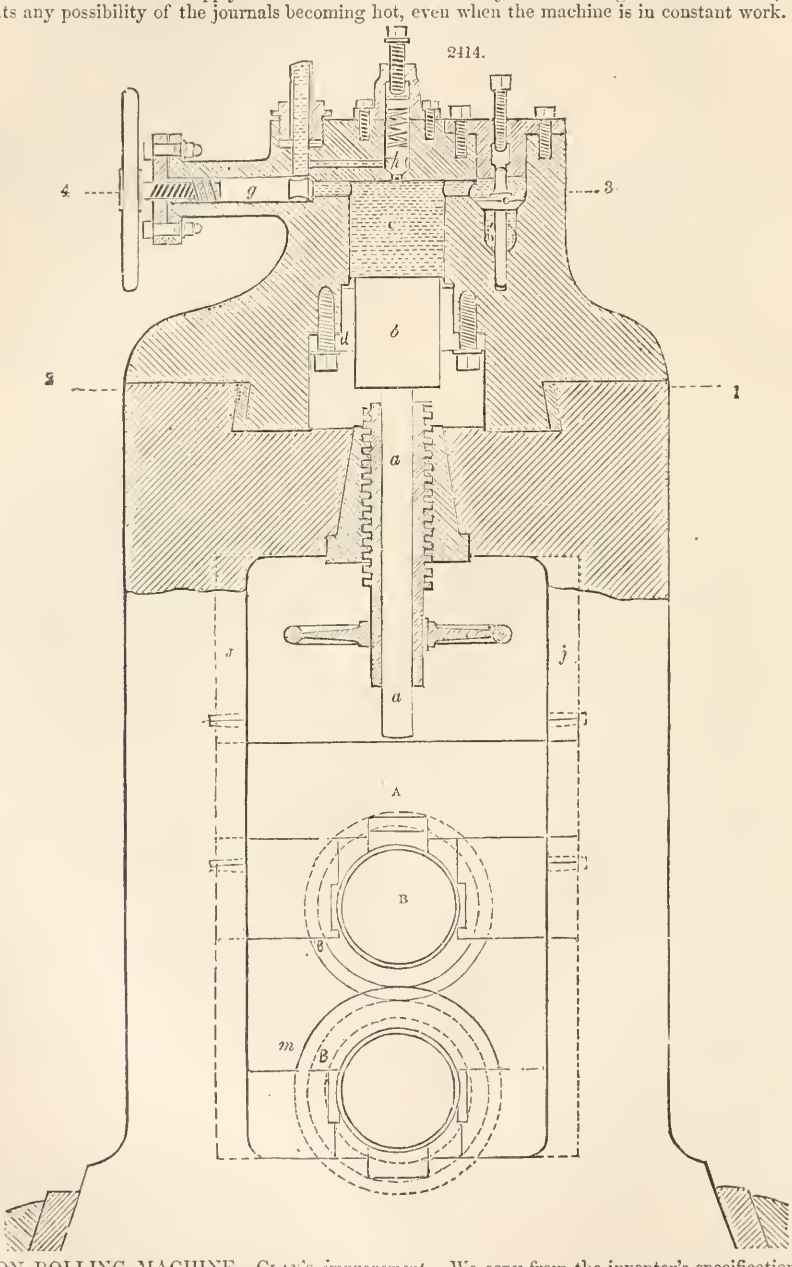
2413.



widened for a short distance beyond the point *l*, for the purpose of allowing the bloom to drop out readily, and admitting the fresh ball.

A provision is made to prevent risk of breaking the rollers by any unusual size of ball being put in, by means of the two large triple-threaded screws *n n*, which bear upon the journals of one of the top rollers *b*; a small pinion on the head of each of these screws works into a large pinion fixed between them, which has a horizontal lever fixed to it, carrying a balance weight *o* at the end; this weight causes a constant equal pressure on the roller, and in the case of any ball of extra size being put into the machine, the screws yield by turning back and lifting the weight to the extent that may be required, so that a large ball will be worked with the same pressure and in the same effective manner as the smaller sizes. A continual supply of water is run on to all the journals throughout the machine, which prevents any possibility of the journals becoming hot, even when the machine is in constant work.

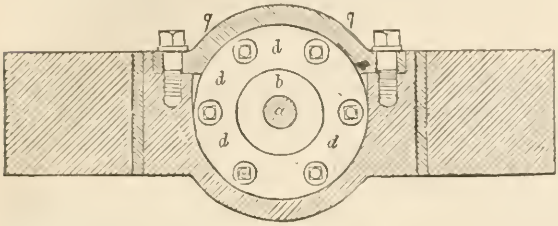
2414.



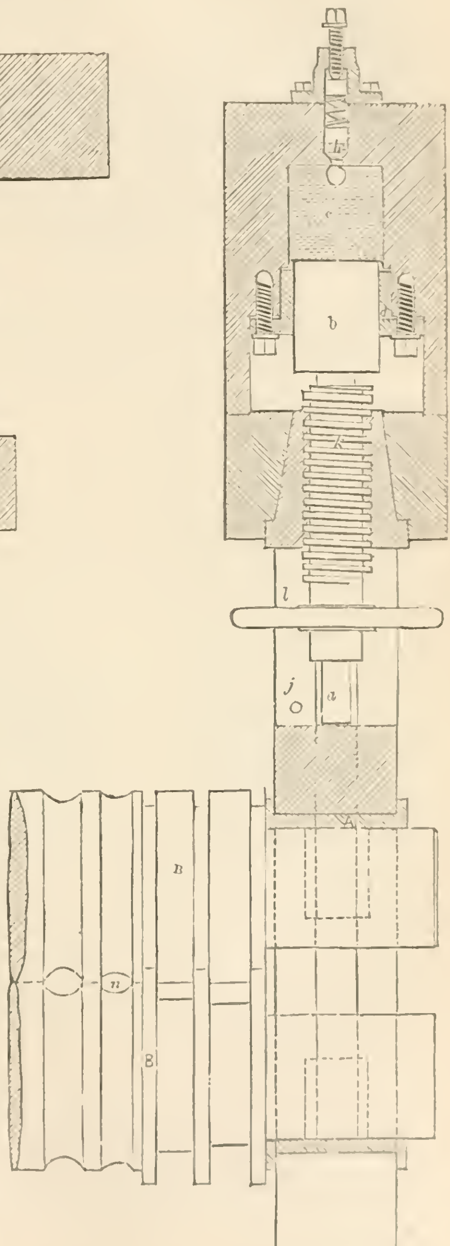
IRON ROLLING MACHINE—CLAY'S *improvement.* We copy from the inventor's specification: My invention of certain improvements in machinery, for rolling iron or other metals, is designed to produce, by the process of rolling, bars of taper forms, as for instance wedge-shaped bars or conical bars.

The tapering of metal bars I effect by allowing one of the shaping-rollers to recede gradually from the other, as the rolling operation goes on, and thus enlarge the space or distance between the rollers,

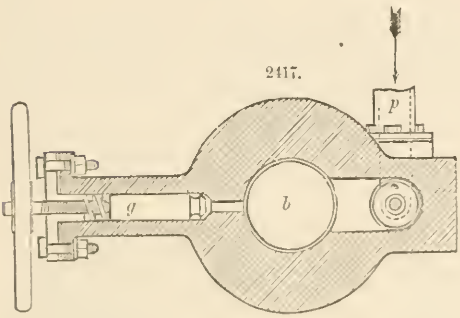
2416.



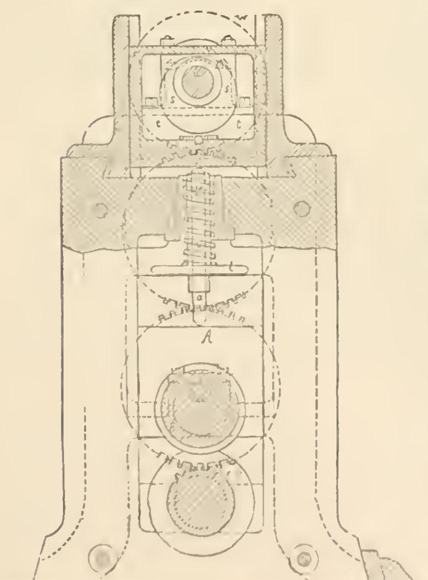
2415.



2417.



2418.



whereby the metal, in passing between them, is made to assume a gradually increasing thickness, either in a wedge, conical, or other form, according to the shape of the grooves cut in the rollers.

My invention consists in the adaptation to rolling machinery of pistons, bearing against confined columns of water, or other non-elastic fluid, the ends of the piston-rods maintaining or affording the means of keeping the bearings of the rollers from shifting their positions, excepting as the columns of water are allowed to relax their resistance by a slow and gradual escape of the fluid from the cylinder, or chamber through an adjustable valve. The apparatus I have arranged for this purpose is shown in the accompanying drawings, in which fig. 2414 represents a vertical section, taken transversely through the head of one of the standards, wherein the bearings of the journals of the rollers are mounted, showing the piston, its rod and appendages, with the column of water against which the piston bears, and the valve whereby a small quantity of the fluid may be allowed gradually to escape. Fig. 2415 represents a partial front view of the rollers, the bearings, and part of the regulating apparatus in the head of the standard, being shown in section.

Of course, it will be understood that two such standards support the ends of the rollers. Fig. 2416 is a horizontal section, taken in the line 1, 2, of fig. 2414, showing the parts inverted, or as seen from below; and fig. 2417 is another horizontal section, taken on the upper side in the line 3, 4, of fig. 2414, showing the entrance and exit valves of the chamber of water, and the means of working or regulating the exit valve. In the rolling-mills usually employed for rolling bar-iron, the rollers are generally mounted in fixed bearings, or bearings which during the operation of rolling, are rendered immovable, by being maintained in their places by strong screws or bolts.

In my improved machinery, or apparatus, the ends of the bearing A, of the upper roller, are let into grooves in the standards, as in ordinary rolling-mills, in such a manner as to admit of their sliding up and down therein, in order that, by so sliding, the parallel distances between the rollers may be allowed to change.

The rising of the bearings with the upper roller is regulated and governed by a piston-rod *a*, which rests on the top of the bearings, the upper end of the piston-rod being connected to the solid piston *b*, of the hydraulic cyllnder, or water-chamber *c*, as shown in figs. 2414 and 2415.

This cylinder *c*, is filled with water, or other non-elastic fluid or liquid, and is furnished with leather or other suitable packing, for the purpose of preventing any leakage of the water.

The packing is kept in its place by a metallic ring or plate *d*, which is firmly secured to the body of the cylinder by strong screw-bolts.

The cylinder is supplied with water from any convenient source, by a lateral tube *p*, shown in fig. 2417, through the rising feed-valve *e*, the construction and operation of which will be clearly understood by referring to the drawing.

f is the exit-valve, through which, when partially opened, the water is allowed to escape from the chamber *c*, on pressure being applied to the lower end of the rod *a*, by which pressure the piston *b* will be made to rise and partially to expel the water, as will be the case when a bar of iron is passed between the shaping rollers B B. The valve *f* is constructed in such a manner that the opening for the discharge of the water may be regulated with the greatest exactness by merely advancing or receding the plug *g*, worked by the screw at its back end, the effect of which will be to open or close the valve to any extent that may be required.

There is a slight spring behind the plug *g*, which is merely intended to push it forward and close the aperture of the valve when the upward pressure of the piston is not in action, as will be the case when the rolling operation is suspended. An additional valve *h*, is also made to communicate with the exit-passage *i*. This valve, however, is always kept closed by a strong spring, as shown, and will never allow any water to escape this way from the cylinder, except when any extraordinary pressure takes place, at which time the power of the spring will be overcome, and, by yielding, prevent the machinery from being too greatly strained.

In introducing into my improved machinery a mass of iron between the shaping-rollers, say for the purpose of producing a wedge-formed bar, having parallel edges, I employ a pair of rollers of the ordinary kind, having the grooves and flanges, as shown in fig. 2415.

The mass of iron being about to be introduced between the rollers in the first groove, I open the valve *f*, by withdrawing the screw behind the plug *g* to such an extent as will allow the escape of water from the chamber *c* in a small current, regulating the opening for the intended discharge according to the required taper of the bar to be formed, the required extent of which opening will readily be found by the experience of the workman. The operation of rolling now proceeding, the pressure of the metal passing between the rollers will cause the bearings of the upper roller to rise and force up the piston-rod *a*, in doing which the piston will be made to rise in the chamber *c*. But the ascent of the piston being resisted by the non-elastic fluid in the chamber *c*, the escape of water through the valve *f* and outlet *i* must take place to allow of the ascent of the piston, and consequently the separation of the rollers: according, therefore, to the rate of the escape of water will the taper or inclined shape of the bar to be produced be determined.

It will thus be seen that, by my improved apparatus, the process of rolling metals is carried on much in the usual manner, except that, by means of opening the valve more or less, the escape of the water from the chamber will allow the upper roller to rise, and consequently give the requisite taper form to the bar under operation, according to the rapidity with which the water is allowed to flow out of the chamber. As I do not intend to confine myself to any particular forms of bars to be produced by my improved machinery, it is not necessary to describe more precisely the shapes of the rollers. I will therefore only add, that by forming the grooves of the rollers in elliptical shapes, as at *n n*, in Fig. 4010, I am enabled, by the gradual rise of one of the rollers, and repetitions of the rolling operation, to produce bars of conical figures.

It is sometimes desirable to roll a bar taper or wedge-formed, for a portion of its length, and level for the remainder of its length.

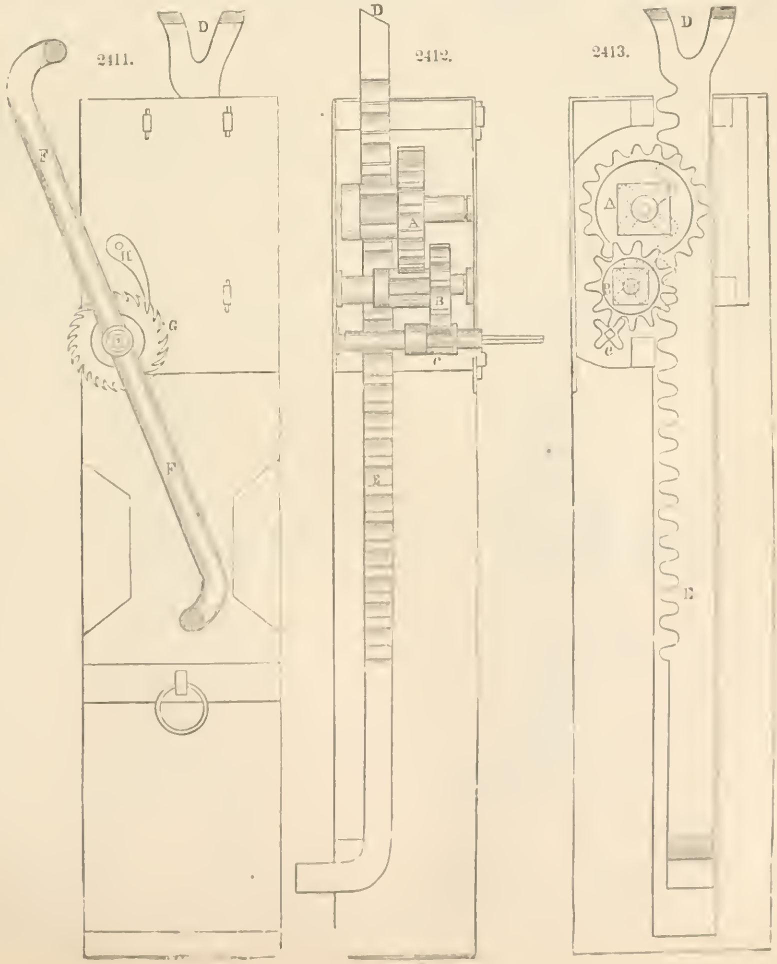
For this purpose, it will be necessary to allow the upper roller to rise to a certain distance only, and then to stop. This I effect by means of adjusting-screws *k k*, one over each bearing of the rollers, similar to those heretofore used, except that it is through the axes of the adjusting-screws, forming guides, that the piston-rods *a* pass, as shown in the drawing at Fig. 2414; and it will, therefore, be understood that when, by the escape of the water from the chamber, the bearings of the rollers have been allowed to force up the piston-rod and the piston a certain determined distance, that then the upper edge of the bearing A, of the top roller will come into contact with the under side of the adjusting-screw *k*, beyond which it cannot rise, and as the bearings will, for a time, become fixed, the bar of iron under operation will, for the remaining portion of the process, be rolled parallel.

The adjusting-screw *k*, passes through a hollow screw made in a socket fixed in the frame, and the screw can be easily raised or lowered, so as to limit the rise of the bearing A, by merely turning the hand-wheel *l*, attached to its lower part.

It may be as well to observe that the standards or housings may be of any convenient known pattern, and that a lever or other known balance may be used with advantage to support the roller in its rise and fall. A portion, also, of the head of the standard in which the piston works is made removable for the purpose of getting at the piston and packing when required, as will be seen at *q q*, in figs. 2415 and 2416.

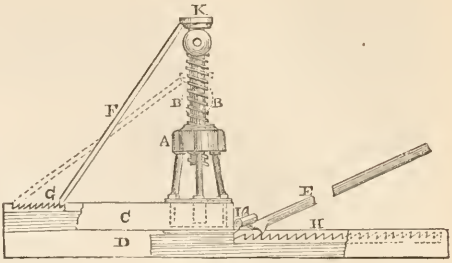
JACK. In mechanics, a sort of crane for raising heavy weights. It consists, first, of a small pinion wrought with a common winch. This pinion works in the teeth of a large wheel, on whose axis there is fixed a small pinion with teeth, working in a rack. The turning of the handle raises the rack, and of course any weight attached to it. If the length of the handle of the winch be 7 inches, and the pinion which it drives contain 4 leaves, working in the teeth of the large wheel having 20 teeth, then will 5 turns of the handle be requisite for one of the wheel. But the length of the arm of the winch being 7 inches, the circumference through which the handle moves will be about 44 inches, and for one turn of the wheel the handle must pass through $5 \times 44 = 220$. The wheel carries a pinion of, say, 3 leaves, of a pitch of $\frac{1}{3}$ of an inch, working the rack that carries the weight; one turn of the pinion will, therefore, raise the rack one inch, and as the power moves through 220 in the same time, 220 will be the power of the jack.

JACK-SCREW. Figs. 2411, 2412, and 2413 represent a plan of a jack-screw for turning large stone, used at the United States Dry Dock, Brooklyn.

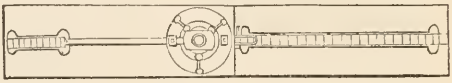


JACK, TRAVERSING SCREW. Figs. 2415 and 2416 exhibit a side view and plan of the screw modification. The screw-jack A is bolted to the plank C; at the other end of the plank is fixed the rack G, in which the toe of the strut F advances as the screw B is elevated; the strut works in a joint in the follower K: the position of the strut when the screw is depressed is shown by the dotted lines. The object of this strut is to relieve the screw of the violent cross-strain to which the apparatus is subject, when the engine or carriage is pulled over by the lever; which strain is entirely transferred to the strut, and the screw has merely to carry the load.

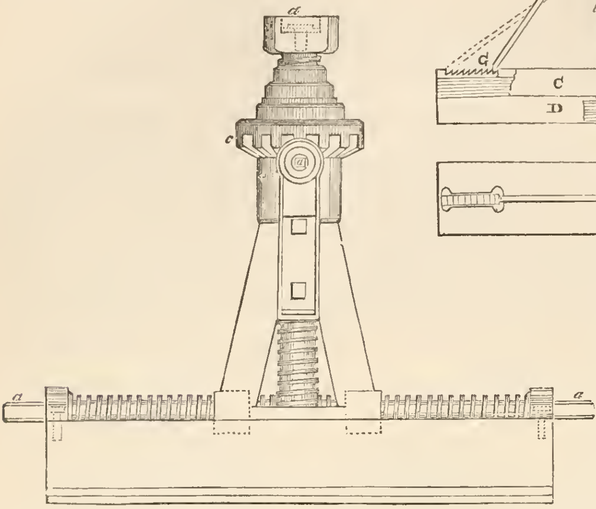
2415.



2416.



2417.

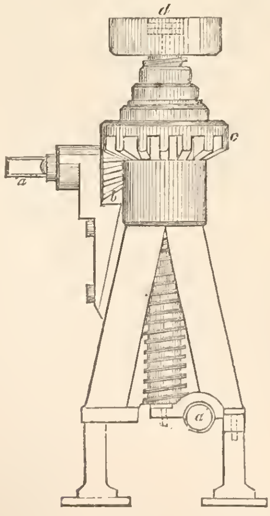


The operation of traversing the jack is as follows: By hooking the link I upon the hook of the lever E, the toe of the lever being inserted into a ratch of the rack H of the lower plank, when a man bearing down the end of the lever, drags the apparatus and engine or carriage towards him with great facility; the same lever is used to turn the screw, and to produce the traverse motion.

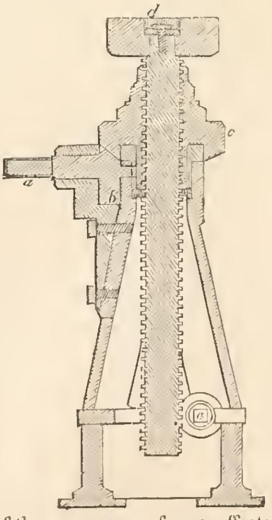
JACK, TRAVERSING. Another form of traversing jack is shown at fig. 2417, side elevation; fig. 2418 end elevation, and fig. 2419 section through vertical screw.

The lift of this jack is effected by means of a crank, or lever, applied to the axis *a*, which works the bevel-geer *b c*, the latter geer being cut on the projecting face of the nut *c;* the revolution of this nut lifts or lowers the vertical screw, and with it the jaw *d;* the screw-head moving freely in a socket of the jaw-head, permits the latter to rise or fall without side movement.

2418.



2419.



The horizontal screw *a a*, working into a nut in the foot of the upper screw-frame, effects the horizontal or traversing movement of the jack, the frame of the lower screw serving as a bed or slide for the latter movement. A ratchet-lever may be used to work either of the screws instead of a crank.

The Hydraulic Jack (Patent Portable Hydraulic Jack, R. Dudgeon, New York) is the simplest and most portable in comparison with the force it is capable of exerting. This jack, or press, appears to the eye, when depressed, a simple cylinder, and when elevated, to one cylinder sliding within another. It is from two to eight or more inches in diameter, according to the power desired, with an enlarged head (attached to the inner cylinder, which is the ram), having a socket for the reception of the lever, by which the piston of the force pump is worked.

The ram, with its head, contains just so much water or other fluid as is required to fill the vacancy in the cylinder, caused by the raising of the ram in the act of lifting; and when this is accomplished the water is returned into its original recess by a valve operated by the lever that works the pump. The force pump, piston and valves are contained inside of the ram.

The lever is detached, and may be put on at pleasure. The joints in the head maintain a parallel motion for the force pump piston, which is the fulcrum of the lever. The ground-lifting attachment is an iron tube screwed into the lower side of the head, and passing down to the bottom of the press outside of the cylinder, on the lower end of which is a claw that supports the weight to be raised.

These presses are light, portable, and of easy application. A press to raise four tons not weighing more than 50 lbs., and one to raise 60 tons, not more than 200 lbs. They are all worked by the labor of one man only, which is capable of raising ten tons through a space of one foot in one and a half minutes, or sixty tons the same distance in ten minutes.

JACQUARD. A peculiar and most ingenious mechanism, invented by M. Jacquart of Lyons, to be adapted to looms for superseding the employment of draw-boys, in weaving figured goods.

Fig. 2420 is a front elevation of this mechanism, supposed to be let down. Fig. 2421 is a cross section, shown in its highest position. Fig. 2422 the same section, but seen in its lower position.

A, is the fixed part of the frame, supposed to form a part of the ordinary loom; there are two uprights of wood, with two cross-bars uniting them at their upper ends, and leaving an interval *x y*, between them, to place and work the movable frame B, vibrating round two fixed points *a a*, placed laterally opposite each other, in the middle of the space *x y*, fig. 2420.

C, is a piece of iron with a peculiar curvature, seen in front, fig. 2420, and in profile, figs. 2421 and 2422. It is fixed on one side upon the upper cross-bar of the frame B, and on the other, to the intermediate cross-bar *b*, of the same frame, where it shows an inclined curvilinear space *c*, terminated below by a semi-circle.

D, is a square wooden axis, movable upon itself round two iron pivots, fixed into its two ends; which axis occupies the bottom of the movable framo B. The four faces of this square axis are pierced with three round, equal, truly-bored holes, arranged in a quincunx. The teeth *a*, fig. 2424, are stuck into each face, and correspond to holes *a*, fig. 2427, made in the cards which constitute the endless chain for the healds; so that in the successive application of the cards to each face of the square axis, the holes pierced in one card may always fall opposite to those pierced in the other.

The right-hand end of the square axis, of which a section is shown in double size, fig. 2423, carries two square plates of sheet iron *d*, kept parallel to each other and a little apart by four spindles *e*, passed opposite to the corners. This is a kind of lantern, in whose spindles the hooks of the levers *f f'*, turning round fixed points *g g'*, beyond the right hand upright A, catch hold, either above or below, at the pleasure of the weaver, according as he merely pulls or lets go the cord *z*, during the vibratory movement of the frame B.

E, is a piece of wood shaped like a T, the stem of which, prolonged upwards, passes freely through the cross-bar *b*, and through the upper cross-bar of the frame B, which serve as guides to it. The head of the T piece being applied successively against the two spindles *e*, placed above in a horizontal position, first by its weight, and then by the spiral spring *h*, acting from above downwards, keeps the square axis in its position, while it permits it to turn upon itself in the two directions. The name *press* is given to the assemblage of all the pieces which compose the movable frame B B.

F, is a cross-bar made to move in a vertical direction by means of the lever G, in the notches or grooves *i*, formed within the fixed uprights A.

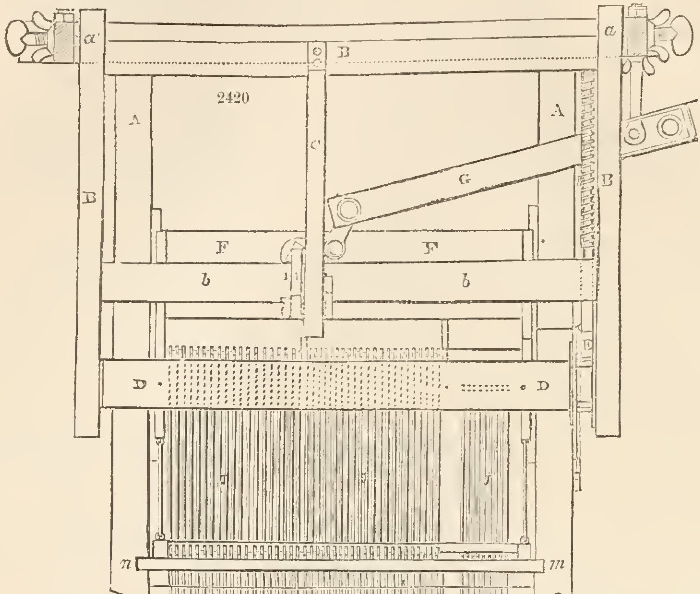
H, is a piece of bent iron, fixed by one of its ends with a nut and screw, upon the cross-bar F, out of the vertical plane of the piece C. Its other end carries a friction roller J, which working in the curvilinear space *c* of the piece C, forces this, and consequently the frame B, to recede from the perpendicular or to return to it, according as the cross bar F is in the top or bottom of its course, as shown in figs. 2421 and 2422.

I, cheeks of sheet iron attached on either side to the cross-bar F, which serves as a safe to a kind of claw K, composed here of eight small metallic bars, seen in section figs. 2421 and 2422, and on a greater scale in fig. 2424.

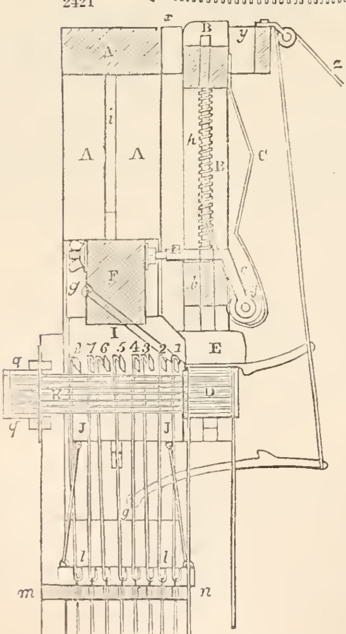
J, upright skewers of iron wire, whose tops, bent down hookwise, naturally place themselves over the little bars K. The bottom of these spindles, likewise hooked in the same direction as the upper ones, embraces small wooden bars *l*, whose office is to keep them in their respective places, and to prevent them from twirling round, so that the uppermost hooks may be always directed towards the small metallic bars upon which they impend. To these hooks from below are attached strings, which after having crossed a fixed board, *m n*, pierced with corresponding holes for this purpose, proceed next to be attached to the threads of the loops destined to lift the warp threads. K K, horizontal spindles or needles, arranged here in eight several rows, so that each spindle corresponds both horizontally and vertically to each of the holes pierced in the four faces of the square axis D. There are therefore as many of these spindles as there are holes in one of the faces of the square.

Fig. 2425 represents one of these horizontal spindles. *n* is an eyelet through which the corresponding vertical skewer passes. *o* another elongated eyelet, through which a small fixed spindle passes to serve as a guide, but which does not hinder it from moving lengthwise, within the limits of the length of the eyelet. *p* small spiral springs placed in each hole of the case *q q*, fig. 2421. They serve to bring back to its primitive position, every corresponding needle, as soon as it ceases to press upon it.

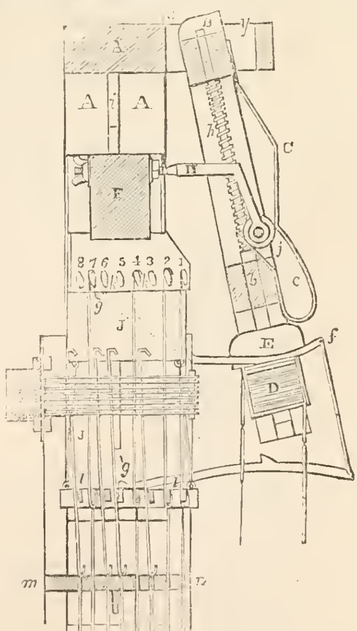
Fig. 2426 represents the plan of the upper row of horizontal needles. Fig. 2427 is a fragment of the endless chain, formed with perforated cards, which are made to circulate or travel by the rotation of the shaft D. In this movement, each of the perforated cards, whose position, form and number, are determined by the operation of tying-up of the warp, comes to be applied in succession against the four faces of the square axis or drum, leaving open the corresponding holes, and covering those upon the face of the axis, which have no corresponding holes upon the card.



2421



2422

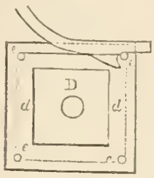


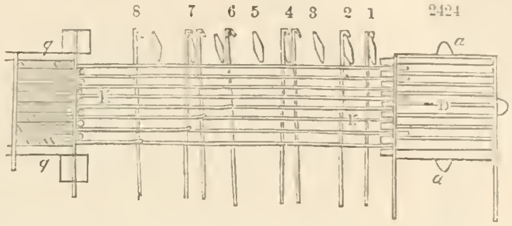
Now let us suppose that the *press* B is let down into the vertical position shown in fig. 2422; then the card applied against the left face of the axis, leaves at rest or untouched the whole of the horizontal spindles (skewers), whose ends correspond to these holes, but pushes back those which are opposite to the unpierced part of the card; thereby the corresponding upright skewers, 3, 5, 6, and 8, for example, pushed out of the perpendicular, unhook themselves from above the bars of the claw, and remain in their place, when this claw comes to be raised by means of the lever G; and the skewers 1, 2, 4, and 7, which have remained hooked on, are raised along with the warp threads attached to them. Then by the passage across of a shot of the color, as well as a shot of the common weft, and a stroke of the lay after shedding the warp and lowering the press B, an element or point in the pattern is completed.

The following card, brought round by a quarter revolution of the axis, finds all the needles in their first position, lifts another series of warp threads; and thus in succession for all the other cards, which compose a complete system of a figured pattern.

If some warp yarn should happen to break without the weaver observing them, or should he mistake

2423





2424

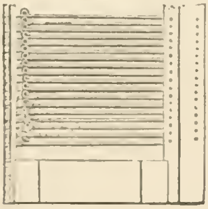
2425

his colored shuttle yarns, which would so far disfigure the pattern, he must undo his work. For this purpose, he makes use of the lower hooked lever f', whose purpose is to make the chain of the card go backwards, while working the loom as usual, withdrawing at each stroke the shot both of the ground and of the figure. The weaver is the more subject to make mistakes, as the figured side of the web is downwards, and it is only with the aid of a bit of looking-glass that he takes a peep of his work from time to time. The upper surface exhibits merely loose threads in different points, according as the pattern requires them to lie upon the one side or the other.

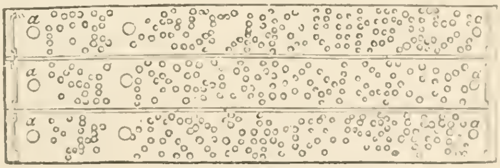
Thus it must be evident, that such a number of paste-boards are to be provided and mounted as equal the number of throws of the shuttle between the beginning and end of any figure or design which is to be woven; the piercing of each paste-board individually, will depend upon the arrangement of the lifting rods, and their connection with the warp, which is according to the design and option of the workman; great care must be taken that the holes come exactly opposite to the ends of the needles; for this purpose two large holes are made at the ends of the paste-boards, which fall upon conical points, by which means they are made to register correctly.

It will be here seen, that, according to the length of the figure, so must be the number of paste-boards, which may be readily displaced so as to remount and produce the figure in a few minutes, or

2426



2427



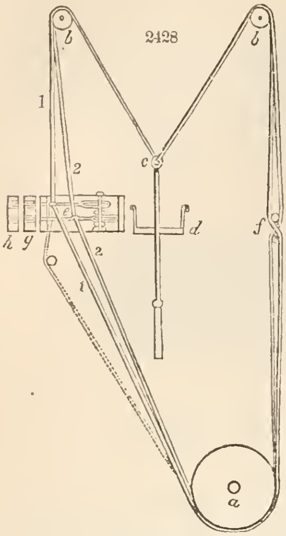
remove it, or replace it, or preserve the figure for future use. The machine, of course, will be understood to consist of many sets of the lifting rods and needles, shown in the diagram, as will be perceived by observing the disposition of the holes in the paste-board; those holes, in order that they may be accurately distributed, are to be pierced from a gauge, so that not the slightest variation shall take place.

To form these card-slips, an ingenious apparatus is employed, by which the proper steel punches required for the piercing of each distinct card, are placed in their relative situations preparatory to the operation of piercing, and also by its means a card may be punched with any number of holes at one operation. This disposition of the punches is effected by means of rods connected to cords disposed in a frame, in the nature of a false simple, on which the pattern of the work is first read in.

These improved pierced cards, slips, or paste-boards, apply to a weaving apparatus, which is so arranged that a figure to be wrought can be extended to any distance along the loom, and by that means the loom is rendered capable of producing broad figured works; having the long lever G placed in such a situation that it affords power to the foot of the weaver, and by this means enables him to draw the heaviest morintures and figured works, without the assistance of a draw-boy.

The machinery for arranging the punches, consists of a frame with four upright standards and cross pieces, which contains a series of endless cords passing under a wooden roller at bottom, and over pulleys at the top.

Fig. 2428 represents a single endless cord 1 1, which is here shown in operation, and part of another endless cord 2 2, shown stationary. There must be as many endless cords in this frame as needles in the weaving-loom a is the wooden cylinder, revolving upon its axis at the lower part of the standard; b b



the two pulleys of the pulley-frames above, over which the individual endless cord passes; *c* is a small transverse ring. To each of these rings a weight is suspended by a single thread, for the purpose of giving tension to the endless cord. *d* is a board resembling a common comber-bar, which is supported by the cross-bars of thestandard frame, and is pierced with holes, in situation and number, corresponding with the perpendicular threads that pass through them; which board keeps the threads distinct from each other.

At *e* the endless cord passes through the eyes of wires resembling needles, which are contained in a wooden box placed in front of the machine, and shown in this figure in section only. These wires are called the *punch projectors;* they are guided and supported by horizontal rods and vertical pins, the latter of which pass through loops formed at the hinder part of the respective wires. At *f* are two horizontal rods extending the whole width of the machine, for the purpose of producing the cross in the cords; *g* is a thick brass plate, extending along in front of the machine, and lying close to the box which holds the *punch-projectors;* this plate *g*, shown also in section, is called the *punch-holder;* it contains the same number of apertures as there are punch-projectors, and disposed so as to correspond with each other. In each of these apertures there is a punch for the purpose of piercing the cards, slips, or pasteboards with holes; *h* is a thick steel plate of the same sizeas *h*, and shown likewise in section, corresponding also in its number of apertures, and their disposition, with the punch-projectors and the punch-holder. This plate *h*, is called the *punch-receiver.*

The object of this machine is to transfer such of the punches as may be required for piercing any individual card from the punch-holder *g*, into the punch-receiver *h;* when they will be properly situated, and ready for piercing the individual card or slip, with such holes as have been read in upon the machine, and are required for permitting the warp threads to be withdrawn in the loom, when this card is brought against the ends of the needles. The process of transferring the patterns to the punches is thus effected.

The pattern is to be read in according to the ordinary mode, as in a false simple, upon the endless cords below the rod *f*, and passed under the revolving wooden cylinder *a*, to a sufficient height for a person in front of the machine to reach conveniently. He there takes the upper threads of the pattern, called the *beard*, and draws them forward so as to introduce a stick behind the cords thus advanced, as shown by dots, for the purpose of keeping them separate from the cords which are not intended to be operated upon. All the punch-projectors which are connected with the cords brought forward, will be thus made to pass through the corresponding apertures of the punch-holder *g*, and by this means will project the punches out of these apertures, into corresponding apertures of the punch receiver *h*. The punches will now be properly arranged for piercing the required holes on a card.

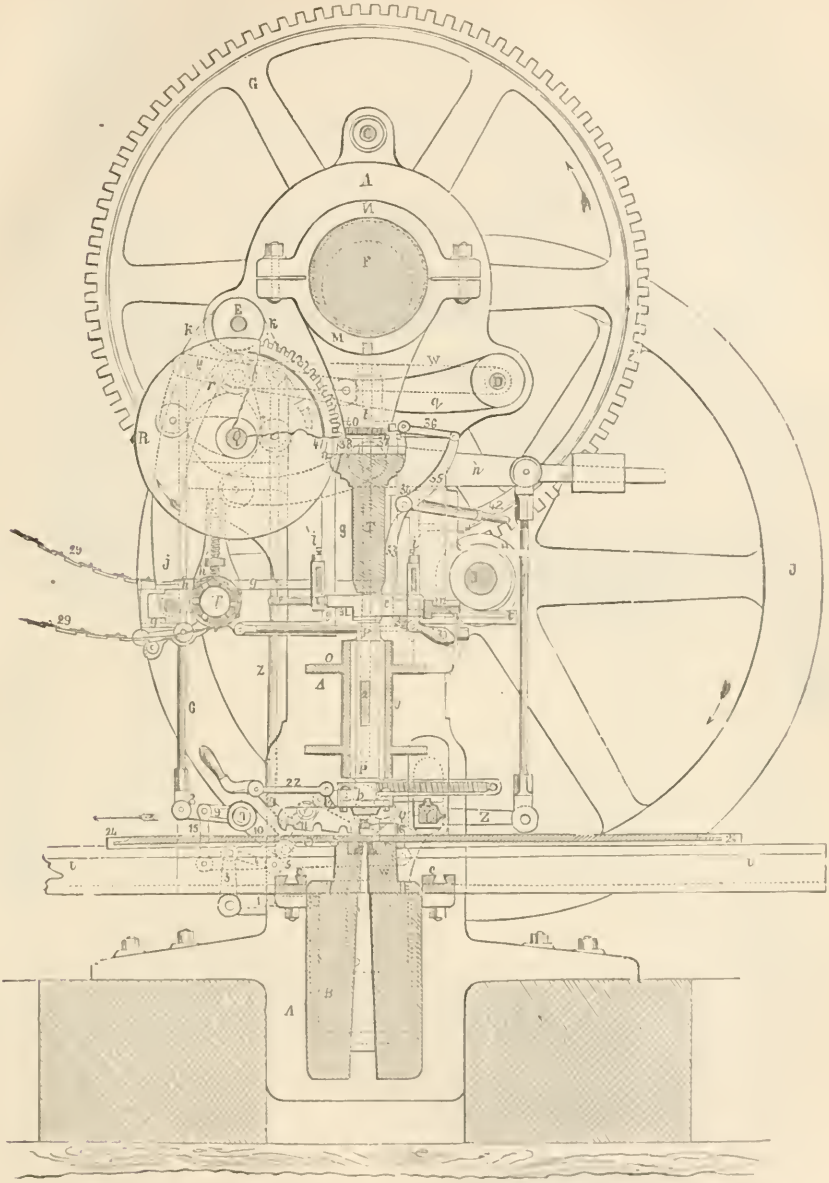
Remove the punch-receivers from the front of the machine; and having placed one of the slips of card or pasteboard between the two folding plates of metal, completely pierced with holes corresponding to the needles of the loom, lay the punch-receiver upon those perforated plates, to which it must be made to fit by mortices and blocks, the cutting parts of the punches being downwards. Upon the back of the punch-receiver is then to be placed a plate or block, studded with perpendicular pins corresponding to the above described holes, into which the pins will fall. The plates and the blocks thus laid together, are to be placed under a press, by which means the pins of the block will be made to pass through the aperture of the punch-receiver; and wherever the punch has been deposited in the receiver by the above process, the said punches will be forced through the slip of pasteboard, and pierced with such holes as are required for producing the figured design in the loom.

Each card being thus pierced, the punch-receiver is returned to its place in front of the machine, and all the punches forced back again into the apertures of the punch-holder as at first. The next set of cords is now drawn forward by ths next *beard*, as above described, which sends out the *punch-projectors* as before, and disposes the punches in the punch-receiver, ready for the operation of piercing the next card. The process being thus repeated, the whole pattern is, by a number of operations, transferred to the punches, and afterwards to the cards or slips, as above described. See Loom.

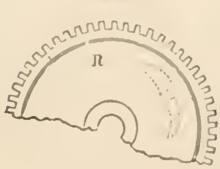
JACQUARD PERFORATING MACHINE. Machine for perforating metal plates, such as are used for steam-boilers, &c.; and employed for punching the plates of the tubular bridge at Conway, made at the Globe Works, Manchester, by Messrs Roberts, Fothergill & Co.

Fig. 2420 represents a sectional elevation of the machine; Fig. 2421 an elevation of the back of the machine; Fig. 2422 a plan view of the apparatus for putting the punches out of action without stopping the fly-wheel; and Fig. 2423 a plan view of a few of the jacquard plates. Fig. 2426 represents a front elevation; Fig. 2427 a side elevation; and Fig. 2428 a horizontal section, taken through the dotted lines A^1A^1, in Figs. 2426 and 2427. Fig. 2429 is a detached view of the traverse apparatus, and Fig. 2430 a detached view of the holding-down or stripping apparatus. A A the standards. B the bed, through which there is an opening for the punchings, or metal punched out of the plate, to fall through; this bed is inserted into the standards. C a stretcher-bar, to connect the top of the standards. D, fulcrum of the levers *q q* which withdraw the punches, and of the lever *w* which traverses the plate. E a fulcrum shaft, to which the levers *j j* and *k k* are keyed. F the main or eccentric shaft, working in bushes in the standards. G a spur-wheel, keyed on the eccentric-shaft. H a pinion, working into the wheel G. I the fly-wheel shaft, on which are the fast and loose pulleys K and L, the pinion H, and the fly-wheel J. M M connecting-rods, fitted to the eccentric necks of the shaft F. N N caps of the connecting-rods M M

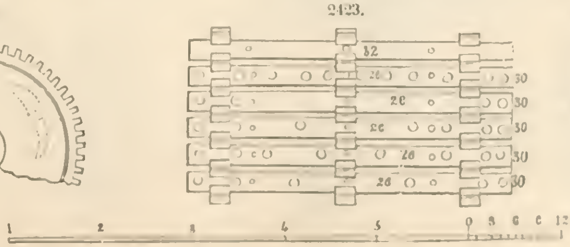
2420.



2425.



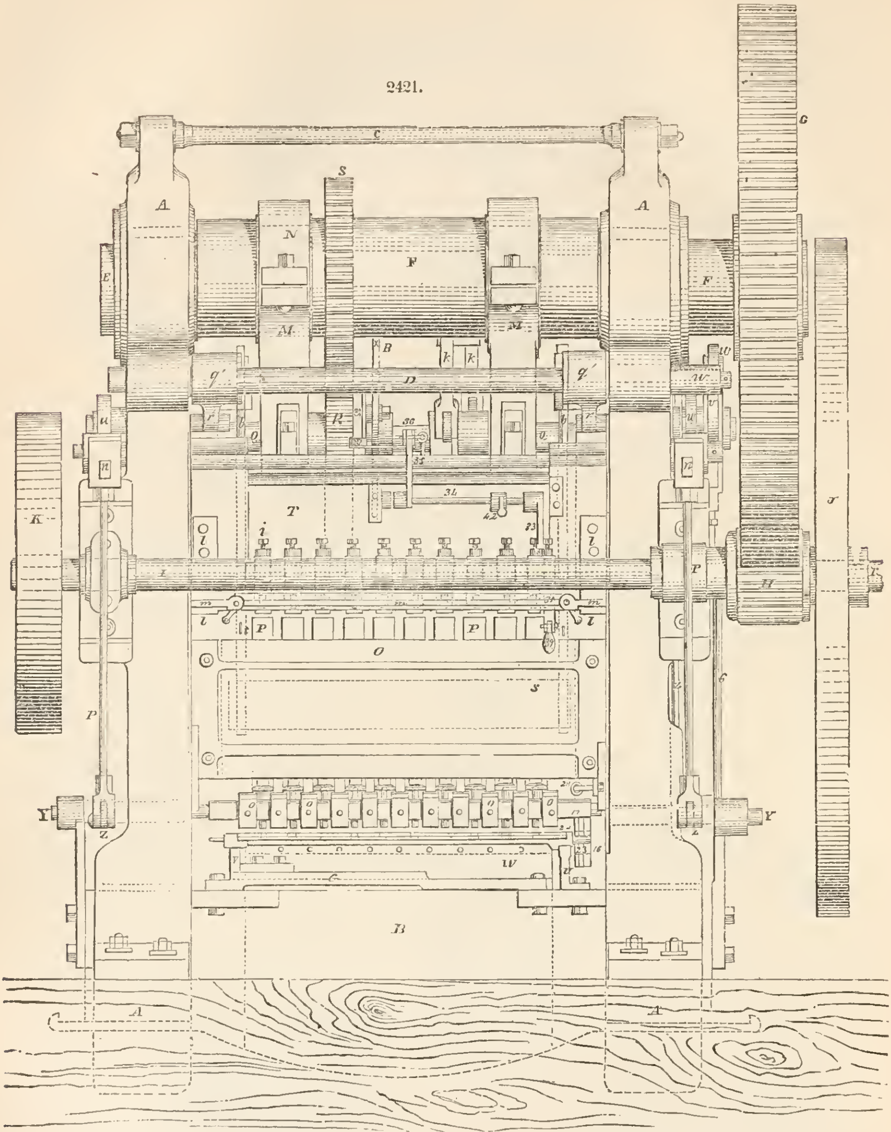
2423.



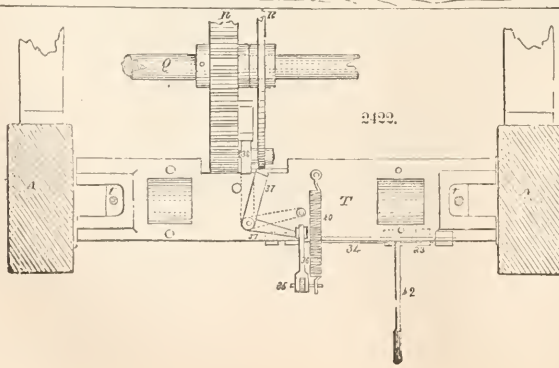
2424.

O O guide-plates for the punch-rams P P. Q the cam-shaft. R a spur wheel, loose on the cam-shaft and having on one side two projections, between which there is an opening. R* a locking disk or plate

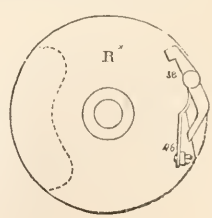
2421.



2422.



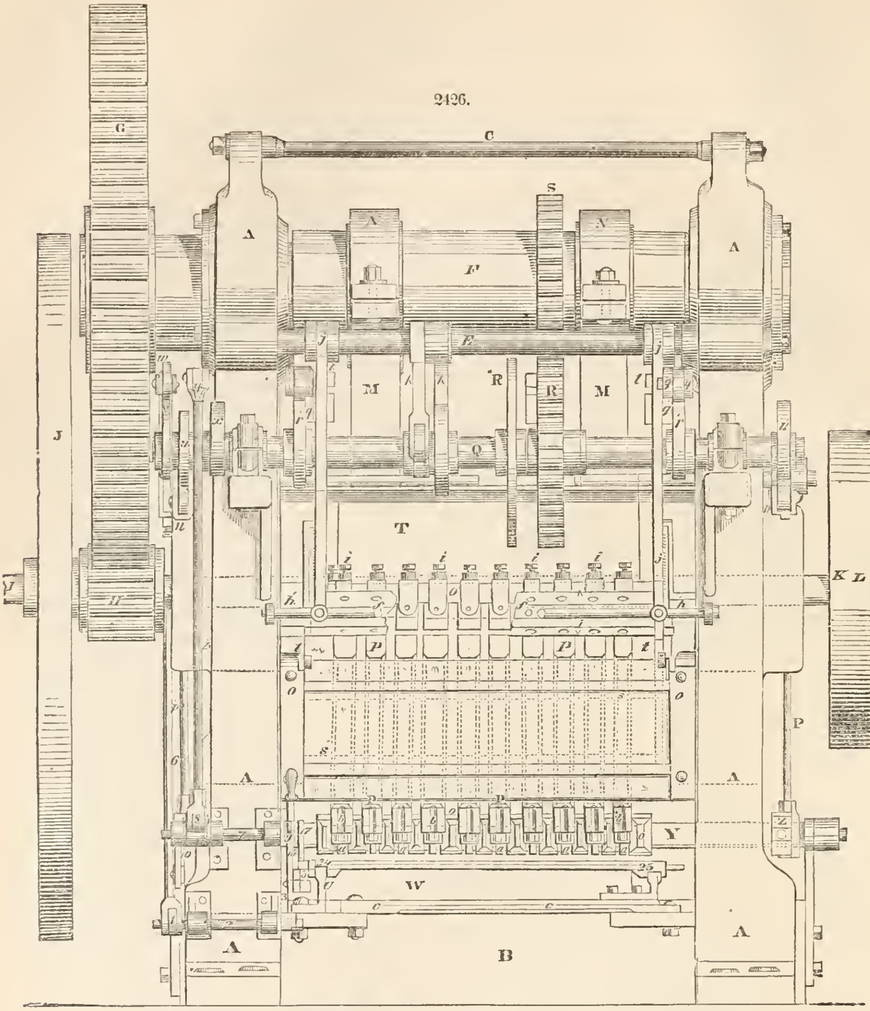
2425².



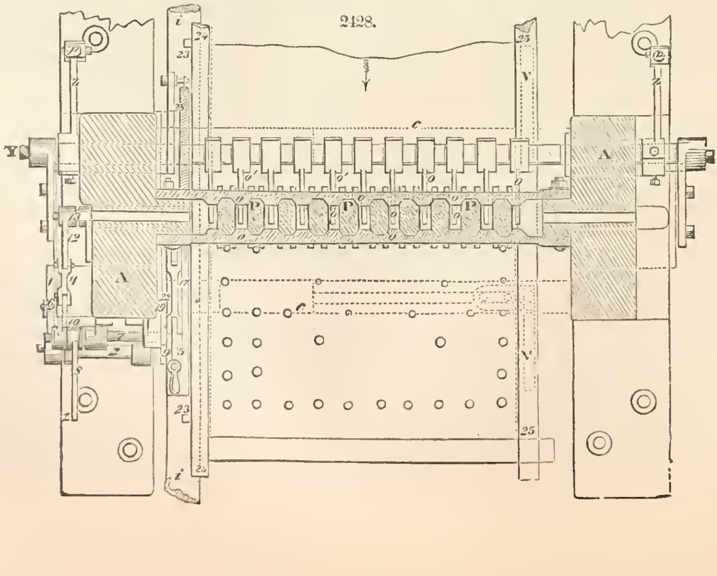
keyed on the shaft Q, having upon it a spring-catch 38, which takes into the opening between the projections on the wheel R. R and R* are seen detached in Fig. 2425,2425²: the dotted lines on R* represent a weight to counterbalance the levers *k*. S a toothed-wheel, keyed on the main-shaft F. T the punch-ram depressor, secured to the connecting-rods M M by knuckle-joints at the lower end of the connecting-rods. U a slide-bar, on which the frame traverses which carries the plate to be punched. V V two short slide-bars, to carry one side of the traverse-frame. W a block of iron, fastened with short wedges to the bed B to carry the die-plate X, into which the dies *d* are inserted, and prevented from rising by a collar at the lower end of each, as seen in Fig. 2430. Y a square shaft, carrying the holding-down levers or stripping-fingers *o o* Z Z levers on each end of the shaft Y. *a a* the punches let into the punch-holders *b b* bolted to the rams P, as seen in the detached view, Fig. 2424. *c c* pieces bolted to the bed B to carry the adjusting slide-bars V V. *d* dies inserted into the holder X. *e e*, Fig 2420, are the selecting slide-bars, which, when allowed to pass through the card-plate, enter the card roller *f*, without being pushed backwards by them; the card-roller has in this case six sides, and the belt of jacquard-plates, after passing over it in the usual manner, passes over a round roller suspended in a swing-frame, at such an angle as shall keep the belt moderately tight, whilst the roller *f* advances towards and recedes from the selectors *e*. *g g* brackets projecting from the depressor T, and carried up and down with it. *h h* sliding-blocks, in which the journals of the card-roller turn. To an upright cast on each of these blocks, is fitted a rod of round iron, thus *, with a flat foot, long enough to extend over two of the six pins in the ends of the card-roller, against which the flat foot of the rods is made to press, by spiral-springs coiled around them in the usual manner employed in the jacquard-loom, which is generally known, and need not be further described. *i i*, Fig. 2420, are two sets of guide-blocks, for the selectors *e*, one on each side of the depressor, adjustable laterally by set-screws on flat bars, extending across the machine; the use of these blocks is to carry the selecting-bars *e*, which are round at the end that enters the cards, and flat at the other end, to keep them in their proper positions; the centre portion of each selecting-bar is a solid piece of iron, projecting as much below the round stem as will, when the selecting-bar is driven backwards by a card-plate, permit the depressor T to complete its downward stroke without the selecting-bar touching the ram P under it. *j j* are levers keyed on the shaft E, and connected at their lower end by links to the slide-blocks *h h*. *k k* are levers also keyed on the shaft E, and having each a friction-roller at its lower extremity. On the shaft Q are two cams, one of which works a lever *k* on one side of the shaft, and the other cam works the other lever *k* on the opposite side. One of the cams, through the medium of the levers *j j*, and the links before referred to, causes the roller *f* to approach the selecting-bars *e*, and the other cam causes the roller to recede from them, until, by a catch employed in the ordinary way in the jacquard-looms, the roller *f* is made to turn through one-sixth of a revolution, and is then retained in that position by the pressure of the spiral-spring and flat foot above referred to. *l l* are brackets attached to the depressor T at the back of the machine. *m* a bar resting on the brackets *l l*, and connected by rods with the sliding-blocks *h h*, which, on receding, cause the bar *m* to bring all the selecting-bars *e* into the position for depressing the rams, as seen in Fig. 2430. *n n* are levers having their fulcra on studs screwed into the standards; one end of these levers is connected by a rod *p* with the levers Z Z; the other end is furnished with a roller which is acted upon by a cam *u* on the shaft Q. *o o* are the holding-down levers, adjustable laterally on the shaft Y, so as to admit of one of them being placed on each side of every punch. *p p* are rods connecting the levers *n* and Z. By adjusting the length of these rods, the levers *o o* are made to press upon plates of different thicknesses, so as to hold the plates down while the punches are being withdrawn. *q q* levers turning on the fulcrum-bar D for withdrawing the punches by means of the cams *r r* that actuate levers *q q*. *s* a broad but rather thin bar, extending through the series of punch-rams P, shown by dotted lines. The punch-rams P are made with slots, through which the bar *s* passes, and these slots must be about two inches longer than the width of the bar *s*, in order to allow the punch-rams to be forced down when the bar is at the bottom of its stroke. *t t* are links connecting the bar *s* with the levers *q q*. *u u* are cams which depress the holding down levers *o o*, through the medium of the levers *n n*, rods *p p*, and levers Z Z, and hold down the plate while the punches are being withdrawn. *v* a cam for the traversing rack 5. *w* a lever turning on the fulcrum-bar D, and worked by the cam *v*. *x* the cam for lifting the rack 5. *y* a lever turning on a stud in the standard, and worked by the cam *x* for lifting the traversing-rack 5. *z* a rod connecting the lever *y* with the lever 8. 1 is a lever on the traverse-shaft 2; 3 another lever on the shaft 2. 4 a link connecting the lever 3 with the rack 5. 6 a rod connecting the lever *w* with the lever 1 for traversing the rack 5. 7 a shaft for carrying the levers 8, 9, and 10. 11 a link connecting the levers 10 and 12. 13 a shaft carrying the levers 12 and 14. 15 and 16 are links connecting the rack 5 with the levers 9 and 14. 17 the upper or retaining rack. 18 a stud carrying the elbow-lever 19, which is provided with a handle. 20 another stud carrying the elbow-lever 21, which is connected by a link 22 with the lever 19. The rack 17 is carried on studs in the horizontal arm of the levers 19 and 21. 23 division-studs in the bar 24 of the traversing-frame.

The plate to be punched is put into a traversing-frame formed of two side-bars 24 and 25, and two stretcher-bars secured by cottars to the side-bars, which are rabbeted to support the plate, and, when required, furnished with clamps to hold the plate down. 24 represents one of the sides of the traversing-frame, in which there is a groove to fit on the slide-bar U; into the outer side of the bar 24 is screwed a series of studs 23, represented in the engravings as being 12 inches from centre to centre apart from each other. The side 25 of the frame slides on the bars V V. When the plates to be punched are very long, rollers may be used to carry the projecting ends of the traversing-frame. In Fig. 2428 is shown part of a frame, with a plate partly perforated. The racks 5 and 17, Fig 2429, are drawn with three teeth in the length of a foot, which will divide plates to a four-inch pitch; but it will be obvious, that for a different pitch the racks must be changed, and it may in some cases, (such as when the pitch required is not an aliquot part of a foot,) be necessary to alter the distance between the studs 23. Fig. 2429 represents the traverse apparatus, in the position it will be in when the retaining

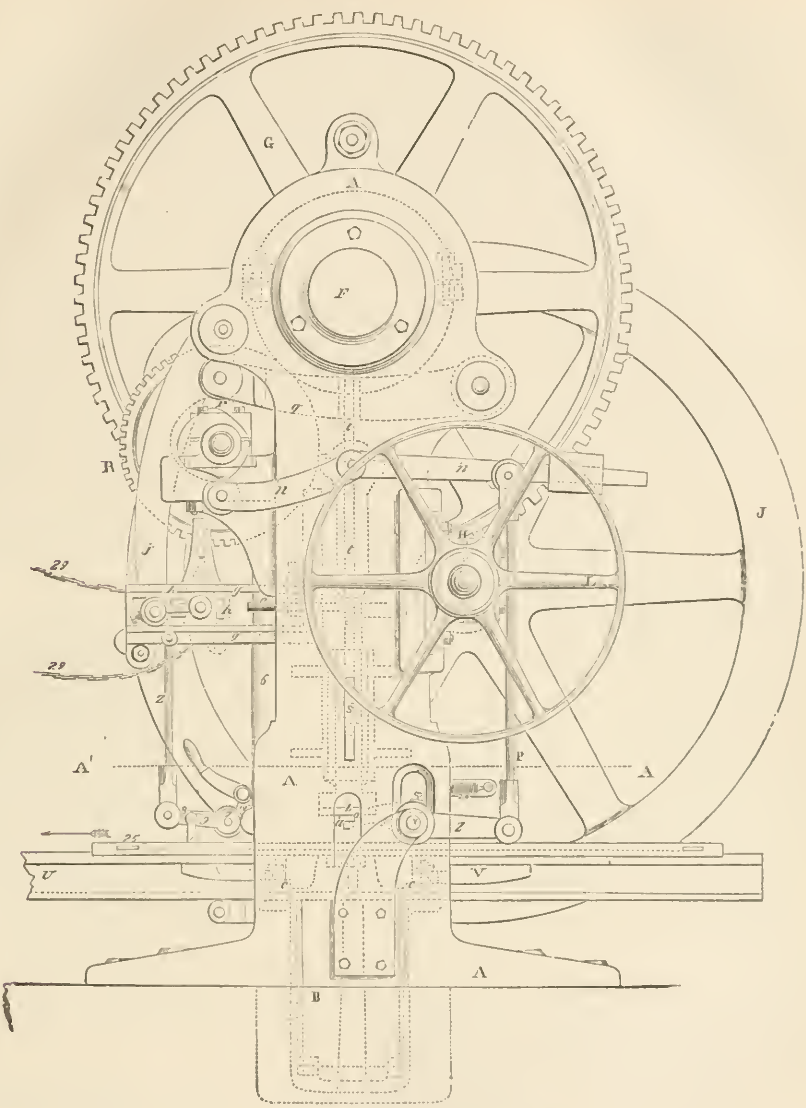
2426.



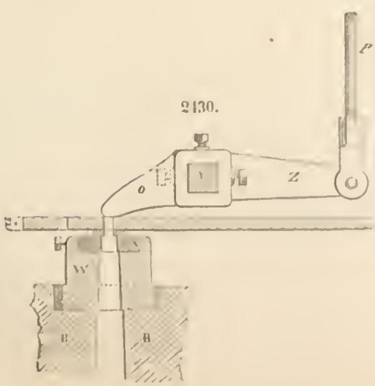
2428.



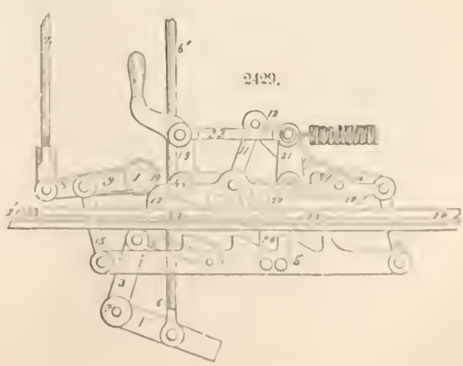
2427.



2430.



2429.



rack is down, and the punches in the act of passing through the plate, and the traversing-rack having completed its return-stroke.

When the punches are being raised, the traversing-rack will rise also; and by the side-piece 26 (which is attached to it) acting against the roller 27, on a stud in the rack 17, will raise it also, and set the frame at liberty to be advanced by the cam *x*, through the mechanical means already described. In Fig. 2420 this traverse apparatus is shown in the position it assumes when the plate is advancing. The spiral-spring 28 acts on the lever 21, and forces the rack 17 down on to the pins 23. For every hole required to be punched in line with the width of the plate under operation, a corresponding hole must be made in a plate of the jacquard, and an additional hole, marked 30, is also made, into which the stopping-bar 31 enters at every stroke until the punching be completed, at which time the jacquard-plate 32, which is left blank, will push all the selecting-bars *e* beyond the rams P, and at the same time, by pushing the bar 31, disengage the cam-shaft Q, by the mechanism to be hereafter explained, at the point where the punches and the levers *o* are held up, and thus will allow the perforated plate to be taken out of the machine, and another plate to be put into it. The stopping-bar 31 is provided with a projection on its lower surface, which depresses the click-lever 39 when the bar is pushed back; the lever 33 is keyed on a shaft 34, moving in bearings at the back of the depressor; on the other end of the shaft 34 is keyed the lever 35, to the upper end of which is attached the link 36, connecting it with the elbow-lever 37; the end of the other arm of this lever is inclined, for the purpose of unlocking the plate R*, and is provided with a stud, on which is a latch 38, the tail of which comes in contact with the incline on the elbow-lever 37, when it is in the position shown in dotted lines in Fig. 2422; and as the wheel R revolves, the latch becomes disengaged from the opening between the two projections cast on the said wheel, at which time the cam-shaft Q ceases to revolve. When the stopping-bar 31 has been pushed back, it depresses the lever 39, and liberates the lever 33 from behind the projection on the lever 39, when the spring 40 will pull the elbow-lever 37 into the position shown in dotted lines. To the blocks *h* a small shaft is attached, on which are two levers, suspending by links a plate of metal similar to a blank card-plate, except that the holes for the guide-pins are cut at the bottom edge. At each end of the same shaft is a lever-handle, held up or down by a side-spring in the ordinary way. The use of this apparatus is as follows: Should it be required to stop the machine before the plate is finished, by raising the lever here referred to, the blank plate will come in front of the roller, and will act the part of a blank jacquard-plate, and stop the machine.

Having now described the principal parts of the machine, we shall proceed to explain the manner of its working. The plate to be punched having been placed in the traversing-frame, on the sides U and V, is then pushed forward. In its progress, the first pin of the series 23 passes under the inclined end of the rack 17, until the first notch in the rack falls upon the pin. The driving-strap being now on the fast pulley K, the machine is set to work by pulling down the handle 42, keyed on the shaft 34, until the lever 33 is latched by the click-lever 39; the elbow-lever 37 is then, by the spiral-spring 40, brought into the position shown in Fig. 2422. The latch 38 being now liberated, will, by the action of the spring 41, Fig. 2420, drop into the notch in the wheel R the first time it comes round; the cam-shaft Q will now revolve at the same speed as the shaft F, and the jacquard-roller *f* will be drawn back and made to perform 1-6th of a revolution on its centres, after which it will be advanced, and the first card of the series will remove those selecting-bars for which there are no holes in the jacquard-plate; the other selecting-bars will remain over their respective rams P, which will then force down the punches through the plate, by the descent of the depressor T. A little before the punches have gone through the plate under operation, the levers *o* are made to press upon it, and are held there while the punches are being withdrawn by the bar *s*, which rises simultaneously with the depressor T, during one-half of its ascent.

Whilst the depressor is continuing its ascent and descent through the other half of the stroke, the roller *f* recedes, and draws with it the bar *m*, which brings all the selectors again over the punch-rams P. The roller *f*, while receding, having performed another sixth of a revolution, will, on advancing, bring another of the jacquard-plates against the selectors, and the operation will be repeated until all the holes are punched in the plate under operation.

JAPANNING. The art of covering paper, wood, or metal with a thick coat of a hard, brilliant varnish: it originated in Japan, whence articles so prepared were first brought to Europe. The material, if of wood or papier-machée, is first sized, polished, and varnished; it is then colored or painted in various devices, and afterwards covered with a highly transparent varnish, or lacquer, which is ultimately dried at a high temperature, and carefully polished.

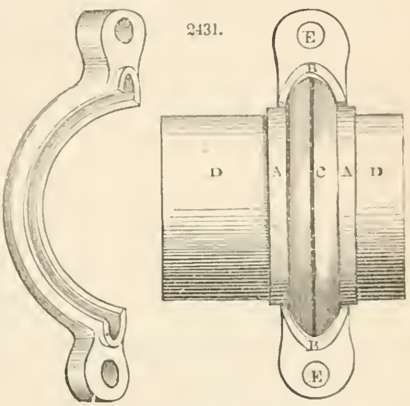
An improved method of performing the above-mentioned operation is thus described by the inventor: The articles which are to be so coated, or covered, or ornamented, may be made of wrought-iron, or of other malleable metal or metals, which will withstand a strong red-heat without injury, such as brass or copper, the making of such articles being performed by any of the usual modes of cutting out of laminated or sheet metal, and hammering, or stamping, or otherwise forming to the required shape for any intended article, by aid of all or any of the various modes of cutting out of laminated sheet metal practised by the makers of articles of malleable metals, except that the more fusible metals which will not withstand a strong red-heat, such as tin, lead, zinc, pewter, or Britannia metal, are not fit to be used for making such articles or any part thereof, and, therefore, tinning and soldering with soft solder is not applicable for taking such coating, or for uniting together the parts of the said articles; but in case of an article which cannot conveniently be formed of one piece of metal, (and which is to be preferred,) then the several pieces or parts must be united or strengthened by all or any of the well-known methods of overlapping, turning down the edges, wiring, creasing, and hammering down, or by riveting or dove-tailing, as may be most suitable for the article; and in case of soldering being resorted to, it must be hard soldering with brass or spelter, usually termed brazing, and by any or all the means aforesaid the articles are to be made of wrought-iron, or of other malleable metal or metals, and in the same manner as if they were intended to be japanned, painted, varnished, lacquered, or tinned. When made, the articles are to be subjected to a full red-heat, by placing them in an annealing oven or furnace, which may be of the same kind as is commonly used for annealing articles of stamped metal, or for annealing metal for being stamped; a number of articles of the same shape and size being piled up one upon another in such furnace in order that they may the better keep their form, and sand may be interposed between the articles so piled up for that purpose. Small articles may be heated in a muffle, such as hereafter described, into which flame does not enter, and after having been kept to a full red-heat for about half an hour, the articles are either withdrawn from the oven or furnace and allowed to cool, or else the oven, or furnace, or muffle, with the articles therein, may be allowed to cool, and the articles removed. By the said heating, all liquid or greasy matter will have been dissipated, and the surfaces of the articles will have been oxidated, and then all oxide or scale is to be removed from the surfaces of the articles by rubbing them with sandstone, for the plain and accessible parts, and with worn-out files, scrapers, or other suitable tools, for the less accessible places. Or articles of such a truly circular or elliptical form as to admit of being turned in a lathe, may be mounted in a chuck and turned; a broad flat tool being presented to every part of the revolving surface in succession, leaving the surface of the metal smooth and even, without the necessity of its being quite bright or polished. The articles being thus rendered perfectly clean, are ready to receive the first coat or covering of partially vitrifiable material, (the composition whereof is hereafter described,) and which is applied to the surface of the articles in a semi-liquid state, which state results from the materials having been ground very fine when in mixture with water, and to the consistence of a thick cream, and then strained through fine lawn. A suitable quantity of such semi-liquid is poured out from a ladle or spoon upon the surface of the article whilst it is held over a large vessel containing such semi-liquid, and by holding the article in the hands with the surface inclined, the semi-liquid runs slowly and gradually along the surface, so as to spread itself out and cover the same, the article being turned about and inclined in different directions in succession, in order to cause the semi-liquid to run over the surface until the whole is completely covered and with a coating of uniform thickness, all surplus of such semi-liquid being allowed to drain off therefrom into the basin or other vessel beneath. Great care must be taken, however, to avoid air-bubbles, specks, or defective places in the coating, and which is only accomplished by using precaution in the previous preparation of the semi-liquid, or by thoroughly grinding or straining it, in order to keep it free from lumps and from any coarse particles, and afterwards avoiding all violent stirring or splashing, so as by no means to get air intermixed with it, but using only a gentle motion when taking it up with a ladle or spoon; and such a quantity only of the semi-liquid at one time as is not materially greater than sufficient for covering the surface of the article to be coated. The operation of coating will be greatly facilitated by performing the same in a warm room, and by making the article rather warmer than the semi-liquid itself, but not so as to feel hot to the hand; and such warmth of the room and of the article will dispose the covering, after it has been spread over the surface of the article as aforesaid, to begin to dry upon that surface, and, in a short time, so far as not to run or move thereon, after which the drying is to be completed by placing the article in an ordinary japanner's stove, which should be kept heated to a temperature of about 180° Fahrenheit, the article being left therein until all moisture is gradually dried away, or so as to leave a dry whitish covering, which adheres sufficiently to the surface of the article for keeping its place thereon, but which would, nevertheless, be easily rubbed off if handled roughly, or if only touched rudely by the fingers. The composition of materials found to be the most suitable for the first coating may be prepared as follows:—

Take six parts (by weight) of flint-glass, broken into small fragments, three parts of the ordinary borax of commerce, one part of red-lead, and one part of oxide of tin. These four ingredients being brought into the state of a coarse powder, are to be well mixed together, by pounding them in an iron mortar, and then the mixture is to be fritted in the same manner as is usually done with the materials for making glass, or by subjecting such mixture to a strong red-heat in a reverberatory furnace for three or four hours or more, it being frequently stirred and turned over to expose every part to the flame, and to more effectually mix the ingredients, as well as to expel all volatile matter; and towards the latter part of the time the heat must be increased, until a partial melting or semi-vitrification has commenced, when the whole is to be withdrawn from the furnace in a pasty state, and let fall into water in order to be suddenly cooled, whereby it becomes cracked, so as to be afterwards easily broken into small fragments, or into a coarse description of powder, which is called fritt, and which is for the first body or coat, but which fritt is only one of the ingredients in the composition of such first coat. With one part (by weight) of the fritt described is to be mixed two parts of calcined bone, ground to powder; and the mixture of fritt and bone is then to be ground with water in a mill, called a porcelain mill, such as is used for grinding the materials for making porcelain; and which operates by trituration of the materials with water between chert stones, or other hard silicious stones, whereof some are fixed at the bottom of a tub or vessel containing water, having the materials mixed therewith; and other such stones rest by their own weight upon the said fixed stones, and are carried round thereon with a circular motion, communicated by the moving part of the mill, so as to rub over the fixed stones and grind the materials between them, which operation is continued until the materials are reduced to a state of extremely minute division in the water, forming therewith the semi-liquid (of about the consistence of cream) already alluded to, and which is ready for use so soon as it has been passed through appropriate sieves, so as to effectually separate any particles that have escaped the operation of grinding.

In articles requiring only one side to be coated, such as the hollow side of a kettle, or pot, or jug, or such as a mug, or plate, or dish, or waiter, or tray, or basin, or cup, or bread basket, or cheese tray, (to all which, as well as to numerous similar articles, this invention is considered as being particularly applicable,) such hollow side may be first coated with vitrified materials after the manner already explained; after which, the outside may be coated or covered by any of the ordinary methods of japanning; and in applying such first coating of semi-liquid to the hollow surface or side of such articles as those stated, it is observed that, instead of pouring out a quantity thereon, as in other cases, the vessel may be filled, or if both sides have to be coated, may be wholly immersed, and in the act of draining off the surplus the fingers of the two hands should be applied to the edges only of the article, and at the two opposite sides of its circumference, so that the weight of such article will balance itself, and render it easy to turn it over and about, so as to drain in succession from either side, extreme care being requisite in all such cases to insure a uniformity of surface. When the coating is so far dried that it will not run, the article is to be laid down upon the points of three small supports, made of burnt earthenware, and which are made to stand upon a small iron plate that serves to carry away the article which is next introduced into the japanner's stove, where it is dried more effectually. When the article is afterwards removed from the said stove, in order to be introduced into the muffle for the firing or burning in of the coating, (and in the manner hereafter described,) it is still to be borne upon the same three supports, the iron plate on which they rest being removed from the stove, and also introduced into the muffle, or with the three supports and the article upon it; and in case of any specks or deficient places appearing in the coating, such places may be mended by applying a portion of the semi-liquid thereto by aid of a brush, and in the manner of painting or pencilling, and then returning the article to the stove, and drying the same, so that every part shall not only be completely covered, but also effectually dried on, and before it goes into the muffle, the ultimate appearance of the article depending very materially upon the manner of conducting this first part of the process, and upon the care with which the coating has been applied, and upon the proper grinding and mixing of the materials, uniformity of surface in the first process being considered absolutely indispensable, in order to insure the successful result of such after-processes as have yet to be detailed. The firing next described is for the purpose of so far vitrifying the materials and hardening the coating as to fasten it on to the surface of the articles, and is performed in a furnace, of the kind used by painters in enamel, being an oven strongly heated by fire applied beneath it, and by the flame therefrom passing in flues around it, and may be called a muffle; but no fire, or flame, or smoke can enter into the interior where the articles are placed. The articles are left in the muffle, and subjected to the heat until such time as the earthy composition will have undergone so much of the commencement of fusion or partial vitrification as to render the particles of the coating firmly adherent one to the other, and also to the surface of the metal articles, and which are then to be withdrawn and laid on a flat iron bench to cool. When cold, such parts of the surface as have been coated will be found to present the dead whitish appearance of earthenware, which has been once fired only, but has not been glazed, being in that state which by potters is termed "biscuit." The time that the articles should remain in the heated muffle will vary from a few minutes to half an hour, depending upon the size and number of the articles, and upon the heat of the muffle; neither can such time be stated with precision, but the operator, it is observed, will soon find out what length of time is most suitable for any particular description of article, and also what heat should be kept up in order to obtain the required result, by observing, so soon as the article shall have become cool, whether the coating has been rendered sufficiently hard, and has or has not become firmly adherent. When cool, the newly formed coating is to be wetted, either by passing over it a sponge that has been dipped in water, or else by dipping the article itself, and a second coating is then applied over the first coat and dried thereon in the japanner's stove, and then fired in the muffle in the same manner as the first, only the composition is to be different; and the patentee goes on to state that the composition he has found to be the most suitable for such second coating is as follows: Take 32 parts (by weight) of calcined bone, ground to a fine powder, 16 parts of china-clay, and 14 parts of Cornwall stone in fine powder, and 8 parts of carbonate of potash; the latter being dissolved in water, the other ingredients are mixed up therewith, so as to make a thick paste, which is then fritted for two or three hours in a reverberatory furnace, until it assumes the appearance of biscuit-china, which is to be reduced to powder; then 5½ parts (by weight) of such powder are to be mixed with 16 parts of flint-glass broken small, 5½ parts of calcined bone ground, and 3 parts of calcined flint ground, the said mixture being afterwards ground with water in a porcelain-mill until it is reduced to a semi-liquid state about the consistence of cream, and which has to be carefully strained, as before, through sieves of lawn, when it will be ready for use in the same manner as already explained in reference to the composition or semi-liquid employed for the first coating. In firing the second coating care must be taken that the articles are kept long enough in the muffle, and that the heat is sufficient for thoroughly incorporating the second coat with the first, also for thoroughly hardening both coats. After firing for the second coat, the article, when cool, will have a stronger and whiter color, and a more decided resemblance to articles of good earthenware, but still only in the state called "biscuit."

The articles having been twice coated with composition as described, and twice fired, so as to assume at this stage the external appearance of a good earthenware biscuit, the patentee further states, that should it be desired to produce a very white color, so as to resemble the very finest earthenware or porcelain, then in lieu of the 16 pounds of flint-glass, mentioned as forming part of the last composition, proper for the second coating, he prefers to substitute a like quantity of the composition prepared as follows: Take four parts (by weight) of feldspar in powder, four parts of white sand, four parts of carbonate of potash, one part of arsenic, six parts of borax, one part of oxide of tin, one part of nitre, and one part of whiting; the mixture of these materials is to be fritted either in a reverberatory furnace (as was before described for the materials of the first coating,) or otherwise such fritting may be performed in a crucible strongly heated in a furnace, the heat in either case being continued until the materials are partially fused, and the appearance when cold will be that of a whitish enamel, which being reduced to powder, such powder is to be substituted, weight for weight, in place of the 16 pounds or parts of flint-glass formerly mentioned as part of the composition of materials for the second coating, all the other materials remaining the same. Excepting only for the purpose of obtaining whiteness of color, the flint-glass is in other respects described as being cheaper, and yet equally good. After the articles have received the second coating, (of either of the compositions described,) and have been fired and then cooled, they are to be wetted with a sponge, or by dipping them into water, as was done after the first coating, and are then ready for receiving the third coat or glaze, which is also applied in a semi-liquid state, great care being required in draining off the surplus semi-liquid glaze, so as to leave only a thin coating or covering, equally distributed over every part of the second coating of partially vitrified material, in order that the article, after being again exposed to the heat of the muffle, and afterwards withdrawn, may present the appearance of glazed earthenware of good quality, and which will not otherwise be the case; whereas, with appropriate care, and when the composition specially adapted for producing whiteness has been employed, it will resemble earthenware, it is stated, of the very best quality. The composition found to be the most suitable for the third coat, or glaze, is as follows: Take twelve parts (by weight) of feldspar, in powder, four and a half parts of china-clay, eighteen parts of borax, three parts of nitre, one and a half parts of carbonate of potash, and one and a half parts of oxide of tin, which materials being well mixed together, the mixture is to be fritted either in a crucible or in a reverberatory furnace, and then the frit being reduced to powder, is to be ground with water in a porcelain-mill to a semi-liquid state, and strained through fine lawn in the same manner as described for preparing the composition for the first coat. Or, instead of the above composition, the following may be adopted for such third coat or glaze: Take nine parts (by weight) of feldspar, in powder, two parts of china-clay, nine parts of borax, two parts of nitre, three parts of carbonate of soda, and one-quarter part of arsenic; which materials being mixed together the mixture is to be fritted, and then reduced to powder, ground in water, and strained as aforesaid. In firing the articles in the muffle for the third coat or glaze, the heat of the muffle, and the time the articles are subjected to such heat, must be sufficient to cause the glaze to become thoroughly vitrified, and to spread over the surface of the second coat so as to become incorporated with that coat, and effectually glaze the surface thereof, as in earthenware of excellent quality; and in case there are any imperfections in the glaze after it has been so fired, then, after the articles are cold, another coating of the same glaze may be applied in a semi-liquid state and dried in the japanner's stove, and then fired in the muffle as was done for the first coating of glaze; and so in like manner a third coating or glaze may be applied and fired, if found requisite.

JOINT, CLASP-COUPLING—West & Thompson's. D D, Fig. 2431, are two pieces of pipe; A A are two flanges joined each to one of the pieces of pipe. It will be observed that the coupling parts of these flanges are bevelled, and have no bolt-holes, as those in common use all have. C is a piece of vulcanized India-rubber, or any other packing that may be thought necessary, although a pressure can be exerted in bringing the flanges so close together that the joint is made perfectly tight without any packing, but we think that it is all the better to use a little packing. B B is the clasp. This is divided into two parts, and this part is represented with the flange resting on it. By placing the concave part over the bevel of the flanges, and securing the two parts of the clasp together by bolts passing through E E, is all the operation that is required in connecting two separate pieces of pipe together. Every mechanic will perceive that the tighter the clasp is screwed up, the faces of the flanges are brought closer together, and the joint is thereby made exceedingly tight. Experience has proven this joint to be excellent for pipes that are used for conducting steam.



2431.

It will be clearly seen that this improved coupling is applicable to vessels and other articles of angular or curved forms, and that whatever may be the form, any desired and effective mode of drawing or forcing together the segments of the ground clamp may be substituted for screw-bolts or the conical rings.

In coupling angular vessels, or other articles, it will be found to be advantageous to make the grooved clamp in as many sections as there are sides to the figure, and for round couplings it will be found sufficient to make it in two parts for all articles of moderate size; but when the diameter is very considerable it may be divided into three or more parts.

This improved mode of coupling is equally applicable to the securing of nozzles, stop-cocks, bonnets, and many other articles not necessary to enumerate, and particularly to cylinder-heads, in which the edge of the head takes the place of one of the flanges.

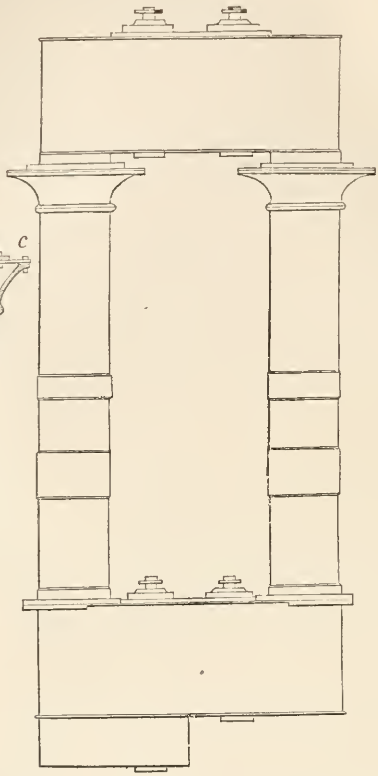
It will be evident to any engineer or machinist, from the foregoing, that shafts and other solid bodies can be coupled together in the same manner as hollow conduits or vessels, and with equal advantage, and by a similar arrangement of parts, and therefore it is deemed unnecessary to give an example.

The flanges, instead of solid projections of the bodies to be united, may be made separate, and connected therewith in any manner desired, as the mode of making the flanges forms no part of the invention.

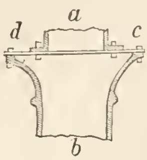
The leading advantages of this mode of coupling over the ordinary double flange and bolts heretofore and now generally used, are, a great reduction in the number of screw-bolts used, which occupy much time in connecting and disconnecting joints, particularly in the parts of steam engines, such as cylinder-heads, and other parts, which require to be frequently connected and disconnected for packing and other purposes, and increased strength and more perfect and continuous support, as the flanges by the improved plan, instead of being reduced in strength by the numerous bolt holes, are pressed together and supported all round by the grooved segmental clamp, and the strain on the threads of the screw bolts, instead of being in the line of the force which tends to separate the coupling, as in the old plan, is nearly at a right angle therewith, and therefore greatly relieved. There are other advantages which, however it will be unnecessary to enumerate.

JOINT, PATENT EXPANSION. Figs. 2432 and 2433 represent a patent expansion-joint, patented by Z. R. DUNHAM, of New York, March 20, 1847.

2433.

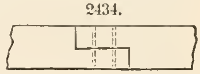


2432.



JOINTS, AND JOINING TIMBERS. As timber cannot always be obtained of sufficient length for tie-beams, or bridges, it is necessary to unite two or more pieces together by their ends, which is called scarfing, and is differently performed by carpenters. The most common means is lapping, or halving, or, as it is sometimes called, ship-lapping. This is nothing more than cutting away a part of the thickness of one piece, and an equal quantity of the other which is to be joined to it, so as to suffer the diminished end of one piece to overlap that of the other, (as in Fig. 2434,) and then uniting them by nails or wooden pins, which are called tree-nails. This method is applied to plates, bond timbers, and others, where there is not much longitudinal compression or extension; where this kind of effect is to be provided for, the upper as well as the lower timbers should be cut and let into each other; the under piece having a tenon formed at its extreme end, with a corresponding cutting to receive it in the upper piece. That these tenons may be enabled to pass each other, it is necessary to cut away a part of the timbers in the middle of the length of the joint, equal to the length of the two tenons, so as to form a square hole, through the middle of the timbers to be joined together, and this is afterwards closed up by driving an oak key into it; this also helps to drive the tenons to their respective mortises, and prevents the timbers from being pulled asunder. The thickness of the key, in order that it may not be compressed, should be equal to a third of that of the piece into which it is inserted. Another principle is here shown, which is more simple, the joint being cut obliquely; to make these two pieces stiff, the ends of both should be cut in an angular form. To strengthen these scarfs, iron straps and screw-bolts are added; but no joining can be made so strong as the timber itself.

2434.

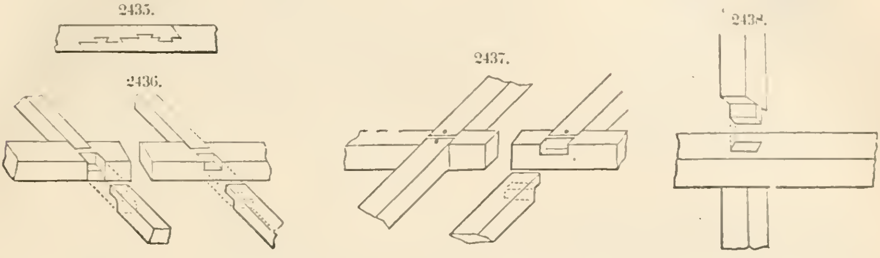


In making joints, it must be remembered that all timber is liable to shrink when dry, and when wet to expand; on this account, dovetail joints should be avoided as much as possible, as they are liable to draw out; and all joints should be made with reference to their contraction and expansion, which sometimes tends to split off portions of the framing. Where iron bolts or straps are introduced, care must be taken that their effect is not lost by the changes that the timber undergoes. The areas of the former should never be less than two-tenths of the area of the section of the beam; it must also be recollected in making a joint, that when force is applied to any portion, the fibres of the timber will slide upon each other.

Fishing a beam is merely placing a piece of the same scantling to one side of the timber to be united, and bolting them or hooping them together. Separate pieces of timber are united either by scarfing, notching, cogging, pinning, wedging, tenoning, &c.

Scarfing consists in cutting away equally from the ends, but on the opposite sides, of two pieces of timber for the purpose of connecting them lengthwise. The usual method of scarfing bond and wall plates is by cutting about three-fifths through each piece, on the upper face of the one and the under face of the other, about 6 or 8 inches from the end transversely, making what is termed a *kerf;* and longitudinally from the end, from two-fifths down, on the same side, so that the pieces lap together like a half dovetail. Fig. 2435 is a scarf.

2435. 2436. 2437. 2438.



Notching is either square or dovetailed, and is made use of for connecting the ends of wall-plates and bond-timbers at the angles, in letting joists down on girders, binders, purlins, or principal rafters.

Cogging, or *cocking*, is a species of notch extending on one side, and having a narrow cog alone in the bearing piece, flush with its upper face. It is principally made use of in tailing joists on wall-plates.

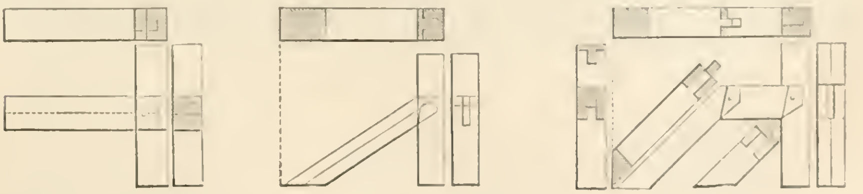
Pinning consists in inserting cylindrical pieces of wood or iron through a tenon.

Wedging is the insertion of triangular prisms, whose converging sides are under an extremely acute angle, into or by the end of a tenon, to make it fill the mortise so completely as to prevent its being withdrawn.

Tenon and mortise of the most simple kind is shown in Fig. 2439, in which the two timbers united are at right angles with each other. The tenon is on that which appears horizontal, while the mortise is cut in the upright timber. The tenon is left one-third of the thickness of the timber, as shown in the upper part of the figure.

The greatest strain upon the fibres of a girder is at the upper and lower parts, decreasing gradually towards the middle of the depth, which is the best situation to make the mortise. The form to be given to the tenon requires consideration. Some carpenters introduce it at the lowest part of the girder, which in a great degree destroys its stiffness: being a sixth of the depth, it should be placed at one-third of the depth from the lowest side. Horizontal timbers, intended to bear great weights, should be always notched on their supports, in preference to being framed in between them; and this rule is applicable to inclined timbers, as common rafters and braces. All the pressures to which they are subjected should be brought to act in the direction of their lengths, and the form of the joint should be such as to convey the pressure as much as possible into the axes of the timber. When subjected to a strain, a partial bearing is liable to very serious disadvantages, particularly in bridges.

2439. 2440. 2441.



Where the mortise is to be made in the upright timber, and the tenon to be cut on another inclined, as in a brace to a partition, a bevelled shoulder, Fig. 2441, is cut on the inclined piece, and a sinking made in the upright post to receive it—the pin which secures it in its mortise passing through the tenon.

The bevelled shoulder adds greatly to the strength of a mortise and tenon joint, and should never be dispensed with: it renders the junction of the two pieces of timber more exact, and makes the abutments of all the fibres stronger and more capable of resistance.

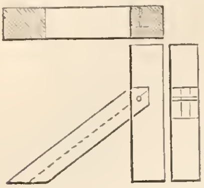
The common method of effecting such a junction does not occupy so much time or labor, but is not so effective: it is usual to drive one or two wooden pins through holes bored for the purpose at right angles through the timber in which the mortise is made, as well as through that which has the tenon.

Boring the hole for the pin requires to be nicely performed, in order that it may draw the tenon tight into the mortise prepared to receive it, and make the shoulder-butt close into the joint, without running the risk of tearing out a portion of the tenon beyond the pin. Square holes and square pins are preferred to round, as they bring more of the wood into action, and there is less liability to split.

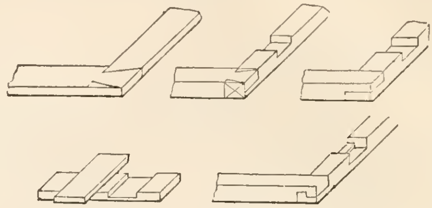
Foxtail wedging, adopted by ship carpenters, is made with long wooden bolts, which do not pass completely through the timbers, but take a very fast hold: they are subject to be crippled in drawing if they are too nicely fitted: this is remedied by placing a thin wedge into the hole previous to the insertion of the wooden bolt, which, when driven, is split by the wedge, and thus squeezed tight to the sides of the hole.

Bond-timbers and wall-plates require to be carefully notched together at every angle and return, and scarfed at every longitudinal joint.

2442.

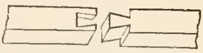


2443.



To make a good tie-joint requires great attention on the part of the carpenter; and, for uniting wall-plates, the dovetail joint, Fig. 2444, is sometimes adopted. If the effects that shrinking may produce be taken into consideration, the more usual system of halving, Fig. 2443, is decidedly preferable. Whenever this joint is employed, a stout pin of tough oak, or an iron bolt, should be driven through to render it secure; and, where there is the slightest tendency for one piece to slide from the other, iron straps must be used.

2444.

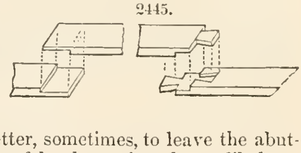


Timbers which are laid upon the plates, and intended to act as ties, should be cut with a dovetail and let into the timber it is to secure. Generally, where they cross at right angles, *halving* or cutting away the moiety of each is adopted, and one is let into the channel cut in the other.

For joining two pieces of timber together, *notching* is the most common and simple method; for, when four angles are to be formed, the surfaces of one piece are both parallel and perpendicular to those of the other. A notch may be cut out of one piece (Fig. 2444) the breadth of the other, which may be let down on the first; or the two pieces may be both notched to each other, and then secured by an oak pin: this is the best practice when each of the timbers is equally exposed to a strain in any direction. When one piece has to support the other transversely, the upper may have a notch cut across it, to the breadth of two-thirds the thickness of the one below, which must also have a similar notch cut out on each upper edge, leaving two-thirds of the breadth of the middle entire, by which means the strength of the supporting or lower piece is less diminished than if a notch of less depth were cut the whole breadth. Such joints are particularly adapted for purlins, when let down upon the principal rafters.

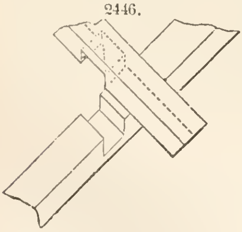
Lapping is performed in a variety of ways—either by simply halving the end of each timber, or by halving and dovetailing, as in Fig. 2445. In the latter case, the timbers act as a tie, and cannot be readily pulled asunder.

2445.

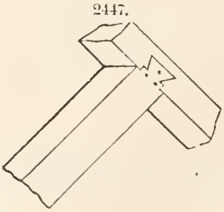


In these joints the greatest attention is required to make the several parts abut completely on each other, as the least play or liability to motion at once destroys their efficacy. The butting joints, being slightly tapered to one side of the beam, require very moderate blows with a hammer to force them into their place: if driven too hard, the parts will be liable to strain, and the abutments to split off. It is better, sometimes, to leave the abutments open, and afterwards drive in a small wedge, which, if made of hard wood and not likely to

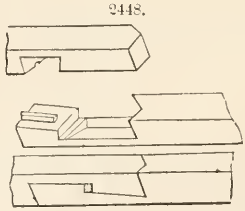
2446.



2447.



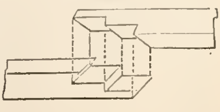
2448.



compress, is an excellent substitute. Iron has been said to injure the fibres of the timber, from its too great hardness; otherwise it is well adapted for the joggles and wedges.

Two pieces of timber may be united in such a manner that they preserve the same breadth and depth throughout, which is of great importance in the construction of beams for bridges or roofs of considerable span. The length to be given to the scarf must depend upon the force that will cause the fibres of the timber to slide upon each other; and that for oak, ash, or elm should be six times the depth of the timber; in fir, twelve times: but where bolts are used so much is not required in either case. The simplest method for uniting the ends of two timbers is by cutting away an equal portion of each, and letting one down upon the other. Fig. 2449.

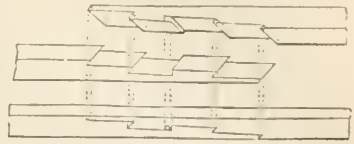
2449.



Timbers united together by a number of such cuttings, afterwards united and bolted through or hooped round with iron, are capable of sustaining great resistance: a stirrup-iron at each end holds the timbers in their places, and one or more bolts are sufficient to prevent their being drawn asunder.

The carpenter frequently exercises great ingenuity in joining timbers of considerable scantling, Fig 2450; and, by the introduction of iron or small cubes of harder wood into the joints, can prevent their being thrust or drawn out of their position either longitudinally or laterally.

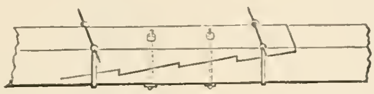
2450.



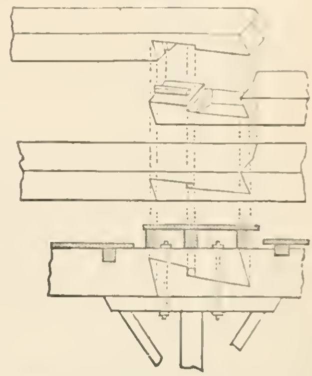
The scarfing of girders and beams have a great variety of forms given them, and are sometimes bolted through, at others strapped round with strong hoops of iron, Figs. 2449 to 2454. Where bolts are dispensed with, it is perfectly clear that the joint cannot have half the strength of an entire piece. Where the stress is longitudinal, two irons put on each side will prevent the scarf that is merely indented from pulling asunder; but such a provision will not maintain the constant horizontal position of the timber.

When a scarf is forced to its bearings by the introduction of keys or wedges driven tight, they sometimes receive an additional strain, and it is often found advisable to omit them, and to bring the joints

2451.

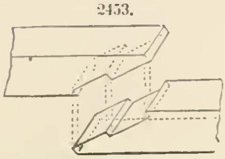


2452.

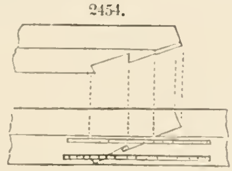


Scarfing.

2453.



2454.



to a bearing by some other means before the bolts are inserted. When keys are made use of, they should be of very hard wood, having a curled grain, which resists the insertion of the fibres opposed to it.

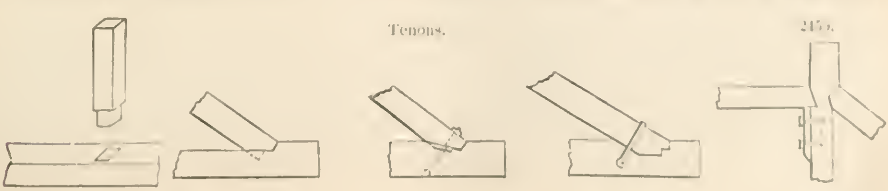
To prevent lateral movement cogging is adopted, in addition to the ordinary method, and a small tenon or cog is left upon a portion of the scarf, which enters into a notch prepared in the piece which is to cover it, as shown in Figs. 2448 to 2452. Beams intended to resist cross-strains require to be lengthened more frequently than any others, and, from the nature of the strain, a different form of scarf must be made use of from that which is required for a strain in the direction of its length. When timber is subjected to both strains, the cross-strain is that which demands the greatest attention. Where a floor is supported, the scarfing requires to be further secured by iron bolts, made to pass through a longitudinal piece laid to cover the under side of the joint.

Bearing-posts, when used to support the floors of a magazine or warehouse, are generally formed exactly square. Some timber will support, while that of another quality will suspend, the most; therefore, in the selection of story-posts, we must pay attention to these peculiarities. Iron, however, is generally used for these purposes, in consequence of its horizontal sectional area occupying less space than timber of the same strength.

When a tie-beam is mortised through to receive a king or queen post, and it is necessary to provide for the means of holding it up, the tenon should not be pinned through, as it is not advisable to depend entirely on the pins for the support: the tenon should be cut like a half dovetail, or in a sloping direction on one side, and left straight on the other: the mortise-hole should be so cut that the lower end can just pass. When it is in its place, a wooden key or wedge is driven tightly on the straight side, which forces the tenon against one side of the mortise-hole, and prevents it effectually from being drawn out: oak or iron may be added, or an iron strap may be applied.

Tenons may be wedged at the end; but to do this they must be made long enough to pass entirely

Tenons. 2455.

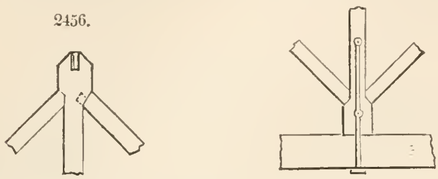


through the mortise: two saw-cuts are then made across it, and the wedges are driven home. The tenon sometimes splits, but not sufficiently to injure its strength. When in machinery it is not practicable to cut the mortise through, the fox tail wedging is adopted: the tenon is made to fit the mortise exactly, the wedges are loosely put into the saw-cuts, as before, and the whole is driven to its place When the wedges touch the bottom of the mortise, they cause it to spread, and thus hold the tenon firmly in its place.

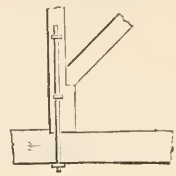
Dovetailing in some degree resembles mortising and tenoning, and is more adapted to uniting together the angles of framework. The feet of the rafters require the mortise and tenon to be carefully made, and the thrust is destroyed to a certain extent to obtain greater strength. A portion of the rafter is tenoned into the tie-beam, and another small part is let into the upper part of it: both rafter and tenon are cut at right angles with the inclination of the roof. In Fig. 2455, the rafter has two bearing shoulders in its depth, one behind the other, in addition to the tenon which unites them. Struts and braces which are loaded require but little mortising to keep them from sliding out of their places: the more flat their ends can be cut, the more efficient will they be. The shrinking of timbers sometimes occasions them to become loose, particularly where there is not much stress upon them.

King-posts, queens, and principal rafters, which are subject to great strains, should have iron straps or ties when they unite with the tie-beam, as in Figs. 2456 and 2457; and an iron strap should embrace

2456.



2457.



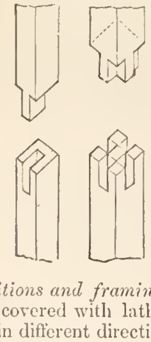
the head of the kings and queens, and unite with the principal rafters, the feet of which, in large buildings, sometimes have their abutment in a cast-iron shoe, which prevents the splitting off the end of the tie-beam.

The ends of king or queen posts may have a screw-bolt passed into them, which allows the nut to be turned at pleasure; and thus the framing may be tightened again when shrinking of the timbers renders it necessary. This, in many instances, is preferable to the iron strap, and keys or screws put in the ordinary way.

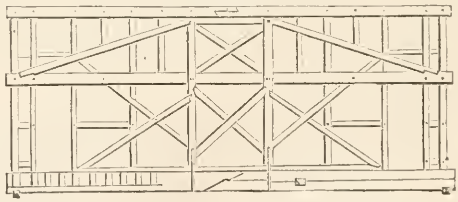
Whatever form we adopt for the butting-joint, we must be careful that all parts bear alike; for, in the general compression, the greater surfaces will be less affected and the smaller undergo the greatest change. When all have come to their bearing, they should exhibit an equally close joint; and as large timbers are moved with some difficulty, the joint cannot be often put to the test of trying whether it fits nicely: it must, therefore, be set out with great precision, and worked, with regard to its lines, with exactness. A very small portion of a tie-beam left at the end is sufficient to withstand the horizontal thrust of a principal rafter, and blocks may be used at the ends where the rafters abut to give additional strength.

Scarfing a timber in a perpendicular direction.—When the top surface is divided into nine squares, if four are cut down, the other five serve as tenons to enter into as many vacant spaces left in the piece of timber placed upon it, as seen in Fig. 2458; or two may be cut away, as in the same figure, to receive a tenon left on the upper piece.

2458.



2459.



Partitions and framing for the outside of buildings, &c., Fig. 2459, are a species of timber walls, usually covered with lath and plaster, and formed of upright posts, mortised into a head and sill, braced in different directions, and filled in with quarters. The posts are placed at the extremities, as well as at the sides of all doors and openings. When a partition dividing two or more rooms has a bearing which is perfectly solid throughout, it is better without braces: the posts or quarters have only then to be maintained in an upright position, which is effected by driving pieces between them horizontally, so as to strut them, and prevent their bending. Where they rest upon joists, which are liable to shrink, and yield to a weight placed upon them, the partition should be trussed in a manner to throw its load on the parts able to sustain it. In most houses we find great neglect upon this subject, which occasions cracking in the cornice, inability to open and shut the doors, and many other inconveniences.

The thickness given to partitions which do not exceed 20 feet in length, is 4 inches. The posts are then 4 inches square, and the other timbers 4 by 3. When they are of greater extent, they should be increased in thickness. When it is required to make a doorway in the middle, the truss may be formed by the braces, the inclination of which should be at an angle of about 40° with the horizon. When the doors are at the sides, the truss may be formed over the heads. The posts should all be strapped to the truss, and the braces halved into the upright posts.

The weight of a square of quartered partition may be estimated at from 12 cwt. to 18 cwt., and every precaution should be taken to discharge its weight from the floor on which it is placed, to the walls, which are its best points of support. In ancient timber houses, mills, &c., the fronts or external sides are formed of upright posts, placed at a distance equal to their scantling: these are mortised and tenoned into a top and bottom plate, which serves also to carry the floors. The posts at the angles are of a larger scantling; and into these, which form openings for doors and windows, are framed horizontal pieces, which serve for heads and sills. Braces are then introduced, crossing each other, like a St. Andrew's cross. Above the lintholes, and beneath the sills, short quarters or punchions fill in the space, and the whole are mortised, tenoned, and pinned together. The framing should be placed on brickwork, or a wall of masonry, so as to be kept quite clear of the ground.

Floors.—When the bearings are equal, if joists of the same width, but of different depths or thicknesses, are used, their strength is increased in proportion to the squares of their vertical thickness: when the joists are but 6 inches deep, they are in strength to those of 8 inches in depth, as 36 to 64—the square of 6 being 36, and that of 8, 64. The quantity of timber in the one case to that of the other is as 4 to 3—so that one-third more timber gives a strength double that of the other.

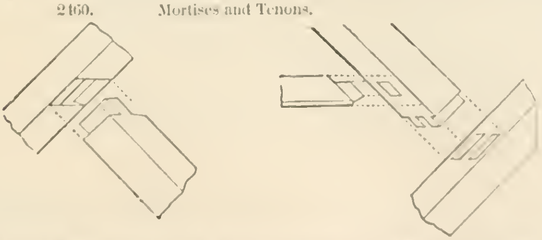
Where square oak joists are used, and the bearing 12 feet, their scantlings should be 6 inches, and laid at a similar distance apart. Such a floor contains the same quantity of timber as if entirely formed of 3-inch plank: the strength of timber being as the square of its vertical thickness, it results that the strength in these two instances is as 2 to 1: the floor composed of 3-inch plank is only half the strength of the other; but had the whole been formed 6 inches thick, instead of with joists 6 inches apart, it would have been 4 times as strong—the square of 3 being 9, and the square of 6, 36.

Naked floors are divided into *single-joisted, double*, and *framed floors:* and it must be remarked that unsawn timbers are considerably stronger than planks or scantlings cut out of a round tree. When a tree is cut longitudinally, and formed into two pieces, these will support less than they would do when united in the original tree, arising from the circular concentric rings which compose the tree being cut through, which renders the timber more compressible on one side than on the other; and as the texture is less close where it has been sawn, it is also more susceptible of change from humidity on alternation of temperature.

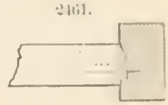
Joists whose width is less than half their vertical thickness, are subject to twist and bend if not strutted; and for this reason squared timber was usually employed by the builders in the middle ages; and we have numerous examples four or five hundred years old, where the timber selected has the pith in the centre, and the concentric rings nearly entire, being in a sound and perfect condition. Experience also teaches us that timber, whether sawn or unsawn, used for a floor of 16 feet bearing, composed of 12 joists, 8 inches square, placed at a distance of a foot apart, is much stronger than another of 24 joists, 8 by 4, placed edgeways, at a distance of 6 inches apart, although there is the same quantity of timber in both cases.

Single-joisted floors consist of one series of joists, which ought to be let down or halved on to wall-plates of a sufficient strength and scantling to form a tie, as well as a support to the floors. Each joist should be spiked or pinned to the timbers on which it lies. Wherever fireplaces occur, and the joists cannot get a bearing on the wall, they are let into a trimmer or piece of timber framed into the two nearest joists that have a bearing: into this the other joists are mortised. As the trimming joists support a greater weight, they must be made stronger than the others, and should have an eighth of an inch additional thickness given to them for every joist they carry. When the bearing exceeds 8 or 9 feet the joists should be strutted, or they will have an inclination to turn sideways: the joists in use, being generally thin and deep, require strutting on all occasions, and a rod of iron is often passed through them, which, being screwed up after the strutting-pieces are placed, gives the entire floor great solidity and firmness. The weight of a square of single-joisted floor varies from 10 cwt. to 1 ton, and the joists should never extend to a greater bearing than 20 feet in ordinary cases.

2460. Mortises and Tenons.



2461.



To find the depth of a joist, when the length of bearing and breadth in inches is given: divide the square of the length in feet between the supports by the breadth of the joist in inches, and the cube root of the quotient, multiplied by 2·2 for fir and 2·3 for oak, gives the depth in inches. A single-joisted floor which has the same quantity of timber as a double floor, is considerably stronger, particularly if properly strutted, than the latter. The plates, bedded on the walls, upon which the joists are to be tailed down, should have their depth equal to half that of the joists, and their width half as much more. In many instances the plates are not bedded entirely in the wall, but have one half resting beyond the face on corbels let into the wall, at a distance of 6 feet apart. To form the cradle or dovetail, great care should be used, to prevent the joist from drawing out of its place when once pinned down.

Double floors are formed of *joists, binders*, and *ceiling-joists*. The binders rest upon the plates bedded on the walls, and serve the purpose of supports to the joists which are bridged on them, as well as to the ceiling-joists, which are pulleys mortised into their sides. When the depth of a binding-joist is required, the length and breadth being given, divide the square of the length in feet by the breadth in inches, and the cube root of the quotient, multiplied by 3·42 for fir, and 3·53 for oak, will give the depth in inches. When the length and depth are given, and the breadth is required, divide the square of the length in feet by the cube of the depth in inches, and multiply the quotient by 40 for fir, and 44 for oak, which will give the breadth. The above rules suppose the binders to be placed at a distance of 6 feet from each other.

Binding-joists (Fig. 2461) must be framed into the girders, and care must be taken that the bearing parts fit the mortise made for them very accurately: the tenon should be one-sixth of the depth, and placed at one-third of the depth, measured from the lower side. When binding-joists only are employed to carry the ceiling, their scantlings may be found in the same manner as those of ceiling-joists, which are small timbers, and only of a sufficient thickness to nail the laths to. When their length and bearing are given, their depth may be found by dividing the length in feet by the cube root of the breadth in inches, and multiplying the quotient by 0·64 for fir, or 0·67 for oak, which will give their depth in inches. Ceiling-joists are usually notched to the under sides of the binding-joists, and nailed to them: this is better than mortising, which weakens the binder, and gives more labor.

KALEIDOSCOPE. This instrument, the invention of Dr. Brewster, in its most common form consists of a tin tube, containing two reflecting surfaces, inclined to each other at any angle which is an aliquot part of 360°. The reflecting surfaces may be two plates of glass, plain or quicksilvered, or two metallic surfaces, from which the light suffers total reflection. The inclination of the reflector that is in general most pleasing is 18°, 20°, 22½°, or the twentieth, eighteenth, and sixteenth part of a circle; but the planes may be set at any required angle, either by a metallic, a paper, or cloth joint, or any other simple contrivance. When the two planes are put together, with their straightest and smoothest edge in contact, they will have the form of a book opened at one side. When the instrument is thus constructed, it may be covered up either with paper or leather, or placed in a cylindrical or any other tube, so that the triangular aperture may be left completely open, and also a small aperture at the opposite extremity of the tube. If the eye be placed at the aperture, it will perceive a brilliant circle of light, divided into as many sectors as the number of times that the angle of the reflectors is contained in 360°. If this angle be 18°, the number of sectors will be 20; and whatever be the form of the aperture, the luminous space seen through the instrument will be a figure produced by the arrangement of twenty of these apertures round the joint as a centre, in consequence of the successive reflections between the polished surfaces. Hence it follows that if any object, however ugly or irregular in itself, be placed before the aperture, the part of it that can be seen through the aperture will be seen also in every sector, and every image of the object will coalesce into a form mathematically symmetrical, and highly pleasing to the eye.

The eye-glass placed immediately against the end of the mirrors, as well as another glass similarly situated at the other end, is of common transparent glass. The tube is continued a little beyond this second glass, and at its termination is closed by a ground glass, which can be put on and off. In the vacant space thus formed, beads, pieces of colored glass, and other small bright objects are put. The changes produced in their position by turning the tube give rise to the different figures.

KEDGE. A small anchor used to keep a ship steady and clear from her bower anchor while she rides in a harbor or river. They are generally furnished with an iron stock, which is easily displaced for the convenience of stowing.

KEEL. The principal piece of timber in a ship, which is usually first laid on the blocks in building. It supports and unites the whole fabric—since the stem and stern posts, which are elevated on its ends, are, in some measure, a continuation of the keel, and serve to connect and enclose the extremities of the sides by transoms, as the keel forms and unites the bottom by timbers.

False-keel is a strong, thick piece of timber bolted to the bottom of the keel, which is very useful in preserving its lower side. In large ships of war the false keel is composed of two pieces, called the upper and lower false keels.

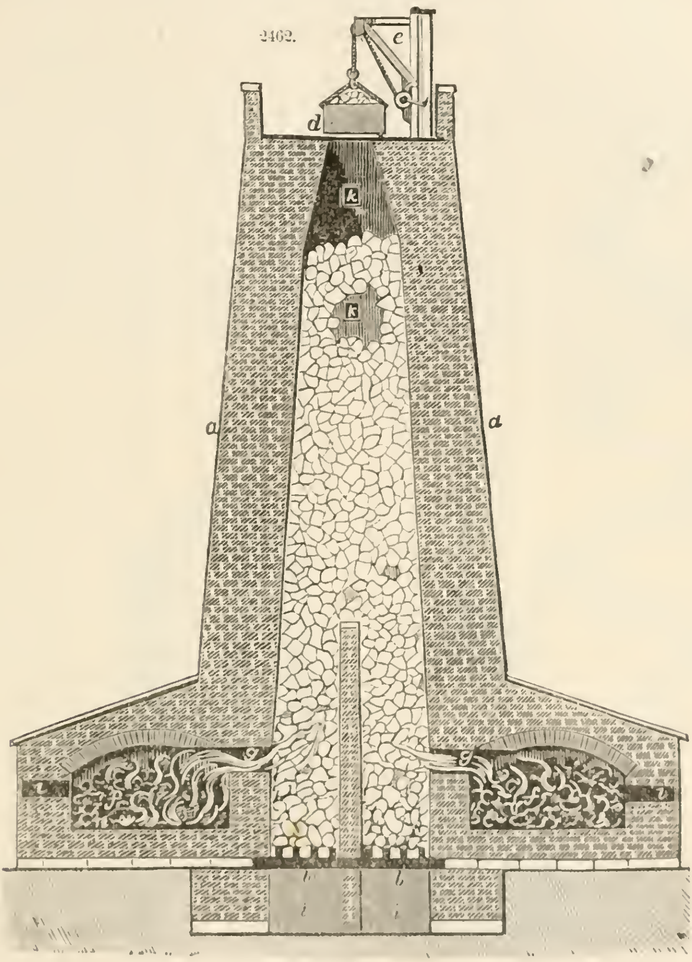
Keel is also a name given to a low, flat-bottomed vessel, used in the river Tyne to bring the coals down from Newcastle for loading the colliers: hence a collier is said to carry so many keels.

KEELSON. A piece of timber forming the interior of the keel, being laid upon the middle of the floor-timbers immediately over the keel, and serving to bind and unite the former to the latter by means of long bolts driven from without, and clinched on the upper side of the keelson.

KILN. A structure or machine designed for drying substances by the application of heat. Their forms are as various as the substances or manufactures for which they are designed; for, although it may be said that a certain kiln will answer several purposes, yet for one single purpose we often find a variety of kilns employed. The requisite qualities in a good kiln are cheapness and durability of construction, effectiveness in producing the required result with the utmost economy of fuel, a perfect command of the temperature, and facility of working. Ovens must be regarded as of the same class of apparatus as kilns: indeed, the terms kiln and oven are often indiscriminately applied to the same structure, as may be noticed under several articles in this work. Under the head of LIME the usual form of lime-kilns is described; and under COAL and IRON, several forms of coke-ovens. In this place we shall notice a combination of both, which was the subject of a patent granted to Mr. Charles Heathorn about seven years ago, since which time it has been in successful operation.

Heathorn's patent combination of a lime-kiln with a coke-oven.—The object of this invention, as expressed in the specification of the patent, is the preparation of quick-lime and coke in the same kiln at one operation. The economy of this process must be evident from the circumstance, that the inflammable part of the coal which is separated to form it into coke, is the only fuel employed to burn the lime, and as the coke is in many places as valuable as the coal from which it is prepared, the cost, if any, of making lime, must be reduced to the most trifling amount. Fig. 2462 presents a vertical section of the lime-shaft and coke-ovens: *a a* are the side walls, 4 feet thick, of a rectangular tower, the internal space being filled with limestone from the top to the iron bars *b b* at bottom, whereon the whole column rests. The limestone is raised in a box *d*, or other proper receptacle, to the top of the building, by means of a jib and crane *e*, or other tackle, which is fixed at the back of the tower, together with a platform projecting beyond the walls for affording security and convenience for "landing" the limestone when raised as represented, the jib is swung round, and the lime-box tilted, by which the whole contents are thrown down the shaft. The coke-ovens, of which there may be two, or a greater or lesser

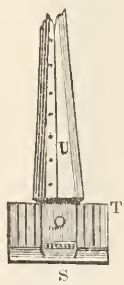
2462.



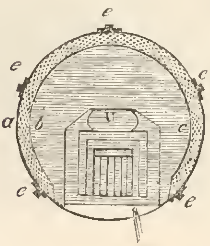
number, according to the magnitude of the works, are constructed and arranged in connection with the lime-shaft in the same manner as the two represented in the diagram at *f f*. These ovens are supplied with coal through iron doors in the front wall, (not seen in the section;) the doors have a long and narrow horizontal opening in the upper part of them to admit sufficient atmospheric air to cause the combustion of the bituminous or inflammable part of the coal; the flames proceeding from thence pass into the lime-shaft through a series of lateral flues, (two of which are brought into view at *g g*,) and the draught is prevented from deranging the process in the opposite oven by the interposition of the partition wall *h*, which directs the course of the heat and flames throughout the whole mass of the lime, the lowermost and principal portion of which attains a white heat, the upper a red heat, and the intervening portions the intermediate gradations of temperature. When the kiln is completely charged with lime, the openings in front and beneath the iron bars at *i i* are closed and barricaded by bricks and an iron-cased door, which is internally filled with sand to effectually exclude the air, and prevent the loss of heat by radiation. Therefore, when the kiln is at work, no atmospheric air is admitted but through the narrow apertures before mentioned in the coke-oven doors. When the calcination of the lime is com pleted, the barricades at *i i* are removed, the iron bars at *b b* are drawn out, by which the lime falls down and is taken out by barrows. It sometimes happens, however, that the lime does not readily fall, having caked or arched itself over the area that encloses it, in which case a hooked iron rod is employed to bring it down. To facilitate this operation in every part of the shaft where it may be necessary, a series of five or six apertures, closed by iron doors, is made at convenient distances from the top to near the bottom of the shaft: two of these are brought into view at *k k*. Two similar apertures are shown in section in the coke ovens at *b b*, which are for the convenience of stoking and clearing out the lateral flues *g g* from any matter that might obstruct the free passage of the heated air. When the coals have been reduced to coke, the oven doors in front (not shown) are opened, and the coke taken out by a peel iron, the long handle of which is supported upon a swinging jib that acts as a movable fulcrum to the lever or handle of the peel, and facilitates the labor of taking out the contents of the oven. The operation of this kiln is continuous, the lime being taken from the bottom whenever it is sufficiently burned, and fresh additions of raw limestone being constantly made at the top.

Kilns for drying corn.—If air and moisture be carefully excluded from grain, it may be kept uninjured for an indefinite length of time. This is proved by an extraordinary experiment made with some Indian corn found in the graves of the ancient Peruvians, buried more than 300 years ago. Some of this corn being sown, it vegetated and came to maturity. We believe a similar fact is recorded respecting some grain found in the ruins of Herculaneum. But to preserve corn, even for a short period, it should be perfectly dry when housed, and carefully protected from dampness. But it not unfrequently happens, during a wet harvest season, that the corn is necessarily carried from the field in a damp state; and as few farmers have the means of properly and speedily drying it, large quantities are irrecoverably spoiled after all the labor and cost of production. The method of drying on the perforated floor of a kiln (which is usually resorted to *where it can be obtained*) is a very tedious, defective, and expensive mode, and is attended with great labor, owing to the grain requiring to be continually turned over and spread by a workman, whose utmost care is insufficient to cause every part to receive an equal degree of heat. It therefore becomes a matter of considerable importance to devise a simple, efficacious, and economical method of drying grain under these circumstances; and we think Mr. Jones's apparatus for this purpose, shown in the following figures, is well adapted to the end proposed. Fig. 2463 is a vertical section of the apparatus, which is formed of two iron cylinders *a b*, placed one within the other,

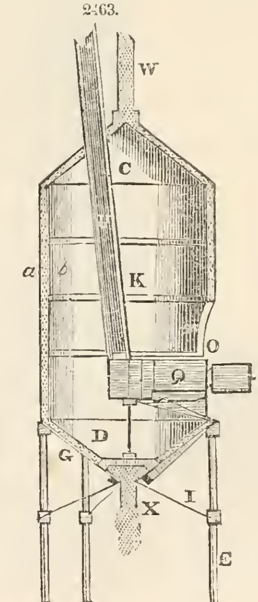
2465.



2464.

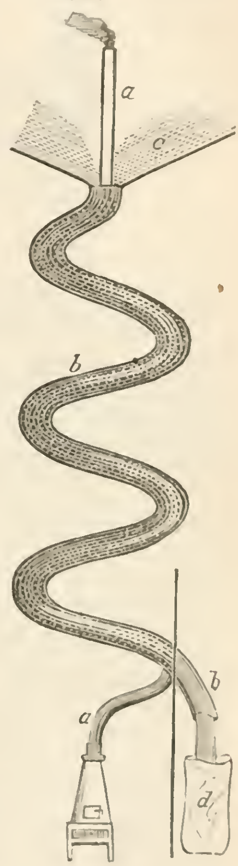


2463.



each being closed at the upper and lower end by two concentric cones, C D. The annular space between the cylinders, as also between the cones, is an inch and a quarter in width, for the reception of the grain, to be dried by its passing through the machine: both the internal and external bodies are perforated throughout with about 2300 holes to the square foot. The kiln is supported on five cast-iron columns, or legs, three of which are shown in the section as at E: these are attached to a strong iron ring which surrounds the base of the cylinder. From the heads of these columns descend, along the sides of the cone, five long bolts, as at G, which are passed through the same number of legs in the cast-iron ring surrounding the neck of the lower cone. From this ring proceed five stays, as at I, which are fastened to the middle of the columns by a nut on each side. The body is sustained, both externally and internally, by iron hoops, as at K, and the distance between the cylinders is preserved by a number of short stays. In the front of the kiln a passage is cut out, as at O, in which is fixed the fire-place, through which are passages for the heated air to pass into the cylinder. These passages, as well as the flues, which proceed circuitously from the fire to the chimney, are best shown in the horizontal section, Fig. 2464. And in the vertical section of the detached fireplace, Fig. 2465, Q is the fire-hole, S the ash-hole, T the fire-bars, and U the chimney, which passes up nearly in the middle of the kiln. The wheat is admitted into the kiln from above through a hopper, and through the tube W, and, falling upon the apex of the cone, is distributed equally on all sides between the cylinders, the little asperities in which not only slightly retard the descent of the grain, but likewise impart to the particles a constant, slow, rolling motion, whereby every individual grain is exposed to the same degree of temperature; the grain from thence converges into the lower cone, and ultimately escapes through the spout at bottom into sacks, or on to the ground, as may be required. The passage of the grain through the machine may be either accelerated or retarded, according to its peculiar condition, by enlarging or contracting the aperture through which it is discharged. The moisture is carried off by evaporation through the perforations of the plates, with great rapidity. The kilns may, of course, be made of any dimensions. One of 6 feet internal diameter, and 12 feet in length, between the apexes of the upper and lower cones, has been said to be capable of perfectly drying more than 100 quarters of wheat in 24 hours.

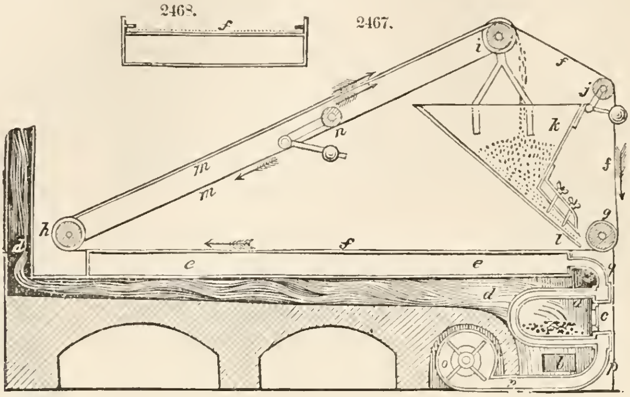
2466.



In Fig. 2466 is shown a contrivance for drying grain which has been noticed in several French papers, and announced as having been successfully adopted in one of the departments. The apparatus consists of a long spiral tube *a a* like a distiller's worm, reaching from the basement to the upper floor and through the roof of the granary, which forms a passage for the heated air from a close stove below. Externally round this tube is placed another tube *b b*, winding, like the interior one, in a spiral direction, and at about an inch and a half from it. This external tube receives the corn from above, through a hopper *c*, and it is punched throughout with numerous small holes, through which the vapor escapes, as it is formed by the damp corn coming in contact with the inclosed heated chimney. The corn, in consequence, becomes thoroughly dried before being discharged at the bottom, and that without the intervention of any manual labor.

Hebert's patent kiln was devised for drying washed grain; but as this kiln is equally applicable to the drying of malt, seeds, and all other matters of a similar kind and form, and by a mode that is as novel as it is efficacious, we give a description of it in this place. In the following engravings, Fig. 2467 exhibits a longitudinal section of the apparatus, and Fig. 2468 a transverse section of a long air-trough, shown at *e* in Fig. 2467. At *a* is shown one of a series of five or six common iron gas-tubes, placed side by side, and curved in the form represented to constitute a fireplace; the space between the tubes serving for the admission of air for combustion, which enters through the ash-pit door *b* at the side, provided with an air regulator: the fireplace is inclosed in front, at *c*, by a common door and frame. The heated air, and other products of combustion from the fuel, pass along the flue *d* to the funnel or chimney. The bottom and two sides of the flue *d* are of brick, but the top is of iron, being formed of the bottom of a long, shallow iron box, or air-trough, *e*; this box has no cover but one of extremely open-wove canvas, which forms a part of an endless cloth or band *f f f*, that is continually made to travel lengthwise over the whole area of the said trough—the edges of the cloth gliding between grooves and over tie-rods, (shown in the cross section, Fig. 2468, where the dotted line *f* indicates the endless cloth,) that prevent the cloth from sagging. This cloth is made to travel by the revolution of three rollers or drums *g h i*, to either of which the moving power may be applied. The cloth is kept distended by a self-acting tightening roller, which is screwed against the hopper *k*; this hopper receives the grain to be dried, and is provided with a shoe at *l*, adapted to deliver a thin and uniform stratum of grain upon the endless cloth, while the same is made to pass under it, and over the trough. Another endless band *m m*, of a similar fabric to the other, passes round the drums *h i* only, and is likewise provided with a self-acting tightening roller, fixable to any convenient object. The lower ends of the six tubes *a* of the fireplace before mentioned have an open communication with a rotative blower *o*, by means of a broad channel *p p*; and the upper ends of the tubes *a* also open into another broad channel *q*, which conducts the air into the long air-trough *e*. The operation of this machine is as follows: A slow rotation, derived from any first mover, is to be given to either of the drums *g h i*, which will cause the endless cloth *f* to glide gradually over the top of the air-trough *e*; at the same time the blower *o* has been put into action (by connection with the first mover) at a high velocity, so as to produce a rapid current of air, which derives an increase of temperature on passing under the heated metallic bottom of the ash pit; hence proceeding through the tubes *a*, it acquires considerable heat, which is subsequently moderated by an extensive diffusion in the air-trough *e*, before it passes through the meshes of the endless cloth *f* above, carrying with it the moisture from the grain deposited thereon. The course taken by the endless cloth is shown by arrows in the figure: upon its arriving at the drum *h*, the other endless cloth *m m* comes in contact with the grain on the cloth *f*, and, upon both the cloths passing round the end drum *h* the corn becomes inclosed between the two cloths, and is thus carried up an inclined plane over the drum *i*, where the cloths separate, and discharge the grain back again into the hopper *k*, to undergo a repetition of the operation, should it not be perfectly dry. But when the grain is thoroughly dried, instead of allow ing it to fall back into the hopper, a shoot, or the band of a creeper, (not shown in the drawing,) is brought under the roller *i*, which conducts it to the required place. A very little experience in the working of this apparatus enables a person so to regulate its operations as to complete the drying of

2468. 2467.



damp grain by a single passage through it; such as varying the velocity of the air-forcer, the quantity of fuel in the stove, the supply of air through the ash-pit, the speed of the endless cloth, &c., the means of doing which are so well understood by mechanics as to render a description of them unnecessary in this place.

KITE. This well-known juvenile plaything has been applied to several objects of utility. The most important of these is the invention of Captain Dansey, for effecting a communication between a stranded ship and the shore, or, under other circumstances, where badness of weather renders the ordinary means impracticable. The following is an abbreviated description of the invention, extracted from the forty-first volume of the *Transactions of the Society of Arts*, where the subject is given more in detail, with engraved illustrations:—A sail of light canvas or holland is cut to the shape, and adapted for the application of the principles of the common flying kite, and is launched from the vessel or other point to windward of the space over which a communication is required; and as soon as it appears to be at a sufficient distance, a very simple and efficacious mechanical apparatus is used to destroy its poise and cause its immediate descent, the kite remaining, however, still attached to the line, and moored by a small anchor with which it is equipped. The kite, during its flight, is attached to the line by two cords placed in the usual manner, which preserves its poise in the air; and to cause it to descend, a messenger is employed, made of wood, with a small sail rigged to it. The line being passed through a cylindrical hole in this messenger, the wind takes it rapidly up to the kite, where, striking against a part of the apparatus, it releases the upper cord, and by that means the head of the kite becomes reversed, and it descends with rapidity. In the experiments made by Captain Dansey, with the view of gaining communication with a lee-shore, under the supposition of no assistance being there at hand, a grapnel, consisting of four spear-shaped iron spikes, was fixed to the head of the kite, so as to moor it in its fall; and in this emergency, the attempt of some person to get on shore along the line would be the means resorted to. In those cases where a communication has been gained, and the maintenance of a correspondence has been the object, the person to windward has attached a weight to the messenger—in some cases as much as three pounds—which, having been carried up, has of course descended with the kite; the person to leeward has then furled the sail of the messenger, and loaded it with as much weight as the kite could lift; then replacing the apparatus, and exposing the surface of the kite to the direct action of the wind, it has rapidly risen, the messenger running down the line to windward during its ascent. The kite with which Captain Dansey performed the greater part of his experiments extended 1100 yards of line, five-eighths of an inch in circumference, and would have extended more had it been at hand. It also extended 360 yards of line $1\frac{3}{4}$ inches in circumference, and weighing 60 lbs. The holland weighed $3\frac{1}{2}$ lbs.; the spars, one of which was armed at the head with iron spikes, for the purpose of mooring it, $6\frac{3}{4}$ lbs.; and the tail was five times its length, composed of 8 lbs. of rope and 14 lbs. of elm plank. A complete model of the apparatus was deposited with the society, who presented Captain Dansey with their gold Vulcan medal for his invention and communication.

KNEADING is the process of making the stiff paste of flour and water for being afterwards baked into bread. It is usually effected by a sort of pommelling action of the hands and arms, and sometimes of the feet of the bakers. A variety of machines have been at different times proposed for superseding the barbarous process we have just mentioned; they have, however, been but very partially adopted, the bakers in general preferring to continue their "good old-fashioned" dirty practice. It is said that at Geneva all the bakers of that city are compelled by law to send their dough to be kneaded at a public mill constructed for that purpose. At Genoa, also, mechanism is employed for kneading: the apparatus employed at this place has been published in several of the journals, from which it appears to be so rude and ill-contrived as not to need a description in this place.

1. The *pétrisseur*, or mechanical bread-maker, invented by Cavallier and Co. of Paris, consists in a strong wooden trough, nearly square, with its two longest sides inclined, so as to reduce the area of the trough in the direction of its width, and adapt it to the dimensions of a cast-iron roller, the axis of which

passes through the ends of the trough; the bottom of the trough is semi-cylindrical, leaving a small space between it and the roller, which space is adjustable by levers. All along the top of the outside of the roller is fixed a knife-edge, which, with the roller, divides the trough into two compartments Upon the axis of the roller is a toothed wheel, which takes into a pinion; this pinion is turned by a winch, and communicates thereby a slower motion to the roller; and the roller, by its rotation, forces the materials or dough through the narrow space before mentioned left between it and the bottom of the trough—the knife-edge on the top of the roller preventing the dough from passing by it. Being thus all forced into one of the compartments, the motion of the roller is reversed by turning the winch the contrary way, which then forces the dough back again through the narrow space under the roller into the first compartment; in this manner the working of the dough, alternately from one compartment to the other, is continued until completed.

2. Another plan was to make the trough containing the dough revolve with a number of heavy balls within it. The trough in this case is made in the form of a parallelopipedon—the ends being square and each of the sides a parallelogram, whose length and breadth are to each other as five to one. One side of the trough constitutes a lid, which is removed to introduce the flour and water, and the trough is divided into as many cells as there are balls introduced. The patentee states, that by the rotation of the trough the balls and dough are elevated together, and by their falling down the dough will be subjected to beating, similar to the operations of the baker's hands.

3. Instead of employing a revolving cylinder, it is fixed, an agitator is made to revolve, having a series of rings angularly attached to an axis, extending the whole length of the trough.

4. Mr. Clayton, a baker of Nottingham, had a patent in 1830 for a machine somewhat similar to the last mentioned, inasmuch as a set of revolving agitators are employed to produce the kneading action. The agitators are longitudinal bars, fixed to arms, which radiate from the axis, and they are forced through the dough in their revolution; but the cylinder in which they revolve, and which contains the materials, is made to revolve at the same time in a contrary direction—the motion of the latter being imparted by a short hollow axis, while the axis of the former is solid and passed through the hollow one. The solid axis, which is turned by a winch, has on it a bevelled pinion, which, by means of an intermediate bevelled wheel, actuates another bevelled pinion fixed on the hollow axis, and therefore causes it to revolve in the opposite direction. These two simultaneous and contrary motions constitute the novelty claimed by the patentee, who *states*, that dough-making machines similar to his own have all failed for want of such an arrangement. This statement, coming from a baker, commands attention; but we cannot concur in its truth, since we know that the following plan of a kneading-machine works well without opposite simultaneous motions, and without any agitators or beaters, which absorb a great deal of power without producing an adequate effect.

5. *Hebert's patent kneading-machine.*—In this a cylinder of from 4 to 5 feet in diameter, and only about 18 inches wide inside, is made to revolve upon an axis, which is fixed by a pin during the revolution of the cylinder. The flour is admitted by a door in the periphery, which closes air and water tight; and the water or liquor passes through a longitudinal perforation in the axis, and thence through small holes among the flour, in quantities which are regulated externally by a cock. By the rotation of the cylinder the dough is made to be continually ascending on one side of it, whence it falls over upon the portion below. When the mixture becomes pretty intimate and uniform, its adhesive property causes it to stick to the sides of the cylinder, and the dough would then be carried round without much advancing the process, were it not for another simple contrivance. This is a knife-edge, or scraper, 18 inches long, which is fixed along the top of the cylinder in the inside, so as barely to touch its surface: the knife is fixed to two flat arms extending from the axis, and these arms have sharp edges so as to scrape the sides of the cylinder; thus the cylinder is kept constantly clean from the sticking of the dough, which, as soon as it ascends to the top of the cylinder, (if it does not tear away of itself,) is shaved off by the knife, and falls down with great force upon the bottom; and as this effect is constant during the motion of the cylinder, it must be evident that the process of kneading is soon completed by it. When that is done, the door of the cylinder is opened, and the contents discharged into a recipient beneath; at which time the scraper is caused, by a winch on the axis, to make one revolution of the now fixed cylinder, which clears off any adhering dough, and projects it through the doorway. As the dough in this machine may be said to knead itself—there being no arms, beaters, or agitators whatever—it is calculated that the power saved by it is very considerable; while, from the simplicity of its construction, the cost is moderate.

The patentee is at present engaged in combining with this kneading machine an apparatus for preparing carbonated water, highly charged with the gas, with which he proposes to mix up the flour to form dough, for the purpose of making the bread spongy or vesicular, without having recourse to the fermentative process; the result of which process, under the most favorable circumstances, he considers to be detrimental to the health of those that eat the bread, (owing to the deposition of fermentable matter in the stomach,) while it is destructive of a portion of the nutriment of the flour.

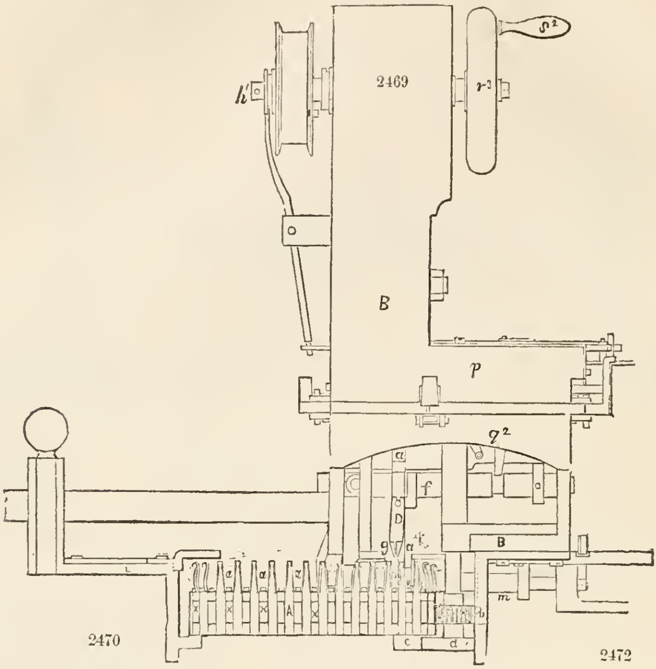
KNITTING MACHINE, *Improved.* From the specification of the inventor, J. R. Ellis, of Boston, Massachusetts, patented June 17, 1851. Fig. 2169,* denotes a front elevation of the said improved knitting machine. Fig. 2177 is a vertical and transverse section of it, the same being taken in such manner as to exhibit the yarn guide or director, the stitch hook, and the contrivance for forcing the work down towards the roots of the needles, after the formation of each new loop. Such other figures as may be necessary to a proper representation of the various parts of my improvements, will be hereafter referred to and described.

The machine as improved, is not what is usually termed a stocking loom, but is more properly named a knitting machine, for the reason it forms each stitch of the work in regular succession, and not a number of stitches at once, as does the stocking loom. It is a machine in character like others in use, al-

* The letters in the cut are by mistake made capitals instead of small letters.

though it differs from the same in sundry important particulars which constitute my invention, anc which I shall hereafter describe.

In the drawings above mentioned, A denotes the endless chain belt of knitting-needles, which is sc made that the needles *a a a*, &c., instead of being arranged or made to stand horizontally, and at right angles to the vertical surface of the belt, are made to stand vertically or in the plane of the belt, as seer at *a a a a*, figures 2469 and 2477.



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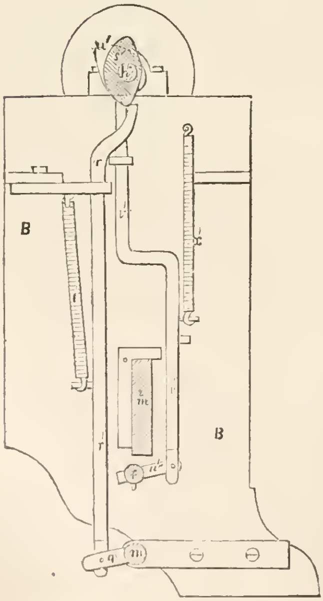

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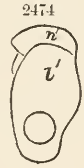

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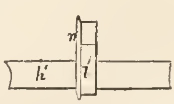
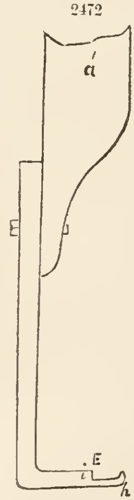


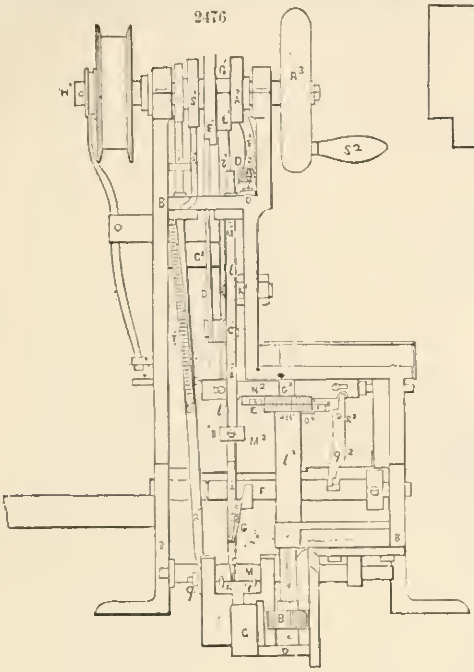
2472



The driving pinion *b*, instead of being arranged within the belt as it has been in other machines of this character, is disposed on the exterior surface of it, and works against, or with the projecting points of the belt. That part of the inner surface of the belt, which is immediately adjacent to the pinion, i supported by, and works round a stationary vertical post or guide *c*, (see fig. 2471, which is a vertical section of the belt and its support) that extends upwards from a horizontal arm *d*, which projects from the main frame B. The opposite end of the endless belt is supported by a straining contrivance L, which is similar to such as are in common use in such machines. The work or knitting hands within is the endless belt, instead of without it, or on the outside of it.

The yarn guide or director is seen at D. It consists of a curved arm, made to extend from a horizontal rocker shaft *f*, and to have a small conical and split tube *g*, on its outer end, through which tube the yarn is carried from the bobbin placed in any convenient position.

2476



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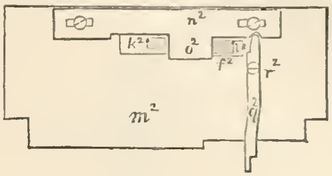

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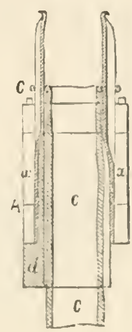

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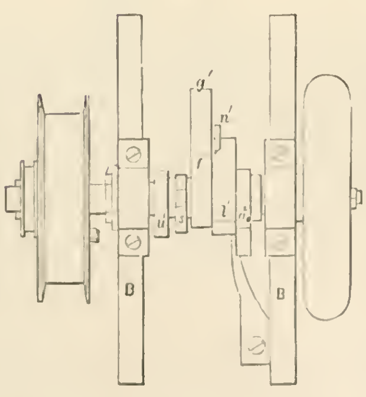

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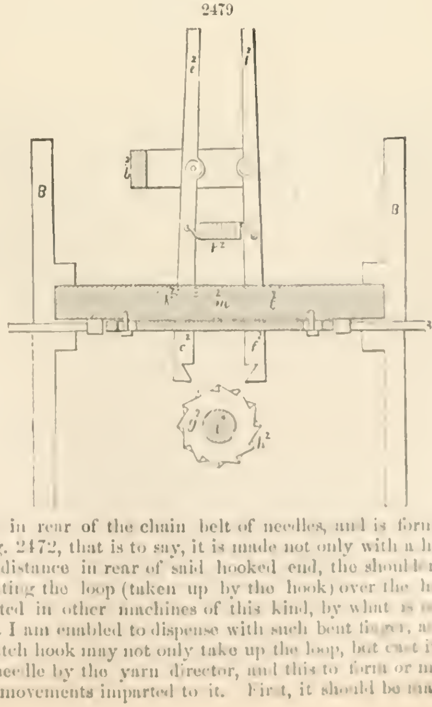
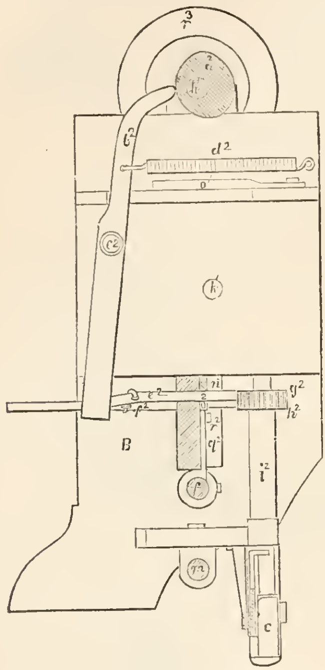
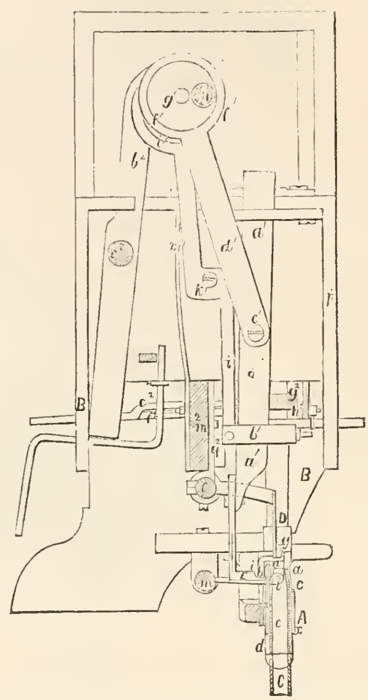


The stitch hook is seen at E. It is arranged in rear of the chain belt of needles, and is formed as represented in side view on an enlarged scale, fig. 2472, that is to say, it is made not only with a hooked end, as seen at *h*, but with a shoulder *i*, a short distance in rear of said hooked end, the shoulder performing the important office of piercing or casting the loop (taken up by the hook) over the hooked point of the needle, the same having been effected in other machines of this kind, by what is usually termed the "bent finger." By my improvement I am enabled to dispense with such bent finger, and the machinery for operating it. In order that the stitch hook may not only take up the loop, but cast it over the end of the needle and the yarn laid on the needle by the yarn director, and this to form or make a new stitch, the hook should have the following movements imparted to it. First, it should be made to pass into the groove of the needle, and under the stitch on the needle. Next, it should be made to rise upwards so as to carry the stitch up to the hooked end of the needle. Next, it should be moved laterally far enough to be opposite the space between the needle (first operated upon) and the next needle. Next, it should be moved forwards between the two needles and so as to cause the shoulder i, to press or force, or cast the stitch over the hooked end of the needle. The stitch hook should next be drawn backwards, and depressed so as to disengage it from the stitch. The movements of the stitch hook may be produced by various kinds of combinations of mechanism. No such machinery forms any part of my invention, and I lay claim to none in particular, but employ such as may be suitable: that adopted by me is as follows, viz:

2478



2477



The stitch hook E, is fastened to the lower end of a bar a', which works or slides freely up and down through a piece of metal b', and is jointed by a joint screw c', to a connecting rod d', on whose upper end is a strap f', passing around an eccentric g', fixed on the main driving shaft h', of the machine. The upward and downward movements of the stitch hook are effected by such eccentric during its entire revolution. In order to produce its forward and back movements, a lever i', working on a fulcrum k', is jointed at its lower end to the rear end of the piece of metal b'. The upper end or arm of the said lever rests against a cam l', fixed on the driving shaft (see fig. 2473,) which denotes a top view of the said shaft, and the cams applied to it. See also figures 2474 and 2475, the former of which is a side view of the said cam, and the wing cam to be hereinafter described, while the latter is a top view of the same, made so as to show the form of the wing cam. During the revolution of the cam l', the lever i' will be moved forwards and backwards by the action of the said cam and a spring m', made to bear against the rear side of the said lever. The small wing cam n', placed on the side of, or to project above the cam l', serves to press the upper end of the lever i' laterally, in order to produce the lateral motion of the stitch hook. A spring o', (see fig. 2473,) presses the end of the lever i', against such wing cam.

Both the stitch hook and the yarn guide, are arranged between the arms of the presser, which presser consists of two arms, k, l, extended at right angles from a horizontal rocker shaft m, and long enough to play between the needles. These arms should be made to operate so as to press the work down to the roots of the needles, after the formation of each stitch; they should next be raised upwards far enough to allow of the movement of the chain belt, which having taken place, they should be depressed so as to hold the work down until the stitch hook has fairly hooked under or taken up the stitch on the needle, against which it may be acting.

The presser should next be elevated with the stitch hook, so as to allow the work to rise. While the stitch hook is casting the stitch or loop over the hook of the needle, the presser should be stationary, but as soon as this has been effected, and the hook has withdrawn itself from the stitch, the presser should be depressed so as to force the work down to the roots of the needles. Such movements may be attained by any suitable machinery applied to the rocker shaft of the presser, such mechanism constituting no part of my invention;—but that which I employ may be thus described:—Fig. 2476 is a front elevation of the machine as it appears when its front plate p', and the endless chain A, are removed from the remainder of the mechanism. Fig. 2470 is a vertical cross section of the machine; the same being taken looking towards the left through the cam, which operates the presser.

From the shaft m of the presser, an arm q' extends towards the front, and is joined at its outer end to an upright and bent bar r', whose upper end is forced upwards against the cam s', by means of a spring t', one end of which is attached to the bar r', and the other to the frame or box B, as seen in figs. 2476 and 2470. The cam s' is fixed on the driving shaft, and during its revolution, it, in conjunction with the spring t', produces the rocker motions of the shaft m, such as will cause the presser to operate in the manner required.

Directly after each movement of the chain belt, the yarn guide or director D, should be moved forward beyond the back needles, so as to lay the yarn on that needle on which the new stitch is to be made. After the stitch has been formed, the yarn guide should be retrograded and carried back of the needles, in order that the chain belt may perform its next movement without obstruction. The mechanism for operating the yarn guide or director D, consists of a cam u', fixed on a driving shaft, a slide rod or bar v', (whose lower end is jointed or hinged to the outer end of an arm w', extended from the shaft f,) and a spring x', which forces the bar v' up against the cam—the said cam being shown in fig. 2470 by dotted lines.

The machinery for moving the chain belt forms no part of my invention, except so far as the arrangement of the gear or pinion B and the joints $x\,x\,x$, &c., of the chain belt is concerned. On the main driving shaft, there is another cam a^2, which operates against the upper end of a lever b^2, which turns upon a fulcrum c^2. See fig. 2478, which is a transverse section of the machine, taken through such cam, and looking towards the right, serves to show the machinery actuated by it. A spring d^2, is used to draw the upper end of the lever against the cam. The lower end of the lever is bent at right angles, or horizontally, and has two impelling pawls $e^2 f^2$, jointed to it, and made to extend forwards, and respectively to act in concert with two ratchet wheels $g^2 h^2$, fixed upon the upright shaft i^2, of the pinion b which works the chain belt. These ratchet wheels and pawls are seen in fig. 2477 and 2479, the latter figure being a horizontal section of the machine, taken just above the pawls, and so as to exhibit them. The teeth of one of the ratchet wheels are arranged in a direction opposite to those of the other, in order that when its pawl is in action with it, a motion of the shaft i^2, may be produced in a direction the reverse of that effected by the movements of the other pawl and its wheel. By the movement of either pawl an intermittent rotary motion of the shaft i^2 will take place.

The two pawls pass respectively through slots $k^2 l^2$, made in a vertical stationary plate m^2; (see fig. 2480,) which is a front view of the plate m^2, and the shifting contrivance attached to it. Such shifting contrivance is a slide n^2, which is capable of being moved longitudinally, and has a projection o^2 extending down between the two pawls. When the slide is moved in one direction, it bears against one of the pawls, and throws it out of action upon its ratchet wheel, and at the same time, in consequence of the two pawls being connected by a spring p^2, it draws the other pawl against the other ratchet wheel, thereby creating a reverse motion of the shaft i^2. The object of the *two* pawls is to enable the movement of the endless belt A to be reversed, so as to cause the knitting to be produced in an opposite direction; one pawl, however, is sufficient to produce the movement necessary to knit in one direction.

The shaft f, which carries the yarn director D, is made to slide longitudinally in its bearings, and is connected into the slide n^2, by a lever q^2, which turns upon a fulcrum r^2, and has its ends inserted in notches made in the slide n^2, and the shaft f, and this so that the movement of the slide in one direction may create a sliding movement of the shaft, sufficient to move the yarn guide into the proper position to commence the knitting in the reverse direction.

The shifting contrivance may be operated by the attendant, or by any other proper means. Some parts of other mechanism which I append or attach to the above described machine, and for purposes not necessary to mention, may be seen in the drawings. As such mechanism forms no part of my invention, I make no further reference to it or description of it.

On the driving shaft there may be a fly wheel r^3, from which a crank s^3 may extend, and for the purpose of enabling a person to put the shaft in motion—or the said shaft may be revolved by a pulley applied to it, and made to receive an endless belt from any suitable driving drum.

By having the endless chain of needles made and operated in the above described manner, the chain extends *around the work*, instead of the work *encompassing the chain*, as it does in other well-known knitting machines. My improved arrangement and disposition of the work exposes all the joints of the links of the chain so that a workman or attendant can readily remove one or more of the needles, with much greater convenience than can be done on the said well-known machines, as in the latter he would be obliged to wholly or partially *remove the work from the needles* in order to accomplish the addition or subtraction of one or more of the needles, such addition or subtraction being for the purpose of enabling him to "*widen*" or "*narrow*" the work. My improvement affords great advantages in knitting a heel, as the same can be effected in a much more perfect manner, without that strain upon the work and needles that is incident to the old and well-known machines.

KNIVES, (*including Forks.*) Knives are well-known instruments, made for cutting a great variety of substances, and adapted by differences in form to various uses; but the two principal sorts may be classed under the terms of pocket knives and table-knives, with their accompaniments, forks.

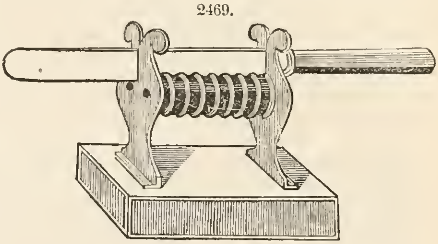
In the making of pocket-knife blades, one workman and a boy are generally employed; the boy attends to the heats, (that is, to the rods of steel in the fire,) which he successively hands to the forger, and takes back the rod from which the last blade was formed. One heat is required to fashion the blade, and a second to form the tang, by which it is fastened into the handle. The skill of the forger is displayed in forming it so perfectly by his hammer, as to require but very little to be filed or ground off in the subsequent operations. The springs for the back of the knife, and the scales which form the rough metal under handle, and to which the other pieces are riveted, are made by a distinct class of workmen. In the forging of table-knife blades, and other blades of a similar or greater size, the forger has an assistant, who, with a large hammer, strikes alternately with him; and the hammering of all blades is continued after the steel has ceased to be soft, in order to condense the metal and render it very smooth and firm. Table-knife blades are usually made with iron backs, which are welded to the steel by a subsequent forging, to that of forming the cutting edge; the thick piece that joins the handle, called the shoulder or bolster, as well as the tang that goes through the handle, is forged out of the iron immediately after the welding of the steel blade: dies and swages being employed to perfect and accelerate the shaping of these parts. When the forging is completed, the blades undergo the processes of hardening and tempering, explained in article TEMPERING. The blades are then ground upon a *wet* stone, about 4 feet in diameter, and 9 inches wide, which roughs out the work; they are subsequently finished or *whitened*, as it is termed, upon a finer *dry* stone; and the shoulders or bolsters are ground upon a narrow stone, about 3 feet in diameter, which completes the grinding. The next process is that of glazing the blades, which is effected upon a wooden wheel, made up of solid segments, well fitted and secured together, and with the ends of the fibres of the wood presented to the periphery of the circle; over this is extended a piece of leather, which is charged with emery or other powders, adapted to the finish or nature of the work required.

The cheaper kind of forks are made by casting them from malleable pig-metal, sometimes denominated "run-steel;" and some of these, which are well annealed and worked under the hammer, turn out very serviceable and good. Those made of wrought-metal, were formerly either forged, and the prongs drawn out by the hammer, and welded together, or they were forged into one solid piece, and the spaces between them formed by cutting away the metal. These processes, however, were tedious and expensive, and a great improvement in their manufacture has been introduced. The tang, shoulder, and a thick, flat piece, called the blade, are forged, and the blade is then submitted to the action of a pair of dies, contained in a powerful fly or stamping-press; the dies being so formed as to force or cut out the superfluous portion of the metal and raise the curved swelled portions at the junction of the prongs, termed the bosom. The forks after this operation are filed up, ground, glazed, and burnished, when they are ready for hafting, which is a distinct business.

The instruments required for hafting knives and forks are few and simple. The principal are, a small polishing-wheel and treddle, mounted upon a stand, a bench vice, and a kind of hand vice to fix in the bench vice, termed a snap-dragon; it has a pair of long projecting jaws, adapted to hold a piece of metal or other substance, with the flat side uppermost, in order to be filed or otherwise worked; a few files, drills, drill-box, and breast-plate, burnishers and buffs, emery, rotten-stone, &c. The substances used for covering the handles are almost infinite; the chief are bone, horn, ivory, tortoise-shell, and wood of every kind. The several pieces of the handle being filed to the shape intended, holes are drilled through them for the pins by which they are afterwards riveted together. The pinning is at first loosely done, until the blades, springs, and all the parts are well adjusted and fit closely; they are then firmly riveted together. The handles are afterwards scraped and then polished, by means of buffing, on the wheel.

KNIFE-SHARPENERS. This term has been given to a variety of convenient modern instruments, especially adapted to the sharpening of knives at table, but particularly carvers, and are intended as substitutes for the common steel. For these instruments several patents have been obtained, and a considerable manufacture of them has been established.

2469.



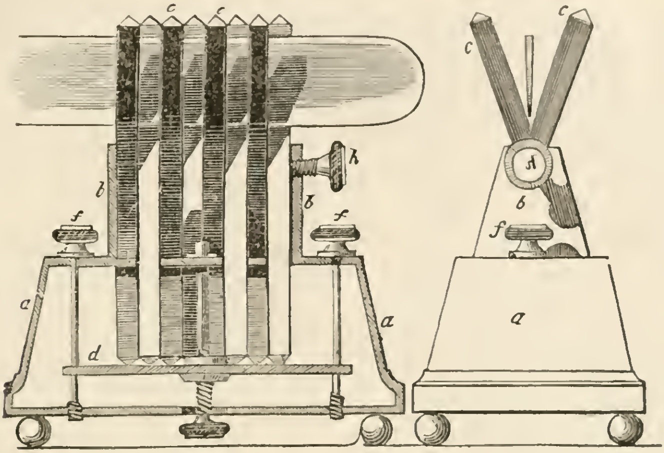
Filton's patent sharpener, represented in Fig. 2469, consists of two horizontal rollers, placed parallel to each other, which revolve freely upon their axes, (represented by the two black dots;) at uniform distances, there are fixed upon each roller narrow cylinders or rings of hard steel, the edges of which are cut into fine teeth, and thus form circular files; the edges of the files in the opposite rollers overlap each other a little, so that when a knife is drawn longitudinally between them, the edge of the knife is acted upon on both of its sides at once. The rollers turn round with the slightest impulse; consequently, they wear uniformly, and will last a considerable time. A good edge is given to a knife by just drawing it from heel to point two or three times between the rollers; and thus obviates the necessity of imitating the skill exercised by a butcher upon his steel.

Westby's knife-sharpener, which was patented in 1828, is an ingenious instrument; an immense quantity of them have been sold, and it is said, have been the means of greatly enriching the proprietor of the patent. Fig. 2470 exhibits an end elevation of the instrument, and Fig. 2471 a side elevation of the bars, with a section of the boxes *a* and *b*, to show the interior. The same letters in each figure have reference to similar parts; *a* is a small oblong box, surmounted by a smaller box *b*; in the top of the latter there is a slit made throughout its length, and of sufficient width to receive the square steel bars *c c*. The box *a* has two similar slits. The surfaces of the bars are draw-filed; they pass through the slit in *b*, and alternately through both slits in *a*, so as to cross each other, as shown in Fig. 2470. The lower ends of these bars are supported upon a plate of metal *d*, which can be elevated, so as to bring a different portion of the bars into operation, by means of the screw underneath; *f f* are two screws passing through the holes in *d*, to preserve its parallel motion, and likewise to support the bottom of the box; *h* is a tightening screw to steady the bars *c c*.

The mode of operating with this instrument is merely to place the edge of the knife upon the bars, so as to bisect the angle formed by them, and then draw the knife backward and forward. As the surfaces of the bars wear away, different sides can be presented, or they can be shifted from end to end, so as to present fresh surfaces to the knife.

Church's patent knife-sharpener consists of two very flat truncated cones, fixed with their smaller surfaces together, and with several rectangular projections in the one, fitting into similar cavities in the other. The conical surfaces of both pieces are serrated with a series of very fine teeth extending angularly towards their centres; these are placed upon the shank of the fork, between the shoulder and the handle, with which they correspond in diameter so nearly as to constitute an ornamental finish to the small end of the handle. In the position and size of these consist the principal merit of the sharpener. When used for sharpening scythes, or other large cutting instruments, the conical pieces are made larger, and fitted on an axis between two prongs of a forked apparatus, with an appropriate handle.

2471. 2470.



Westby's second patent.—The extraordinary success attendant upon Mr. Westby's contrivance for sharpening table-knives induced him to figure a second time as a patentee, "for certain improved apparatus to be used for the purpose of whetting or sharpening the edges of the blades of *penknives, razors, and other cutting instruments.*" The first improvement mentioned in the specification consists in the application to a hone, or oil-stone, of a guide to keep the edge of the razor, or other cutting instrument, at the same angle with respect to the surface of the hone, during the operation of whetting. This is effected in two ways: first, by placing over the hone a plate of metal extending its whole length, and adjustable, at any required distance parallel to its surface, by set-screws; now, in the operation of sharpening, the back of the instrument is kept resting upon the guide-plate, while the edge is applied to the hone. The second method consists in the application of two hones placed in an erect position, with a space between them for the razor, which is to be fixed by screws into a small horizontal frame, made to slide upon a circular rod, so that the edge can be applied alternately to the hones; these can be elevated and depressed at pleasure, so that their surfaces may be uniformly worn while in use. The patentee also mentions in his specification a method of attaching to his hone a leather strap which is made double, and kept stretched by adjusting screws attached to the frame of the hone, or else to the end of a rod extending lengthwise between the two folds of leather. This last contrivance does not appear to us to be scientifically adapted to the object in view, as the pressure of the edge of the instrument upon a strap of leather only supported at its extremities, must produce a tendency in the leather to wrap round the acute angle of the edge of the instrument, and render it obtuse.

LABURNUM WOOD is in use among turners: pulleys and blocks are made of it. Being a hard and compact wood, it is capable of endurance when exposed to the weather, and for various purposes is extremely valuable. When perfectly dry, a cubic foot weighs 52 lbs. 11 oz.

LAC. A resinous substance, the product of an insect found on several different kinds of trees in the East Indies. These insects pierce the small branches of the trees on which they feed, and the juice that exudes from the wounds is formed by them into a kind of cells for their eggs. Lac is imported into this country adhering to the branches in small transparent grains, or in semi-transparent flat cakes. The first, encrusting the branches, is called stick-lac; the second are the grains picked off the branches, and called seed-lac; the third is that which has undergone a simple purification, as we shall presently notice. There is a fourth, called lump-lac, made by melting the seed-lac, and forming it into lumps. To purify the lac for use the natives of India put it into long canvas bags, which they heat over a charcoal fire until the resin melts; a portion of the lac then exudes through the bags, which are subsequently twisted, or wrung by means of cross sticks at the ends of the bags, the surface of the latter being scraped at the same time to accelerate the process. The chief consumption of lac in this country is in the manufacture of sealing-wax and varnishes. It has been a great desideratum among artists to render shell lac colorless, as, with the exception of its dark-brown hue, it possesses all the properties essential to a good spirit varnish in a higher degree than any other known resin. The process given by Dr. Hare leaves nothing to desire, excepting on the score of economy. Were the oxymuriate of potash to be manufactured in the large way, the two processes, that of making the salt and of bleaching the resin, might be advantageously combined. "Dissolve in an iron kettle one part of pearlash in about eight parts of water; add one part of seed or shell lac, and heat the whole to ebullition; when the lac is dissolved, cool the solution, and impregnate it with chlorine till the lac is all precipitated. The precipitate is white, but its color is deepened by washing and consolidation; dissolved in alcohol, lac bleached by the process above mentioned yields a varnish which is as free from color as any copal varnish."

The following is Mr. Field's process: Six ounces of shell-lac, coarsely powdered, are to be dissolved by gentle heat in a pint of spirits of wine; to this is to be added a bleaching liquor, made by dissolving purified carbonate of potash, and then impregnating it with chlorine gas till the silica precipitates and the solution becomes slightly colored. Of this bleaching liquor add one or two ounces to the spirituous solution of lac, and stir the whole well together; effervescence takes place, and when this ceases, add more to the bleaching liquor, and thus proceed till the color of the mixture has become pale. A second bleaching liquor is now to be added, made by diluting muriatic acid with thrice its bulk of water, and dropping into it pulverized red lead, till the last added portions do not become white. Of this acid bleaching liquor, small quantities at a time are to be added to the half-bleached lac solution, allowing the effervescence, which takes place on each addition, to cease before a fresh portion is poured in. This is to be continued until the lac, now white, separates from the liquor. The supernatant fluid is now to be poured away, and the lac is to be well washed in repeated waters, and finally wrung as dry as possible in a cloth. The lac obtained in the foregoing process is to be dissolved in a pint of alcohol, more or less, according to the required strength of the varnish; and after standing for some time in a gentle heat, the clear liquor, which is the varnish, is to be poured off from the sediment.

Mr. Luning's process is as follows:—Dissolve five ounces of shell-lac in a quart of rectified spirits of wine; boil for a few minutes with ten ounces of well-burnt and recently heated animal charcoal, when a small quantity of the solution should be drawn off and filtered: if not colorless, a little more charcoal must be added. When all color is removed, press the liquor through silk, as linen absorbs more varnish, and afterwards filter it through fine blotting-paper. In cases where the wax found combined with the lac is objectionable, filter cold; if the wax be not injurious, filter while hot. This kind of varnish should be used in a temperature of not less than 60° F.; it dries in a few minutes, and is not afterwards liable to chill or bloom; it is therefore particularly applicable to drawings and prints which have been sized, and may be advantageously used upon oil paintings which have been painted a sufficient time, as it bears out color with the purest effect. This quality prevents it from obscuring gilding, and renders it a valuable leather varnish to the bookbinder, to whose use it has already been applied with happy effect, as it does not yield to the warmth of the hand, and resists damps, which subject bindings to mildew. Its useful applications are very numerous, indeed, to all the purposes of the best hard spirit varnishes; it is to be used under the same conditions, and with the same management. Common seed-lac varnish is usually made by digesting eight ounces of the bright, clear grained lac in a quart of spirits of wine, in a wide-mouthed bottle, putting it in a warm place for two or three days, and occasionally shaking it. When dissolved it may be strained through flannel into another bottle for use. In India, lac is fashioned into rings, beads, and other trinkets. Its coloring matter, which is soluble in water, is employed as a dye. The resinous portion is mixed with about three times its weight of finely powdered sand, to form polishing stones. The lapidaries mix powder of corundum with it in a similar manner.

LACE. A delicate kind of net-work, composed of silk, flax, or cotton threads, twisted or plaited together. See Bobbin-work.

LACQUERING is the application of transparent or colored varnishes to metals, to prevent their becoming tarnished, or to give them a more agreeable color. The basis of them is properly the lac described in the preceding article; but other varnishes made by solutions of other resins, and colored yellow, also obtain the name of lacquer. Strictly speaking, lacquer is a solution of lac in alcohol, to which is added any coloring matter that may be required to produce the desired tint; but the recipes that have been published in various scientific journals contain apparently a great many useless articles.

Lacquer for Brass.

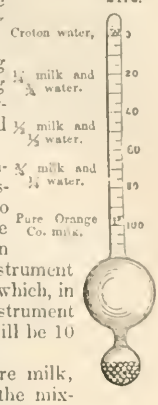
¾ oz. of gum guttæ,	¾ oz. of terra merita,
2 oz. of gum sandarac,	2 oz. of oriental saffron,
2 oz. of gum elemi,	3 oz. of pounded glass,
1 oz. of dragon's blood, of the best quality,	and
1 oz. of seed-lac,	20 oz. of pure alcohol.

Before, however, the reader ventures to meddle with so formidable a list of ingredients as the foregoing, we would recommend him to make trial of the following more simple compound:—Take 8 oz. of spirits of wine, and 1 oz. of annatto, well bruised; mix these in a bottle by themselves; then take 1 oz. of gamboge, and mix it in like manner with the same quantity of spirits. Take seed-lac varnish, (described under the previous article Lac,) what quantity you please, and color it to your mind with the above mixtures. If it be too yellow, add a little from the annatto bottle; if it be too red, add a little from the gamboge bottle; if the color be too deep, add a little spirits of wine. In this manner you may color brass of any desired tint: the articles to be lacquered may be gently heated over a charcoal fire, and then be either dipped into the lacquer, or the lacquer may be evenly spread over them with a brush.

LACTOMETER. An instrument for the purpose of ascertaining the different qualities of milk from its specific gravity compared with water. On this subject Dr. Ure observes, that it is not possible to infer the quality of milk from the indications merely of a specific gravity instrument, because both cream and water affect the specific gravity of milk alike. "We must first use as a lactometer a graduated glass tube, in which we note the thickness of the stratum of cream afforded, after a proper interval, from a determinate column of new milk; we then apply to the skimmed milk a hydrometric instrument, from which we learn the relative proportions of curd and whey. Thus the combination of the two instruments furnishes a tolerably exact lactometer."

Frye's lactometer.—Fig. 2472, for testing the quality of milk; made under the direction of the Board of Agriculture of the American Institute, in the city of New York, who have strongly recommended it to public patronage.

2472.



This instrument was invented for the purpose of ascertaining the density, and fixing the standard weight, of pure unadulterated milk, as it is produced in the best grazing districts in the country, and with a view of detecting the frauds practised by adulterating milk with water, so often complained of by the consumer, in large towns and cities throughout the Union.

Directions for using the instrument.—Fill the tin tube, which accompanies the instrument, with the milk to be tested at a temperature of about 60 degrees, and suspend the lactometer in the milk, and if the milk is proof, the instrument will sink to the degree marked 100 on the scale, or p, showing that the milk is at par; but if the milk has been adulterated with water, or has been taken from cows that have been fed on slops from breweries, and kept confined in stables in warm weather, the instrument will, in all such cases, sink below par, and show the per centage of adulteration, which, in some instances, will be 25 per cent. below par; but if the milk is superior, the instrument will rise above p, and show the per centage above par, which, in some instances, will be 10 per cent. Each division on the scale is 5 per cent.

Any person can test the correctness of the lactometer by mixing water with pure milk, and note the per centage of water which they use, and suspend the instrument in the mixture, and it will give the proportion of water added.

To farmers the instrument has proved to be very valuable, as a ready means of testing the relative quality of their cows, by inspecting their milk, and also showing the effects produced by a change of the animals' food, as its quality will change the density of the milk.

LADDER. A portable frame, containing steps for the feet. There are various kinds, most of which are too familiar to the readers of this work to need description. Ladders are very advantageously employed in the raising of weights, by the addition of a pulley-wheel at the top, or suspended over them; passing over this pulley is a rope, to one end of which is attached the article to be raised.

Ladders are the universal means of ascent and descent in mines, the distance between the levels being generally 60 feet; a single ladder in former times reached from one to the other, but the most usual length at present is from 4 to 5 fathoms. In the perpendicular shafts the inclination is commonly such that the ladder may nearly traverse the breadth of the shaft; from 18 to 21 inches in the fathom is the inclination which experience has determined to be the best calculated to facilitate the progress of the miner, being that which enables him to stand upright on the ladder with the leg clear from the stave above, so that the effort is divided between the upper and lower extremities. The distance between the staves is generally 12 inches; in some old ladders they were 14 inches apart, but 10 inches is found the best for facilitating the climbing, by which one-fourth of the labor is estimated to be saved. The staves are of wood, though iron is in some instances preferred; in others it becomes slippery and rough from the corrosive action of water impregnated with copper, &c. Each ladder usually terminates on a *sollar* or platform, which leads to that below, which is generally placed parallel to that above.

LAMPS. The whole series of improvements made in lamps up to the present time, must be considered as the reward of no inconsiderable expenditure of ingenuity in the inventors themselves, and of a clear perception of the working of physical laws, enabling them not only to overcome the difficulties of the subject itself, but also to adapt the new contrivances to general use, and to the management of the unskilled. A general view of this interesting subject will place clearly before us the essential points which it has been the object of the inventors to attain, sometimes singly, sometimes several at once. They are these:

(*a*) To select such a form (section) of wick that the quantity of decomposed oil, and the simultaneous supply of air, may stand in such relation to each other, that the hydrogen and carbon may be consecutively consumed, and consequently no *smoke* produced.

(*b*) To make the distance between the burning part of the wick and the surface of the oil as unchangeable as possible, in order that as much oil may be drawn up at last as at first.

(*c*) To place the reservoir of oil in such a position that the shadow shall occasion little or no inconvenience. The use made of the lamp must, of course, here regulate its form; it is not, however, always a fault when these do not exactly correspond. Thus the shadow thrown by wall lamps is unimportant, as the lamp itself covers the shadow: in like manner, the shadow of a common study lamp cannot be considered as a fault, being used only by one person, although its prevention is always an improvement.

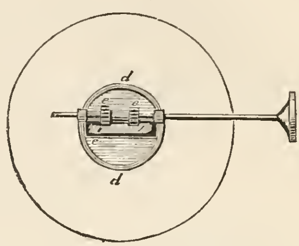
(*d*) To throw the light, radiating from the flame, by means of collectors and reflectors, from those parts where it is of little service, in the direction where it is most required.

The requisitions stated under *a* have been complied with in two ways: on the one hand, by controlling the access of air, (the quantity of air;) on the other, by regulating the supply of oil, and often by both at the same time. They have reference to that part of the lamp called the burner.

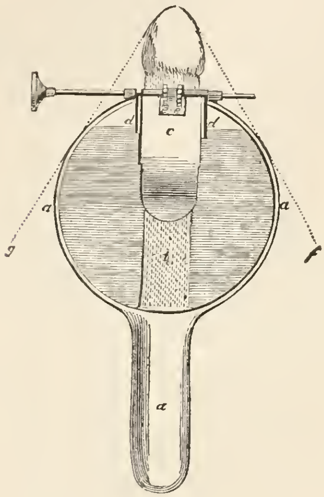
The scrupulous enumeration of the manifold modifications, and, for the greater part, unimportant improvements in lamps, which have been presented to the public during the last twenty or thirty years, would be but a tedious labor; and in the following observations we shall only lay before the reader those inventions which appear to indicate important progress, or form epochs in the history of this subject.

Worms' lamp.—The Worms' lamp, shown in Figs. 2173 and 2174, is well known, and characterized by the shape of the wick *t*. The fibres of the wick, instead of being collected into a round bundle, are placed in small bundles side by side, forming together a flat ribbon. The effect of this is obvious. The edges of the flame are at no point so distant that a nucleus can form in the centre, which, from want of air, will burn incompletely and smoke. The flat socket *c* serves to hold the wick; it is soldered in the diameter of the wide ring *d*, which, with its recurved edge, rests upon that of the glass globe *a a*. An important addition to its flat form is its *movability*, and this is common to all the following kinds of lamps. The teeth of a wheel *e* and *e'*, more distinctly seen in Fig. 2474, are somewhat advanced into the space occupied by the wick, a cut being made in the socket, so that they press the wick in some measure against the back side. According as the screws are turned the wick is either raised or lowered, and a larger or smaller portion of it is engaged in the combustion. When the wick is high a large quantity of oil is decomposed; and when low a small quantity in the same space of time: the supply of oil is, therefore, easily regulated.

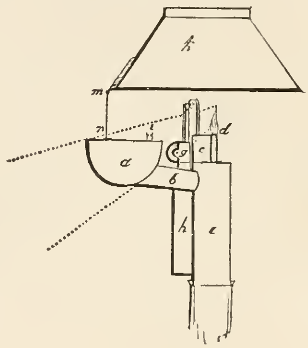
2474.



2473.



2475.



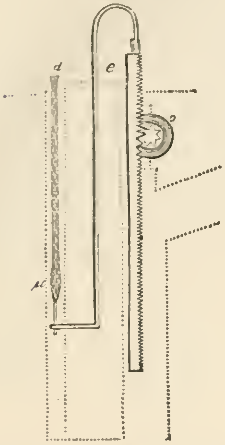
By means of the stem *a* the oil vessel can be placed upon any kind of foot. Besides the very unequal, constantly decreasing height of the surface of the oil, another objection may be raised to this arrangement, on account of the size and disadvantageous direction of the shadow, the conical space between βf and βg receiving no direct light.

Study lamp.—In the common study lamp, Fig. 2475, the oil vessel *a* is more flat, and instead of being situated below, is behind, and at the side of the flame, so that its shadow falls much beyond the immediate vicinity of the flame, and in no way interferes with the person in front of the lamp. The greater part of the light passing upwards, is collected by the shade *k*, and from every point of its inner surface is reflected downwards towards the opposite side. The inclination of the sides of the conical shade is, therefore, not unimportant, and should be at an angle of about 60°. The shade can be turned on the support *m n*. The motion communicated to the wick *d* is not from above, as in Figs. 2473 and 2474, in which arrangement the pressure interferes too much with the supply of oil, and the flame is too much cooled by the proximity of the wheels, but it is from below. The clamp *u*, Fig. 2476, which sustains the wick, is firmly connected with the toothed rod *e*. By turning the wheel *o*, this and the wick is raised up or down; the wheel works in the separate compartment *g*, as does the toothed rod in descending into *h*, whilst the clamp, the rod of wire, and the wick, by means of a rectangular appendage *c*, Fig. 2477, are all inclosed in the space allotted to the burner. This communicates with the oil vessel through the tube *b*; *i* is the inclosure round the burner. The motion of the wick, by means of a toothed rod and wheel, is, under various modifications, common to most lamps. The stopper *l*, at the aperture for filling the oil vessel, must be pierced, that the air without may not depress the oil in the burner.

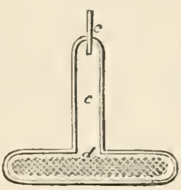
The astral lamp.—The astral lamp, of which a sketch is given in Fig. 2478, was constructed by Bordier-Marcet, with the idea of making as imperceptible as possible the sinking of the level of the oil, and at the same time the diminution of the flame by means of a very flat oil vessel, in which, therefore, a larger quantity of oil only occupies a very insignificant height. It is clear that the annular flat oil vessel will produce only a small unimportant shadow, although this will necessarily be thrown on all sides. At the same time the side nearest the flame *a a* is so inclined that it acts like a shade. The burner is not peculiar to the astral lamp, but is the well-known invention of Ami Argand, in 1789, and named after him; it is by far the most important kind of burner employed for illuminating purposes. The Argand burner, with double draught, consists of two metallic cylinders, one within the other, *c* and *d*: the ring-shaped space between them, which is closed at bottom, contains the oil and the cylindrically woven wick; the latter is clamped between two rings, which are connected with the screw

The inner cylinder is open at top and bottom. The extraordinary advantages of this arrangement are easily understood. It has been already shown that with entire (massive) wicks, a nucleus is formed in the middle of the candle, which illumines but little, and smokes from want of air; with the hollow wick a current of air is directed exactly to that spot, so that the flame is surrounded by two concentric currents of the same kind. The current produced in the air by a freely burning hollow-wick flame, or the natural supply of air, is by no means sufficient to produce the requisite amount of light. As soon as, by

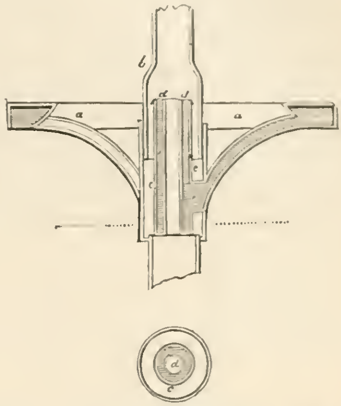
2476.



2477.



2478.

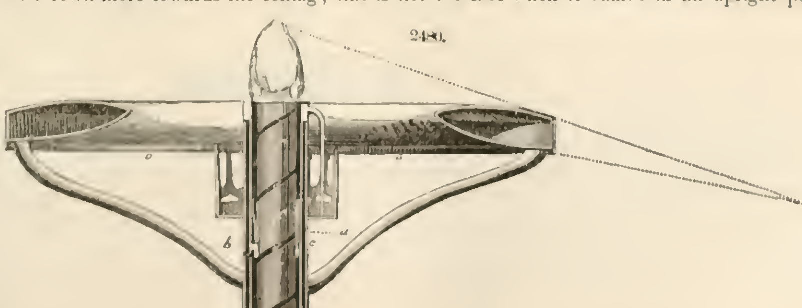


raising the wick, the size of the flame is increased, a thick smoke is the result; and when the wick is so regulated as to produce no smoke, then the flame is weak and deficient. But Argand gave a real practical use to his invention by applying the happy idea of an artificial draught. The principle is the same as that of chimneys: a rest on the outside of the burner supports a straight glass cylinder, which, including the inner and outer draught of air, exerts a powerful influence upon the velocity of both, in proportion to its height. With this arrangement, the point at which smoke begins to be evolved corresponds with a much higher intensity of flame. Another advantage, not at first anticipated, is the great steadiness caused by the chimney. When a draught of air comes in contact with an unprotected flame its force and cooling influence produce diminished combustion, and at the same time flickering and smoke; in Argand's burner, on the contrary, the supply of air to the flame is become self-dependent, whilst the heat itself is made the motive power. The cylinder protects it from any direct interruption, and that arising from the draught apertures is hardly felt at all in the interior. It must not be left unnoticed that the straight Argand cylinders, whilst assisting the draught, fall into an opposite extreme, and supply too large and injurious an amount of air. This was remedied, soon after the original invention, by Lange, and forms an important improvement; it consists in contracting the diameter of the glass chimney at a certain height above the burner at *b*, thus forming a shoulder of a few lines in width, as in Figs. 2478 and 2479. The draught, moving in the simple cylinder, in a parallel direction to the axis of the cylinder, is thus broken at the shoulder, and thrown into the flame at a certain angle. The supply of air is, therefore, lessened, but the direction given to it is preferable; and that part of the current, which, without taking part in the combustion, cooled the flame in a useless manner, and passed along the inner surface of the cylinder, is almost entirely removed. The glass chimneys are, however, applicable to all burners with flat, round, or semicircular wicks.

2479.

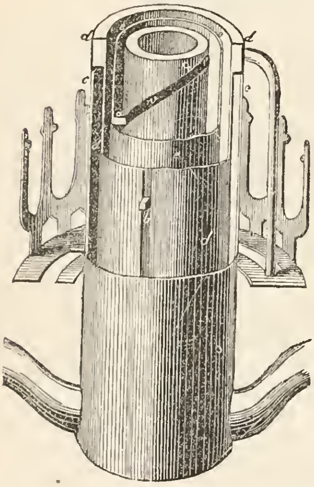
Sinumbra lamp.—When the astral lamp is used as a hanging lamp, the shadow of the circular oil vessel is thrown more towards the ceiling; this is not the case when it stands in an upright position.

2480.

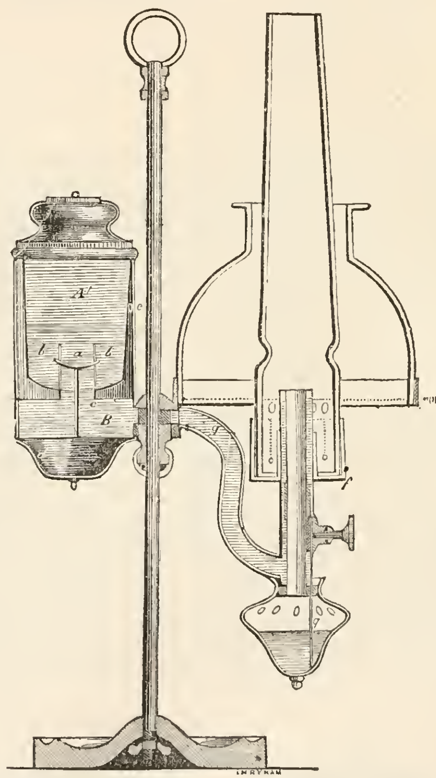


By an ingenious modification, Phillips has succeeded in his sinumbra lamp, Figs. 2480 and 2481, (*sine umbra,*) in rendering the shadow imperceptible even in the latter kind, and this is done by the peculiar section of the circular vessel *o*. Its three surfaces meet in the form of a flat wedge, the sharp edge of which is directed towards the flame. The position of the flame, in relation to the oil vessel is such that two tangents drawn from the apex and base of the flame to the latter, meet a few inches behind it in *x*. Beyond this the vessel can cast no shadow; but even in this small space it is almost entirely destroyed by a vase-shaped ground-glass shade, which, resting upon the oil vessel, surrounds the chimney, and scatters the light in all directions around. The manner in which the wick is moved in the sinumbra burner is original, and deserves notice; there is neither screw nor toothed rod employed. The inner cylinder *f* is furnished on its outer surface with a deep, much inclined spiral groove, into which the short peg or appendage *a* of the wick-holder *e* fits. If, therefore, the latter is turned on its axis, the peg moves along the groove and forces *e* up or down. From its position in the burner, however, *e* cannot be approached by the fingers, and directly turned; this is effected by the cylinder *d*, which, throughout its whole length—that of the burner—has a slit, into which a second peg *b*, on the outer side of *e*, fits. By this arrangement *d* can at any time be freely moved up or down, but cannot be turned without taking with it the wick-holder, causing this either to be raised or depressed. In order that *d* may be moved easily, and without danger from the flame, it is firmly connected with the support for the chimney, terminating above in a thick ring, two or three lines wide, which rests upon the edge of the cylinder *c*, this being purposely made lower, and the whole is thus brought up to the full height of the burner. In this ring the supports for the chimney are fixed. If these are turned with the hand, *d* is turned at the same time, and with it the wick-holder, which is thus moved up or down. Great mobility characterizes this arrangement, and no forcing or compression of the ring holding the wick can occur.

2481.



2482.

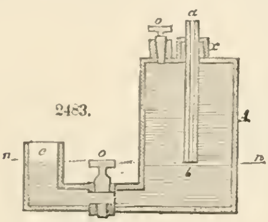


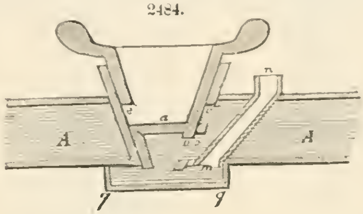
All the lamps as yet described are subject to one common evil, that of having the oil vessel, at all events, within a few lines of the level of the burner; in a position, therefore, which throws the most objectionable shadow. A whole series of contrivances have consequently resulted from the efforts of inventors to transpose this cistern either to a considerable distance above the flame—when its shadow would fall upon the ceiling of the room—or to a position much below the flame, when it would fall at the foot of the lamp. Both resources, however, when applied, give rise to new and critical difficulties; the former requires that the supply of oil which flows *downwards* to the burner, should be accurately regulated. The most common and general application of this method is that adopted in the standing lamp, Fig. 2482. The oil cistern A is a movable metallic vessel, capable of being closed at the bottom by a valve *a*, which moves between the regulating rods *b b*. In the upright position the valve falls back and leaves the aperture open for filling the vessel; if the valve is then pulled up by its rod, the aperture is closed, and the bottle can be inverted and put in its place in the case B, (as in the figure.) It is no sooner there than an alteration occurs. The rod attached to the valve is, namely, so long that the valve is raised as soon as it touches the bottom of the case *d*. The oil, therefore, flows out for a few seconds until it has risen so high in the case as to stop the aperture of the bottle A. From this instant equilibrium is established, and as the mouth of A is on a level with the height of the burner, this becomes filled at the same moment, connection having been made by means of the tube *g*. The lamp has really two oil cisterns—an under one, which directly feeds the burner, and an upper one, the inverted bottle, for the supply of the lower as the oil is gradually consumed. As long as the level of the oil in B remains unchanged, and the mouth of A consequently closed, no air can enter A, and the whole stock of oil is kept up by the pressure of the atmosphere. When the lamp has been lighted some time, and the oil sinks below the mouth of the bottle, a few air-bubbles enter and take the place of an equal bulk of oil, which flowing out, raises the level in B until the mouth is again closed. The same operation is repeated as long as the oil is present in A.

The other parts of the lamp are easily understood: *f* is the support for the cylinder, (the peculiar form of which will be explained below,) *q* is the vessel for the toothed rod, and *e* is an aperture in the case for the easy admission of air into the interior.

On reflection it will be immediately perceived that in all similar lamps, from the peculiar arrangement of the oil cistern, the height of the oil in the burner will not be always quite constant, but will alternately sink and immediately rise again to its former height, whilst in the lamps previously described, the suction of the wick is rendered more and more difficult by the constant sinking of the level of the oil.

The principle in question has been put into practice with better success by means of a simple vessel without case, as for instance, that represented in Fig. 2483. The mouth of the movable oil bottle corresponds here with the lower opening *b* of the tube *a b*, which passing through the air-tight collar *x*, is movable in the lid of A. The oil consumed in the burner *e* is replaced from the stock contained (above the level *n n*) in A, the place of which is then occupied by air, which enters at *b*. As soon as the consumption of oil in *e b* ceases, no more air-bubbles enter, and *vice versa*. As the level of the oil in the burner is dependent upon the position of the mouth *b*, this can be most accurately adapted to circumstances, *a b* being movable. The cocks *o* and *o'* are only used in filling the vessel.


2483.

2484.


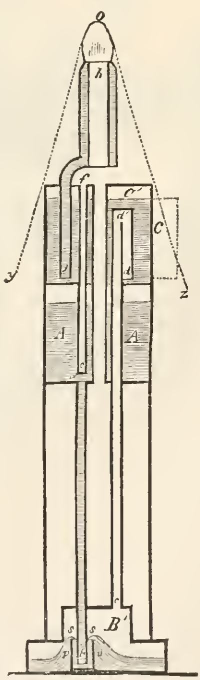
This principle can be applied in the same manner, or in a much more compact form to lamps with circular oil vessels, by means of Caron's stop-cock, Fig. 2484. The conical plug of the cock is completely hollow, and at a certain distance from the middle it is supplied with a cross bottom *a*, dividing the space into two unequal parts. In the upper part the round lateral aperture *e* is made opposite to *o* in the lower part; *e'* and *o'* are the corresponding apertures in the case. In the position represented in the drawing, *e* is closed, whilst *o* is in free communication with the stock of oil in the circular vessel A A. This stock comprises the whole quantity, situated above the mouth *m* of the tube *m n*, corresponding with the tube *a b* of Fig. 2483. The side tube communicating with the burner also opens into *q q*. In the opposite position of the cock (by closing *o*) the space A, and, in the first instance, *q q* is shut off from communicating with the burner, whilst the same space A can then be filled, *e* being open.

By transposing the oil cistern to the foot of the lamp, by which means all shadow is avoided, we forego the important advantage which the free flow (fall) of oil occasions, and by means of which it can easily be conducted to the burner; and, as consumption goes on, the oil must then be *raised*. The lamps made upon this principle are interesting on account of the ingenious, but at the same time very complicated elevating apparatus, which partly depends upon hydrodynamic, partly upon hydrostatic laws, and is partly also a mere mechanical arrangement.

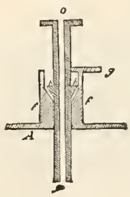
Girard's lamp.—Girard's (hydrostatic) lamp is constructed upon precisely the same principles as the air-chamber of a fire-engine, or resembles rather Hero's fountain, Fig. 2485. In these arrangements it is well known that the pressure exerted in a vessel is transferred to any other distant cistern by means of compressed air, and is the means of forcing a liquid from its previous position, for example, in an upward direction. In Hero's fountain the primary pressure is produced by the column of water *a* fed from the vessel above it; the air inclosed between *c* and the lower bulb is thus compressed, acts upon the surface of the fluid in *c*, and forces it to a corresponding height in *d*. All these compartments are also present in Girard's lamp, but are closely packed together for the sake of saving space, as is seen by the sketch, Fig. 2486, where the unimportant parts are left out. A is the reservoir for the forcing column of oil in the tube *a b*, B the lower vessel with the inclosed air B', which conveys the pressure received from *a b* through *c d' d* to the vessel C, and in the first instance to the air C' contained in it. As long, therefore, as there is pressure from *a b*, the air C' will cause the oil in C to rise in the tube *g h* to a corresponding height, (to the burner.) This height, therefore, depends upon the uniformity of pressure in general, and ultimately upon the constant uniformity of height in the column of oil *a b*, which has a tendency every moment to shorten the play of the whole, both from above and below; from above by the sinking of the oil in A, from below by its rise in B. To avoid the former, at least for the duration of an evening's consumption, the vessel A is furnished with a tube *e f*, upon the same principle as that described in the oil cistern at Fig. 2483, so that the height of the column of oil exerting pressure coincides with the aperture *e*, and all the oil above that must be considered as a store for the supply of that column. The latter is obviated by the narrow vessel *v* which surrounds the aperture *b*, and is filled up to *s s* in a few moments by the oil flowing from A, thus constituting a basis of uniform height for the column. Both contrivances are effective until the oil in A sinks below *e*, and has risen on the outside of *v* above the level *s s* in B. With the requisite height of the lamps the pressure of the column would raise the oil to a greater height than is desirable. To avoid an excessive length of burner, the tube *c d' d* may be curved like a siphon, as indeed was done by Girard, by which means the oil in *e f* is caused to rise as much less as *d* is below the fluid level in C, therefore *x* less. The pressure is first exerted to overcome the column of oil *x*, and it is only the excess that exerts an upward influence in *g h*; the result is, therefore, the same as if the elevation in *g h* was effected, not from the level of the oil at C, but at *g*, for $g\,h = e\,s\,s$.

Future endeavors to bring the principle of Girard's lamp into a form more suited to daily use will, perhaps, be successful; for the limited application which has been made of it must be ascribed to its inconvenient shape. The following points deserve particular notice; first, as is obvious enough, the working of the lamp is not independent of the changes of temperature and pressure in the atmosphere. Increasing pressure (rise of the barometer) and a lower temperature will diminish the bulk of the air inclosed in B and C, and cause an augmented flow of oil from A towards B. A fall in the barometer, and a higher temperature, will produce an opposite effect, and cause the oil to flow from the burner. The effect of temperature is the stronger of the two; but both by proper means can be rendered imperceptible, at least for the duration of an evening. Another and a greater objection arises from the position and the shape of the vessel C, upon which, as may be seen by the sketch, the supply of the burner is solely dependent, whilst the oil of A and B is only employed as a fluid pressure. C cannot well be made deeper without increasing immoderately the height of the lamp; there is, therefore, no other means of affording space for the requisite quantity of oil for an evening's consumption, than by adding to the breadth of this vessel. When this is done, and from its being placed immediately under the burner, the shadow falling between *o y* and *o z* will very much exceed the space occupied by the foot of the lamp. Lastly, the necessary additions and apparatus for filling the lamp deprive it of that ease and simplicity in the management which daily use justly demands.

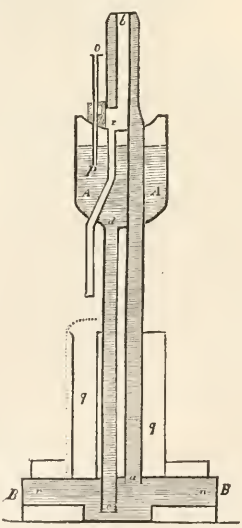
2486.



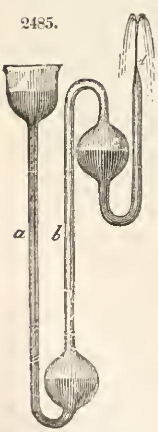
2488.



2487.



2485.

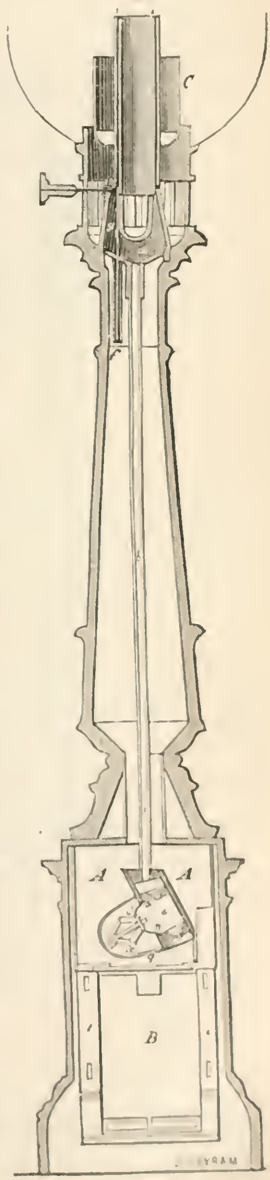


The hydrostatic lamp.—The doctrine of the equilibrium of fluid pressure has found an application in the hydrostatic lamps. Two different fluids, brought into tubes which are connected at the bottom, will balance each other at different heights, according to their respective densities. The one fluid will form a column as many times lower as its density exceeds that of the other fluid. A column of mercury requires to be only one inch in height to balance a column of sulphuric ether of 19 inches, or a column of oil of 14 inches.

After salt and water, syrup, honey, mercury, had all been tried as heavy liquids, Thilorier succeeded in 1825, at Paris, in giving a decided pre-eminence to his lamp by the use of a solution of white vitriol (sulphate of zinc) and by a suitable apparatus. When we consider that the fluid producing the pressure must not affect the oil or the sides of the vessel, (tinned iron,) that it must not become solid (crystallize) at a temperature several degrees below 0° C., that it must be cheap, and have the proper density, we shall then understand how to appreciate the discrimination which led Thilorier to employ a solution of equal parts, white vitriol and water. Such a solution is 1·57 times denser than oil, so that a solution of zinc 10 inches high can support a column of oil 15·7 inches in height.

It is obvious that, with the diminution of the column of oil (the consumption of oil in the burner) the solution of zinc will sink to a corresponding level, and will only be enabled to force the oil to the original height, when it itself is fed by a reservoir of zinc solution. The cistern A in the section of the lamp, Fig. 2487, is solely for this purpose. In a chamber B, in the foot of the lamp, both the equally poised columns terminate, namely, the column of oil in the tube *a b*, which terminates above in the burner, and the column of zinc solution in *e d*, above which the cistern A is situated containing the zinc solution. The flow is effected in the manner described in Fig. 2483, by means of the tube *o* P, through which the external air enters bubble by bubble, as the solution in *e d* threatens to sink. The height of the column must, therefore, be reckoned from P; B is completely filled, and by both fluids at the same time, so that no air remains in it. Into the lower solution of zinc (extending to *n n* in the figure) the tube *e d* is plunged; into the oil above, on the contrary, the tube *a b* does not enter beyond the top layer of the fluid in B. From the time of lighting and during the combustion, the level *n n* naturally becomes higher and higher. At length B becomes quite filled with solution of zinc, and oil must be supplied. This is done by a separate funnel through the burner, which obliges the solution of zinc to return to its former position, an outlet being afforded for the air in A. The tube *o* P, Fig. 2488, (twice its proper size,) is intended for this purpose, having a conical appendage *h* accurately ground to fit into *f f*, and luted into the lid of A. The position represented is that for filling, and this is effected by the peg *g*, which is fixed to *o* P, and only rests on the edge of *f f*; when *h* is to be closed the tube is turned until *g* falls into a perpendicular cavity. The oil which overflows the burner in filling, and at other times, collects in the concave lid of A, and passes off by *i i* to a ring-shaped movable vessel *q*. This vessel is open and ring-shaped, to admit of the passage of *a b* and *e d* through the middle of it.

2489.



It must not be supposed, even when every thing goes on regularly, and the supply in A is not exhausted, that the level of the oil in the burner always remains the same, for the column *n a b* is constantly shortened by the rise in *n n*, and more rapidly than is the case with the zinc column *n* P during the same time. The inventor has succeeded in rendering this imperceptible for a duration of six hours, by making the diameter of B very large in proportion to that of *a b*. The difference of level does not actually exceed two to three lines, whilst the oil in the burners of astral and sinumbra lamps frequently falls one inch.

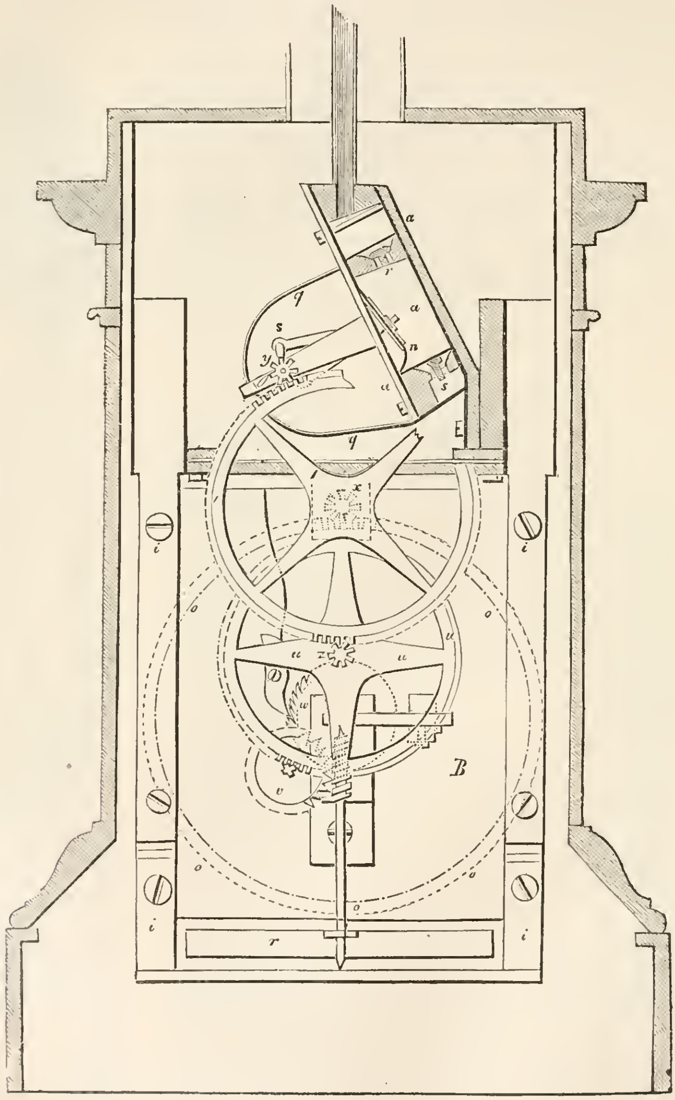
Pump lamps.—The general conclusion may be inferred from what has been said, that the different static lamps either do not attain the important advantages which their construction was intended to confer, or are accompanied with corresponding disadvantages. In contradistinction to these we have the lamps with a mechanical arrangement for raising the oil; and as a pump is generally employed for that purpose, they are called *pump lamps.*

The simplest example of these is the pump lamp with a flat wick, very much used in the south of France, although not in this country: the motion of the pump is produced by the hand, but in a very imperfect manner. The piston of the pump is kept constantly raised by the tension of a spiral spring. As soon as the piston-rod, which is also the ascending tube and in firm connection with the burner, is forced down, by overcoming the power of the spring, the descending piston forces the oil in the cylinder to rise through the tube to the burner. When the stroke is ended, the elasticity of the spring brings the piston to its former position, and the cylinder becomes again filled. As candles require snuffing from time to time, so here, the pump must be used at short intervals. In lamps of this kind, with double draught, the burner is fixed, but then there is a piston-rod with a handle at the side of the ascending tube. The uniform working of such a lamp depends, therefore, upon the care which is taken to supply the oil that is consumed by repeated use of the pump. If this is only done at long intervals, the flame will vary from its utmost intensity to a very dingy light.

The numerous improvements which have here been noticed, with reference to the most successful and interesting inventions, must be considered as important advances; but they have nevertheless left one point out of view, upon which the most indispensable conditions for combining a perfect, and at all times, uniform evolution of light depend; a point which is indisputably the most difficult of all to accomplish. It has been noticed how the lowering of the oil level obstructs more and more the functions of the wick, and consequently diminishes in an equal degree the brilliancy of the flame. The lamps with a supply, upon the principle of connected tubes, are subject to this evil in its entire extent; those with an inverted bottle or similar arrangement are also influenced by it within certain limits. In the former the brilliancy rapidly diminishes; in the latter it becomes lessened, and returns to its original state at regular intervals.

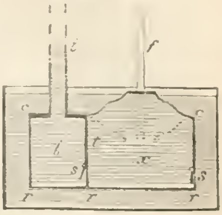
Carcel's clock-work or mechanical lamp.—Carcel, in the year 1800, was the first to carry out the idea of pumping up the oil from the foot of the lamp to the wick, by simple machinery like that of clocks, and, moreover, in such quantity as to exceed the quantity consumed during the whole period of burning. The invention of his clock-lamp is without precedent, with reference to the uninterrupted and perfect supply of oil to the wick. Whilst in the other lamps the burner contains a stationary column of oil, which either constantly decreases from above or is reinstated from time to time, the oil in Carcel's burner forms a constant ascending current, which always supplies the wick with as much as it can possibly require; and lastly, the unconsumed portion flows back to the foot over the outside of the burner.

2490.



Carcel's invention left only unimportant points connected with the works and the pump to his successors, to which the skill of others has been applied. Figs. 2489 and 2490 present a section of Carcel's lamp and its various parts, with Penot's improvements. The chief parts of the lamp are arranged as follows: The case for the works B and the space A for the stock of oil, form the foot of the lamp. The stem of the column contains only the ascending tube *b*, which separates above (over the capital) into a forked appendage, (crutch,) upon which rests the burner with its two concentric tubes *e e* The burner and the ascending tube form, therefore, a space which is connected with A by means of the pump. This latter is a so-called *priest-pump*, and is more simply represented in Fig. 2491. The space *x* is closed at the top by a piece of elastic cloth or leather, in the middle of which, when it is considered as a piston, the piston-rod is fixed. By its upward and downward motion, an alternate expansion and contraction of *x* is effected. In the first case the valve *s* opens, and oil enters *x* from *r r*; in the other case, through the valve *s'*, oil passes from *x*, and is raised in the tube *t*. The motion of the cloth or leather acts in short in the manner of the cheeks and muscles in drinking and blowing. To meet the unavoidable obstructions which would result from the presence of impurities in the oil, it is all made to pass, whilst still in A and before entering the pumps, through a metallic sieve with fine holes *q*, which surrounds the whole of the front part, including the entrances to the valves below.

2491.



The quadrangular box of the pump contains, for preserving uniformity of action, three simple priest-pumps *c c c*, made of gold-beater's skin, which, during every moment they are in action, alter their positions relative to each other. This necessary circumstance is self-evident from the whole arrangement of the pump. Each single pump has two valves, an entrance valve (the under one in the figure) and an exit valve (the upper.) *a* is a separate chamber for each: the space for receiving the oil above the exit valve, on the contrary, is common to all. The three short piston-rods, if they may be so called, work upon three crooked arms B *y x* on the same axis, but in different directions. One pump must, therefore, always be forcing, whilst the second is sucking, and the other midway between the two. Below, or in the direction of B, the chamber A is completely closed, with the exception of a stuffing-box, through which the crooked pin of the axle is moved. The wheel *t* passes under a box placed at the side, in which this stuffing-box is situated. The iron frame *i i* serves to give steadiness to the works in B; the most important parts of the arrangement may be seen in Fig. 2490. Motion is obtained by the spring wound up in the case *o o o*, which is furnished with cogs. The cogs of *o o o* first move the toothed wheel *t* upon the same axis by means of *x*. The wheel *t* catches the second cog *y* above, which has the same axis as the piston-rods, and thus the pumps are set in motion. Below, however, *t* moves the endless screw, on the axis of which is the fly-wheel *d* for regulating the works, by means of *z*, and the toothed wheel *u* and *v*. At the very bottom, on one side of the foot of the lamp, is a small bolt, which, when pushed forward, catches the fly-wheel, and either stops the works, when in motion, or sets them going when it is pulled back, and the whole has been wound up.

The stopping-wheel W is used for winding up the machine with a key.

The toothed rod *g*, with the wick-holder, works below the crutch of the ascending tube, in the case *f*.

Experience has shown that the whole arrangement of the works is not so tender and brittle as might at first sight have been supposed.

The overflow of oil from the burner makes it necessary to screw the wick up somewhat higher than in common lamps; and this brings with it the great advantage of the flame being more raised above the edge of the burner, where less heat is conducted from it, and it burns more perfectly, producing no carbonaceous matter on the wick and about the edge of the burner, which, in general, so materially interferes with the regular flow of oil.

Carcel's lamp would, without exaggeration, have been prized as much as Argand's had been sixteen years previously, if a less expensive and more suitable form for general use could have been given to it.

At an earlier period, and again more recently, the idea has occurred to those versed in these matters, to replace the complicated clock-work, either by the force of a falling body, (for instance, a piston in a cylinder,) or, at least, to cause the tense spring to act upon a larger piston of that kind. In both cases the oil is contained in a lamp-like vessel, resembling the cylinder of a pump, from whence it is slowly forced upwards by the piston (moved either by gravity, or a spring) to the burner.

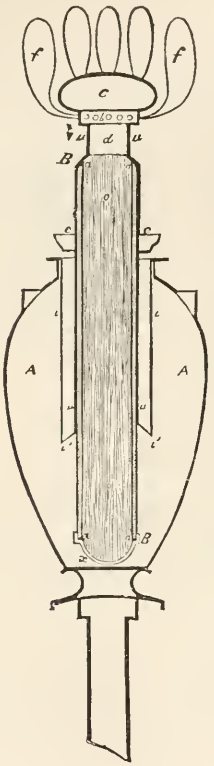
So far, all is simple and easy; but the practical use of the lamps has always foundered on the difficulty of regulating the *acceleration* of the fall, or the *diminution of the force of the spring*, to the uniform demand of the burner. The arrangements of this kind are all wanting in simplicity, or they effect their purpose but imperfectly. Generally, the ascending tube is contracted conically at a certain spot, into which a conical plug fits. The spring in rising enlarges the aperture at the contracted spot, whilst the sinking piston lessens it, by forcing the plug either backwards or forwards, in proportion as their motion is irregular.

The application of a phenomenon for raising the oil in lamps, first proposed by Celarier, is worthy of notice, from its novelty and simplicity, and because it may possibly be productive of something else, not from the use actually made of it at present, which is by no means established. It is of very common occurrence, and may easily be observed. Celarier's lamp consists principally of two vessels, fixed one above the other, which are separated from each other by a partition; the upper contains oil, the lower air. In the partition, a narrow tube is placed, which opens into the air-chamber below by a valve, and somewhat higher in the oil vessel with a simple aperture. On filling the lamp, the oil in this tube rises to the same height as in the vessel; but as soon as the valve is opened, the air begins to escape by the same tube as that through which the oil is passing, in endeavoring to fill the lower vessel. The result is—with such a narrow tube—that with the bubbles of air, drops of oil or rather little columns of oil, are carried up much above the level of the oil. Another plan, applied by Samuel Parker and Mallet, in which the oil is warmed in a ring-shaped vessel above the flame, before reaching the burner, promises theoretically to be of value, but requires to be subjected to further proof.

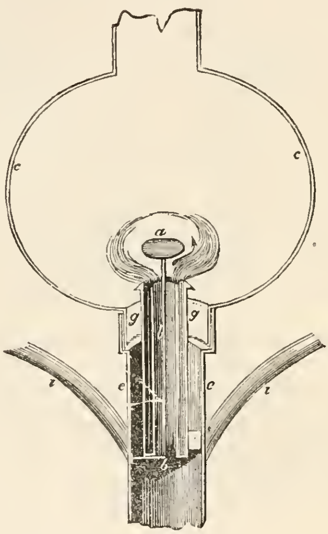
Lüdersdorff's lamp.—In Berlin, the prices admit of using instead of pure oil of turpentine (that is, the lighting material of Ludersdorff) a mixture of this spirit with 4 parts of strong alcohol, of at least 90 per cent. (This is the camphene in use with us.) This strength is necessary; for, with a greater amount of water the flame would be too much cooled, and the oil of turpentine be imperfectly held in solution. The carbon, originally amounting to 88 per cent., or 8 times the quantity of hydrogen, is diminished by this mixture (illuminating spirit) to 63 per cent., or three times the hydrogen, which is much less than is contained in oil or tallow. The lesser evolution of light, from the same weight of spirit, is, however, actually compensated, although at some cost, by the greater rapidity with which the light is evolved from the same quantity. Lüdersdorff's lamp, Fig. 2491½, is well adapted to show the different mode adopted in burning the volatile oils, from that employed with the fats.

A is the vase for the illuminating spirit, into which the burner B descends from above almost to the bottom. It consists first of a straight, pretty wide metal tube *a a*, fitting tightly into the real burner-tube *u u*, which surrounds a loose cotton wick *o o*, and fastens it by the semicircular piece *x*. Above A, at

2491½.



2492.



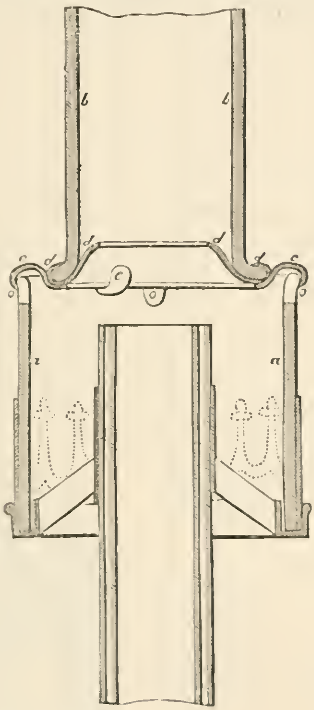
a distance of about two inches, (the wick extending thus far,) the tube becomes narrower, and ends at *d*, in the knob *c*, which is the real burner; at the base of *b*, from ten to twelve holes, ¼ line in bore, are made in a circle at equal distances from each other. When the lamp is to be used, common spirits of wine is ignited in the cup *e e*, to vaporize the illuminating spirit in the upper part of the wick. As soon as the vapor issues from the apertures *b*, it is ignited, and forms the flames *f*, which surround the knob *c*. The metallic mass is then sufficient, on account of its high temperature, to keep up vaporization with ease, (even at the distance of *c* from the wick,) and the lamp continues to burn by itself. To protect A from the action of the burner, which gradually becomes heated, the latter is surrounded, to the depth of three inches, with a wide case *i i*, which is attached to it below, (at *i i*,) so that a space filled with air surrounds it thus far. Lamps of this kind give a costly but brilliant light, free from all the inconveniences of common wicks.

The Liverpool burner.—The original Argand burner *g*, Fig. 2492, is supplied with oil by the tube *i*. At its lower aperture a wire *b* is fastened, which rises through the axis of the burner to a few lines above its upper margin, where the projecting end is furnished with a screw. This is intended to support a round copper plate *a* (in the shape of a button) of equal diameter with the wick. It is difficult, at first, to establish the proper relation of distance between *a* and the margin of the burner, but it is easily found, experimentally, by screwing the plate backwards and forwards. As the result of this arrangement, the internal draught is forced from its original perpendicular direction, and broken against the plate *a*, whence it is propelled at a sharp angle, nearly horizontally, against the flame, which thus assumes a globular, instead of its ordinary cylindrical form, and (as is shown in the figure) is forced into contact with the external current. The form of the flame makes it necessary to have the peculiar bulging chimney *c*, and this is supported by the case *e* of the burner. Complete combustion, together with intense brilliancy and whiteness, characterizes the flame · but there is nevertheless a certain want of uniformity, which, however, does not exist in the nature of the principle, and can be avoided by a proper regulation of the draught.

The lamps constructed by Benkler and Ruhl, in Wiesbaden, since the year 1840, depend entirely upon the same principle, causing the draught to impinge at an angle upon the flame. The apparent novelty of the invention, the surprising brilliancy and peculiarity of the flame, and partly the solid and elegant workmanship of the lamps themselves, led the public, at least for a time, to confound these advantages with the more essential one, namely, the economical consumption of the oil, and created in a short time an enormous demand for this invention. Some hasty experiments, which were published, tended very much to augment this over-estimation of its value.

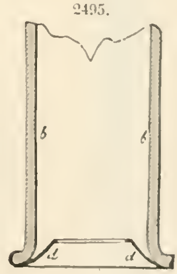
Fig. 2493 is a sketch of the general plan of Benkler's burner. Fig. 2494 is the ground plan; and Fig. 2495 represents the upper distinct parts. The shoulder of the chimney is here formed at the junction of two pieces; a narrower glass *b*, above the flame, and a wider glass *a*, which is below it. Just at this junction is placed the most important part of the arrangement, which consists of a conical

2493.



2494.

2495.

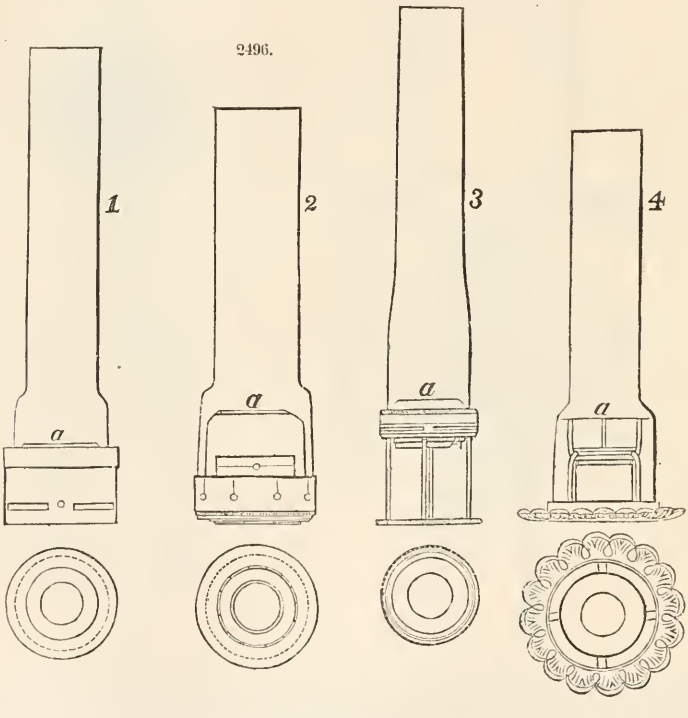


ascending brass ring *d d*, with an aperture of the same diameter as the wick. This flat, open cone is immovably fixed to the upper glass *b*, by bending up its outer edge, Fig. 2495. The connection of *b* with *a* is effected by a so-called bayonet joint. For this purpose, on the lower margin of the plate *d*, there are two tongues *e*, and these correspond with two cuts in the ring *c*, with which the margin of *a* is encircled. When, therefore, *d* is so placed upon *a* that the tongues and cuts correspond, a simple turn of *d* is sufficient to bring the tongues under the ring *c*, and thus secure the whole. The apertures *o o* are made around *a*, to increase the draught from without. The principal addition, therefore, in Benkler's lamp is a sudden contraction in the chimney at a certain distance from the flame, the aperture being of the same diameter as the wick, and this is produced by the insertion of a metallic ring, or cone.

The action of such a contrivance is easily understood. The external and internal currents of air and the flame must pass through the aperture of *d*, where a rapid contraction results. The outer current is driven against the axis of the flame at a sharp angle, and thus forces the flame itself into the inner current, so that an intimate mixture of air is effected with the products of decomposition of the oil. The flame becomes narrower, and three times as long, when, by keeping back all the air which has no part in the combustion, and by giving a proper direction to that which has, the highest and whitest brilliancy, and considerable evolution of heat, is attained. A perfectly white heat is produced; for, in consequence of the well-ordered combustion, the suspended particles of carbon are more intensely heated than in any other lamp. Notwithstanding the intensity of the heat, the chimneys—in corroboration of what was stated above—stand well. A very short portion of the flame, that which produces the least light, is naturally situated below the cone *d*; but the longer portion, the essentially luminous part, is above, and throws a shadow from *d* downwards, which is perceptible in standing and hanging lamps, but is of no moment in the determination of the intensity of light, as it only occurs in the direction of the edges of *d*. As the cone *d* has no other object than that of producing a sudden contraction, chimneys are now made in one piece with an inward bend in the proper place.

The lamps constructed by Benkler and Ruhl are on the principle just described, and have been carried out in this country under the name of Solar Lamps. The main point in the peculiar construction of these lamps, is the manner in which the air is caused to impinge upon the flame by the adaptation of a metallic or glass cone, represented at *a* in the figures below. The introduction of air at this particular part of the flame, or at this certain angle, admits of crude cheap oil being consumed in the lamps, which would produce smoke if burnt in lamps of the ordinary construction. The combustion of this oil in the ordinary manner being attended by an evolution of smoke and smell, indicating an imperfect consumption of the constituents of the oil, gives rise to the necessity for an increased supply of oxygen or air to that particular part of the flame where these. unconsumed portions are evolved, to produce the inodorous and invisible products which alone should result from perfect combustion. The oil in the solar lamp is contained in an annular vessel, similar to that described at Fig. 2478, and the lamps are constructed in precisely the same manner, with the exception only of the burner. The first form in which the new burner was introduced is represented in section at 1, Fig. 2496, and consists of a solid metallic box fixed upon the circular wick-holder of ordinary construction, so that the cone or

2496.

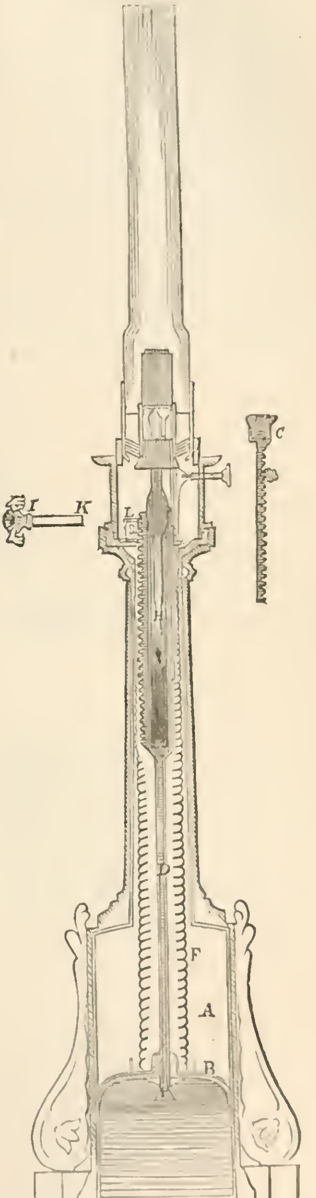


contracted aperture *a*, shall be bare $\frac{5}{8}$th of an inch above the top of the wick-holder. This relative position is observed in all the burners. This form of cone box was found very inconvenient, by becoming exceedingly hot and throwing a considerable shadow, it was consequently soon superseded by that represented at 2, Fig. 2496, in which the metallic box is very much diminished in size, and the cone is composed of glass, with a small ring of metal round the mouth *a*. This ring of metal is essential, as it is necessary that the aperture should be always of the same diameter, and glass cones can never be made with sufficient nicety to present at all times an exactly similar mouth. The solid box was subsequently replaced by the open skeleton cone holder represented at 3, Fig. 2496, called the screw cone glass-holder, in consequence of the tall thin chimney being screwed on to the top of the holder. The last improvement is the plate cone glass-holder represented at 4, Fig. 2496, in which the metallic cone is replaced by a flat metallic ring fixed upon a skeleton support, the external edge of which fits closely to the glass chimney.

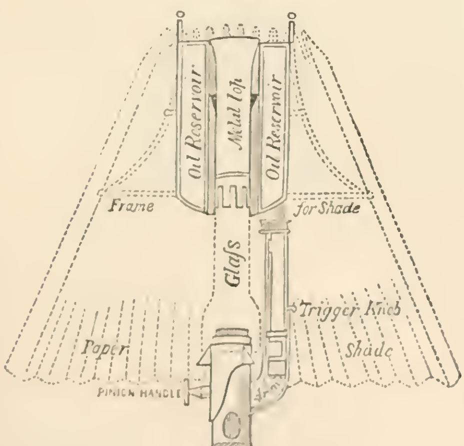
In the last form of burner, little or no external current impinges upon the flame from the outer sides of the cone or its substitute ; but the flame is only forced inwards so as to come more completely into contact with the current of air passing through the interior of the burner. The solar lamp has been extensively used in consequence of the low price of the oil which it consumes ; it requires, however, a good deal of care and cleanliness in trimming, the wick must be freshly cut every time the lamp is used, and the reservoir should be refilled with oil.

A form of pressure lamp, called the Elliptic lamp, in which the constant flow of oil to the wick is regulated in an ingenious manner, has been patented, and is found to answer perfectly, even when crude vegetable oils are consumed in it. Fig. 2497 represents an entire section of the lamp. The foot of the lamp forms at the same time the oil cistern: it is of a cylindrical shape, and a leather piston or valve B, is worked up and down in it by rack and pinion seen at L. F is a spiral spring of strong iron wire fixed at the top to the solid stem of the lamp, and exerting a constant pressure on the piston, so long as it is in any position above the bottom of the oil cistern. The tube D, which opens at the bottom in the shape of an inverted funnel, and ends in a disk pierced with holes, supplies the oil to the burner and passes in an air-tight manner through a stuffing-box in the piston B, and can thus be moved with ease, the piston remaining stationary. This tube D, is widened above on approaching the burner, and receives a fine silver tube several inches long, and one-thirtieth of an inch internal diameter, which is surrounded by a cap of gauze, made of copper wire tinned, to prevent corrosion. This gauze has very small meshes, that no solid particles mechanically mixed with the oil may be carried up into the silver tube, and thus impede or altogether stop the passage of the oil. The whole of the oil must pass through the silver tube before reaching the burner, and the friction thus exerted against the sides of the narrow tube is the only resistance offered to the oil, which would otherwise be forced up all at once to the burner by the pressure of the spiral spring. This, therefore, is the regulator for the supply of oil, and must be so proportioned in length and bore to the force of the spring, as to admit of a constant excess of oil flowing to the wick and over the sides of the burner, where it is caught in a receptacle and carried back into the oil vessel at the foot of the lamp. The lamp is filled with oil by slightly raising the whole interior portion from L, and pouring oil through the stem to the cistern below; the oil then rests in the first instance on the top of the piston. The whole interior portion of the lamp is then wound up by the key I K and the rack-work L, until the top of the cistern prevents the piston B from ascending higher. The tube D and the burner, &c., attached to it is then pushed down by the hand through the stuffing-box until it attains its original position. The oil which was previously above, having passed

2497.



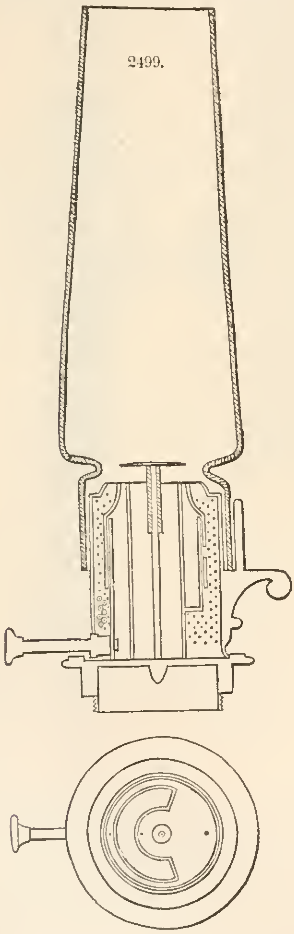
2498.

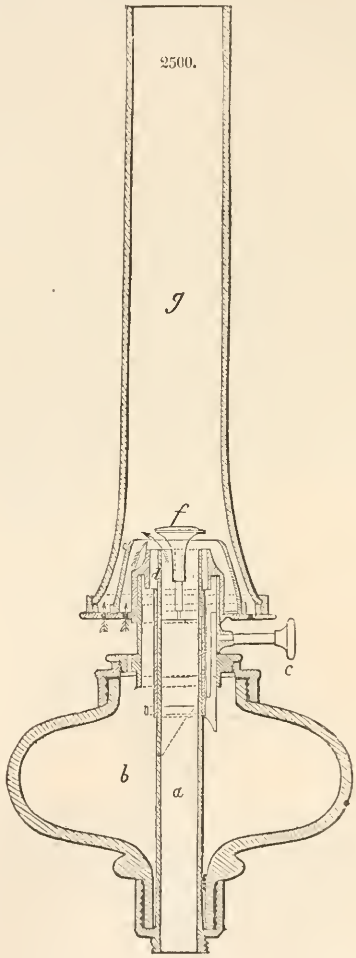


during the ascent of the piston between it and the sides of the cylinder, is now below the piston, and the spring in forcing the latter down will tend to force the oil out through the tube D to the burner. The force of the spring and the resistance offered by the silver tube are so proportioned that the supply of oil shall last eight or ten hours.

The thick consistence of crude whale oil offers such powerful resistance to the action of capillarity at the ordinary temperature of the air, that the oil cannot be burned in common lamps, unless it is previously rendered more fluid by the aid of heat. To effect this a very ingenious form of lamp has been introduced, called the Economic, or hot oil lamp. The oil reservoir of the lamp, Fig. 2498, is composed of a double cylinder surrounding the upper part of the chimney, which is constructed of metal and slightly curved outwards, so as to reverberate the heat upon the oil vessel, and heat the oil to a considerable extent. The hot oil then descends by the arm to the burner, as shown in the figure. The lower part of the arm, which is attached to the oil vessel, is furnished with a slide valve worked by the trigger, so that the supply of oil can be cut off by raising the trigger, and the oil vessel entirely removed from the lamp for the purpose of filling, &c. The oil is introduced by this valve, the oil cistern being inverted, and this should be refilled each time the lamp is used, care being taken that no air remains in the vessel, as this would be expanded very much by the heat, and cause the oil to overflow

The flame is regulated by raising or lowering the bell-mouthed glass chimney, which rests upon three points below and is moved by rack and pinion. The wick is not movable, as is the case in ordinary lamps, and a fresh wick, which is accurately cut by machinery expressly for this lamp, must be inserted every time the lamp is used. A paper or glass shade surrounds the whole of the upper part of the lamp, according as the light is required to be thrown downwards or uniformly diffused through the apartment. Dr. Ure has reported the illuminating power of this lamp to be superior to that of Carcel's mechanical lamp, and when consuming southern whale oil, it would appear from his statements to deserve the appellation of the "Economic" to the full extent of the word.



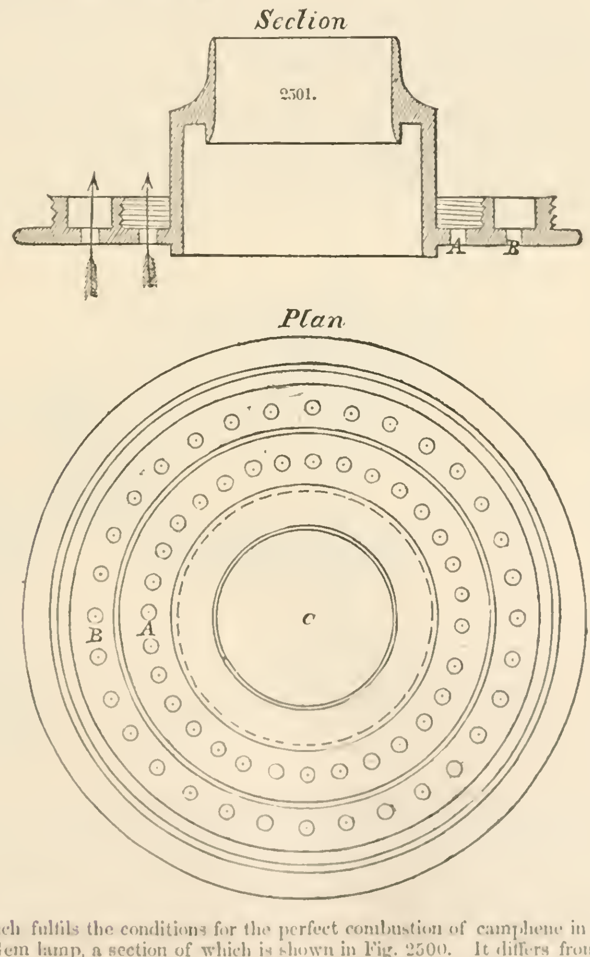


Camphene lamps.—It is only within the last few years that oil of turpentine or camphene has been successfully introduced into general use as a source of illumination; and it is by applying the principle of the solar cone in an extended manner that this highly carbonaceous substance can be completely and conveniently consumed. The pure oil is clear, colorless, and very mobile; it has a peculiar smell and a burning taste. Its specific gravity is 0·86 to 0·87. The commercial oil is frequently adulterated with resin, which raises the specific gravity, and which increases in quantity when the oil is exposed, in consequence of the absorption of oxygen from the air. When pure, the oil boils at 312°, and contains no oxygen, but consists of:

88·46	carbon.
11·54	hydrogen.
100·	

A glance at the composition of this substance, containing so large an amount of carbon, shows that it must be a powerfully illuminating body, if proper modes can be adopted of supplying a sufficient quantity of oxygen or air for the entire consumption of the two combustible constituents, and at the same time so regulating the order of combustion that the full amount of light shall be obtained from it.

Mr. Young was the first who applied the increased draught of air produced by a cone to the flame of oil of turpentine. The burner of Young's Vesta lamp is shown in Fig. 2499. It is an ordinary Argand burner with a Liverpool button *a*, for deflecting the internal current of air, which enters by a space left open near the pinion handle and passes through *a*, against the inner side of the flame; *b* is the wick tube and *c* the space between the latter and the cone, which only rises in this case to the same level as the burner. Through *c* a current of air impinges upon the flame at that part where it is expanded by the button *d* and the internal current of air, and again the air in passing up the inner sides of the chimney is deflected inwards upon the flame by the contracted portion at *e*. *f* is the pinion-handle for raising or lowering the wick. The whole of the burner is screwed upon the glass vessel containing the oil of turpentine, and completely insulated by a ring of wood or other non-conducting material. No metallic tube passes through the spirit to supply air to the interior of the flame, as it was supposed that this would become too strongly heated and give rise to acrid and offensive fumes from the volatile spirit. Fig. 2499 shows a plan of Young's burner. This lamp, when properly managed and supplied with pure camphene, gives an excellent light, much superior to that produced by any oil lamp; but if attention is not paid to the management, or the camphene is not pure, it frequently evolves a strong smell of turpentine, producing headache and other disagreeable sensations, or large flakes of soot escape unconsumed and cover every thing in the vicinity. The evolution of smell or soot is always the result of imperfect combustion, and the lamp has been modified in different ways to avoid the possibility of unconsumed products being evolved.



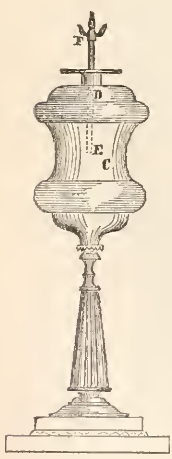
The lamp which fulfils the conditions for the perfect combustion of camphene in the most successful manner, is the Gem lamp, a section of which is shown in Fig. 2500. It differs from Young's lamp, in the mode of deflecting the currents of air, and in allowing the Argand tube supplying the internal current of air to pass through the reservoir containing the oil of turpentine. In Fig. 2500, *a* is the tube supplying the internal current of air which passes through the reservoir *b* to the burner *d*, with which it is in metallic connection, and it is not found that the turpentine is heated by this tube to more than one or two degrees above the temperature which it attains in Young's lamp; the temperature of the spirit in both cases being from ten to fifteen degrees above the temperature of the surrounding air and this appears to be no more than is required for the proper action of lamps of this description. The button *f*, which deflects the inner current upon the flame, and forces the flame to take an outward direction and come into contact with the first outer current, has the form of an inverted cone, and the deflection of the air is consequently not so abrupt. The supply of air to the inside and outside of the cone is regulated by a series of holes drilled in the brass gallery, and the number and size of these holes are proportioned to the size of the burner, or to the quantity of air admitted through the internal channel.

Fig. 2501 shows a plan and section of the gallery. C is the space occupied by the inner current of air deflected outwards by the button, A the first series of holes admitting air to the interior of the cone, and B the series of holes through which the air passes to the exterior of the cone. The circle A has 32 holes, drilled with a drill one-twelfth of an inch in diameter; the circle B has also 32 holes, drilled with a drill one-tenth of an inch, this number and size of the holes having been found by a series of experiments most advantageous for a burner of the dimensions represented in the drawing. The cone *o*, Fig. 2501, in this lamp, rises above the level of the wick tube, so that the inner current of air and the first outer current meet the flame below the button at the point represented by the meeting of the two arrows. The outer current of air, passing through the holes in the circle B, meets the flame at a higher level, and insures the complete combustion of any products that may have been unconsumed after passing the point where the arrows meet. The height of the chimney will of course materially alter the draught, and an additional quantity of air must be admitted if the chimney is heightened. The proper quantity of air and the direction of the different currents to those parts of the flame where they are most beneficial, are the objects aimed at in the construction of this lamp, and they appear to have been attained more perfectly in the Gem lamp, than in any other spirit lamp yet invented. A Gem lamp of the larger form is reported to give a light equal to 20 wax candles: the light from one of the smaller size is equal to 13 wax candles.

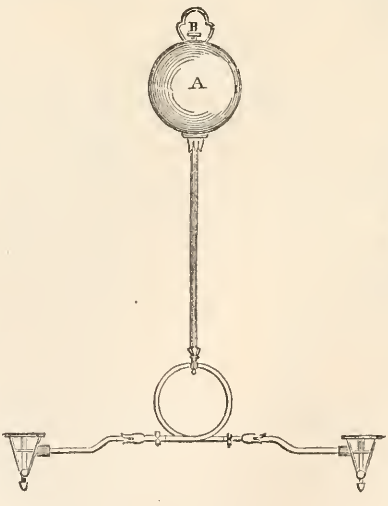
LAMPS, SPIRIT-GAS. The lamps which we here present are designed to burn the gas of the so-called "spirit-gas," which is a composition of alcohol and turpentine distilled together. No wick is burned, and only in the lamp, Fig. 2502, is a wick used, and only for capillary attraction.

C is the reservoir of the fluid. D is a brass tube extending into the fluid, and it has a cap at the top, perforated all around. F is the flame ignition points of the gas, as it comes out of the perforations. E is the wick; the wick, by capillary attraction, carries up the fluid by heating the top of the tube D until the fluid becomes gaseous, it then rushes out through the perforations, and is ignited in a state of inflammable gas, as represented at F. Great numbers of this kind of lamp are now manufactured and used in this city.

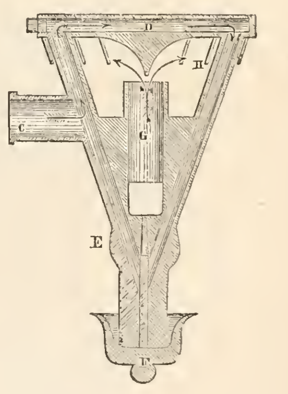
2502.



2503.



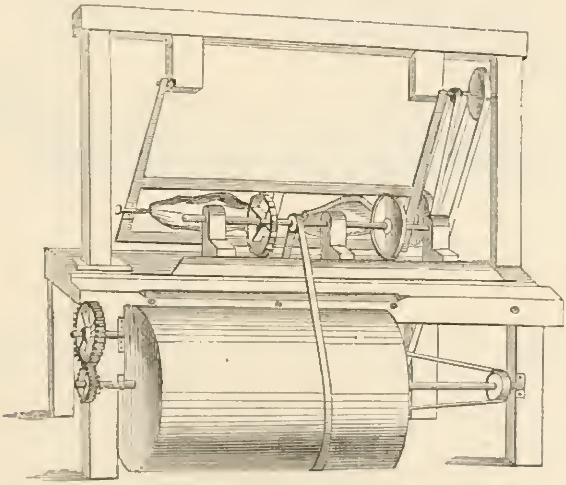
2504.



Figs. 2503 and 2504 is another kind of lamp altogether. It does not use any wick at all. Fig. 2503 is a front elevation of it, and Fig. 2504 is an enlarged section of one of the burners. A is the camphene reservoir, which can be filled at the top. B is a handle passing down the centre of the vessel and fitted to a conical valve at the bottom, where it joins the top of the central vertical tube, so that the flow from the reservoir may be cut off at pleasure. Two curved stems carry the burners, the construction of which is particularly represented in Fig. 2504. C on the right is the screwed attaching branch-pipe. The camphene enters by this branch and passes through the diaphragm, as represented by the arrow; thence upward by a sloping arm into the top horizontal passage D, which is formed on the surface of a circular disk surmounting the whole. It then descends by the opposite arm to the flattened boss E, and rises through a small conical aperture in its centre. This aperture is fitted with a conical spindle, screwed at its lower end, and in one piece with the cup F, which answers as a nut for turning the spindle to adjust the size of the opening. The course of the gaseous matter is then directed through the central chimney G, and is deflected by the inverted cone above it, and it then rushes out by a circular ring of eight, ten, or more jets, like those of Fig. 2502. The burner is of brass, and the rest may be all cast in one piece, with the exception of the bottom cup. By unscrewing the cup a wire can be introduced to remove any obstructions in the side tubes, but no obstructions are at all likely to get in them. In lighting this lamp a few drops of alcohol is poured into the cup F and ignited, when the heat volatilizes the camphene in the passages of the burner, which can then be ignited, and the heat resulting from the ignition of the gases so produced, by acting upon the inverted cone at H, keeps up a continuous stream of gas. For suspension lamps, this one has no ordinary qualities to commend it. It no doubt requires attention, but the way in which it heats the fluid, and generates a very rarified gas, renders it capable of giving a very brilliant light.

LATHE FOR TURNING IRREGULAR FORMS—Blanchard's. Fig. 2505. This machine is represented in the figure in its most simple form, for turning shoe lasts, and is so constructed that, from one as a pattern, an exact *fac-simile* can be formed from a rough block of wood. Both the pattern and block are fixed on the same axis, and are made to revolve around their common centre, in a swinging lathe, by a pulley and bolt on one end of the axis, as shown in the figure. On a sliding-carriage is attached three posts, through which are fixed pivots, to which are suspended the axles of a *cutting* and a *friction* wheel. The cutting-wheel, which is about one foot in diameter, turns on a horizontal axle, and to its periphery is fixed a number of crooked cutters to act like a *gouge* when the wheel is put in motion. This cutting-wheel is placed opposite the rough block. The friction-wheel, which is of the same diameter as the cutting-wheel, is placed opposite the pattern, so as to press against it when in motion. These two wheels are in a line with each other, and are attached to the same carriage. On the axle of the cutting-wheel is fixed a pulley, around which passes a band which puts the cutting-wheel in motion by a large drum revolving under it. A crank or first mover communicates motion to the drum, which in its turn transfers a rapid motion to the cutting-wheel, while a band which passes from a small pulley on the drum-shaft, puts in operation a feeding screw-pulley, which moves the sliding-carriage horizontally from left to right. Another pulley on the drum-shaft gives a slow rotary motion both to the pattern and the rough block, in a direction opposite to the cutting-wheel. The friction-wheel is turned by the pattern resting against it.

2505.

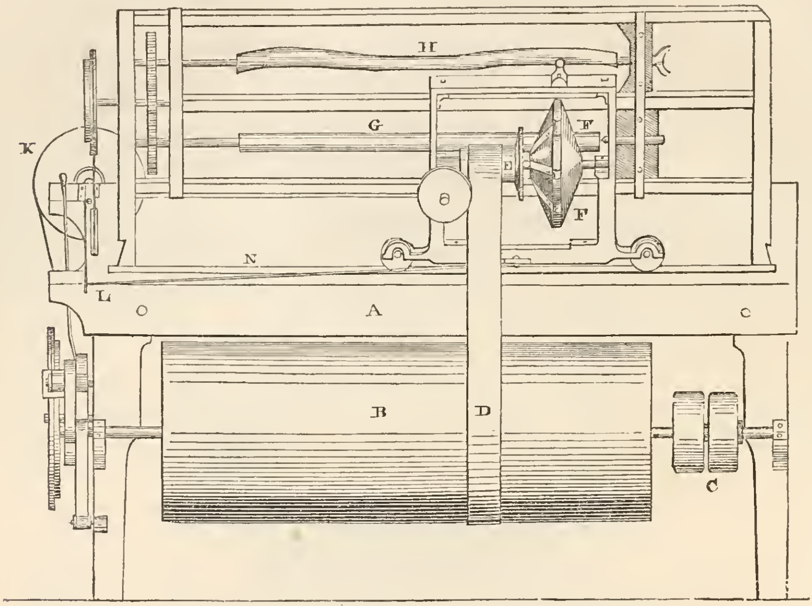


During the revolution the pattern, being irregular in its surface, causes the axis to approach and recede from the wheel. Thus, it will be seen, as it presents its whole surface to the friction-wheel, so in like manner the *block* presents its surface to the cutting-wheel, which being in rapid motion, cuts away all that part of the block which is further from the common centre than the surface of the pattern, and thus forms, from a rough block, an exact resemblance of the model.

Another application of the same principle is shown in Fig. 2506. This machine can turn out a duplicate or *fac-simile* of any pattern whatever, and it is now brought to such perfection that an oar-blade, a spoke, a last, and an axe-helve, are all turned upon it with equal facility and equal perfection.

This is a front view, as seen looking somewhat down upon the machine. A is the frame. B is a large drum. C is a driving-pulley. D is a band which, from the drum, passes over a pulley E, and drives its rotary cutter-wheel F F. This cutter-wheel is fixed on an axis in a small sliding-frame which moves from one end to the other of the lathe by a cord N winding upon a spindle lying across the machine, which cannot therefore be seen, but which is driven by the large pulley K, thus giving it a requisite slow motion. H is the pattern axe-helve, and G the rough material to be cut exactly like H. The pattern and rough material are placed in the lathe, represented by the upright frame, and sustained by spindles. On the back part of the machine there is a curious but beautiful sliding-rest, which is the subject of a patent in itself. It moves along after the cutter-wheel, and has two plane faces on which the pattern and cut helve rest. The pattern and helve roll upon the planes, while the rest has a rocking motion which accommodates itself to all the uneven turning of the patterns, &c., as they revolve. For turning long articles, this rest is a beautiful and positively necessary part of the machine. To turn a *fac-simile* of any pattern it will at once be evident to every mechanic, that if a pattern be placed in a lathe, and the material to be turned be placed with its axis of rotation similar to that of the pattern, and if a guide pressing on the pattern directs a wheel with cutters to operate on the rough material over a surface like the pattern as guided, a perfect representation of the pattern will be produced on what was the rough material—simply by the cutters chipping away all the rough material outside of the axis of direction—in other words, all the wood on the rough material outside of the pattern. This is the principle upon which this machine is constructed. The cutter-frame slides from one end to the other of the pattern; and the small guide seen on the frame pressing on the pattern, makes the cutters chip away all the rough material outside of the pattern on G, as the cutter-frame moves from end to end of the lathe. The cutter-wheel has three motions—a rotary, a horizontal, and an eccentric motion

2506.



The pattern and rough material revolve in the lathe. This is done by three pinions on the right, moved by the pulley seen above K. The speed of the spindles in the lathe is regulated by a very excellent arrangement of a small gang of pulleys and straps, seen on the right at the end of the machine. These pulleys are operated by a lever L, and they are so arranged that a slower motion is communicated to the spindles when the thicker part of the pattern is to be turned, or such a part as an oar-blade. The cutter-frame moves along from one end to the other of the lathe upon a rail, and it is pressed out and in according to the shape of the pattern, by the upper guide; and the cutter-wheel being directed in the same manner, thus cuts the pattern on the rough material. The strap D is retained in its proper place by a grooved pulley on the cutter-frame, and the whole kept firm and snug to the work to be turned.

LATHE, SMALL ENGINE. Fig. 2507, side elevation. Fig. 2508, end elevation.

S is the bed-piece and head-stock, cast in one piece.

B, spindle which runs in gun-metal boxes.

C, cone-pulleys on live spindle.

D, upper cone-pulleys for driving feed-shaft.

D′, lower cone-pulley for driving feed-shaft. It runs loose on a stud, and has a pinion on inner end to drive the two worms.

E, worms—one right, the other left—which drive the two worm-wheels so as to feed towards the right or left, as the operator may wish. On the worm-geer shaft there is a pinion driving a geer on the shaft above, which has a chain-pinion, around which an endless chain passes, attached to the rest.

A is a hand-wheel for moving rest by hand. There is a pinion on the other end of the hand-wheel shaft geering into a rack K on the side of the bed, as shown in Fig. 2507.

F is the tool-holder.

J, top part of the rest which slides crosswise of the bed by means of the crank and screw.

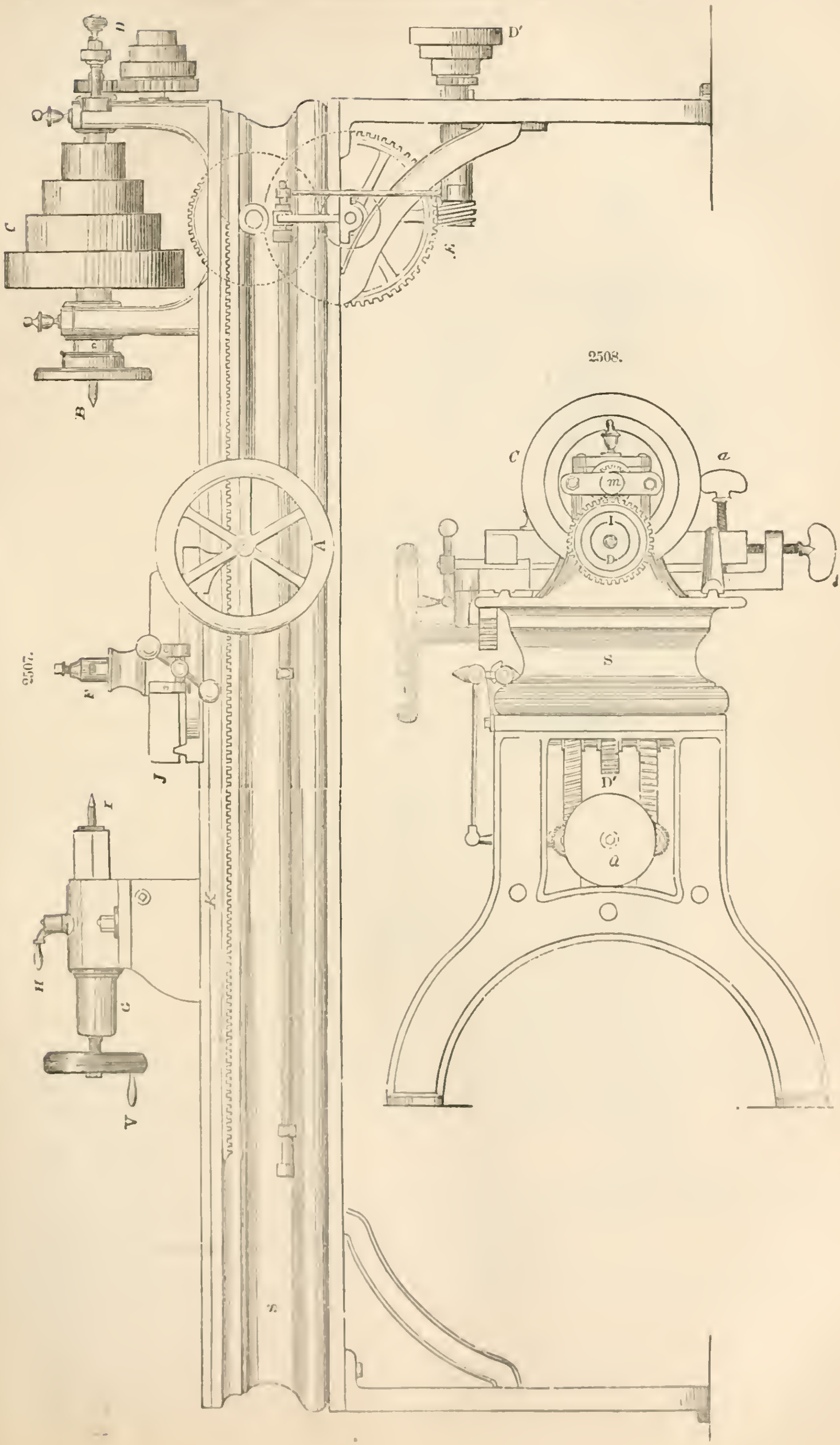
I, square spindle, which is moved by hand-wheel V, and screw inside of shell G. It is held firm in its place by the handle-nut H.

a, thumb-screw for raising rest.

m, step-screw.

b, thumb-screw for adjusting tool in rest.

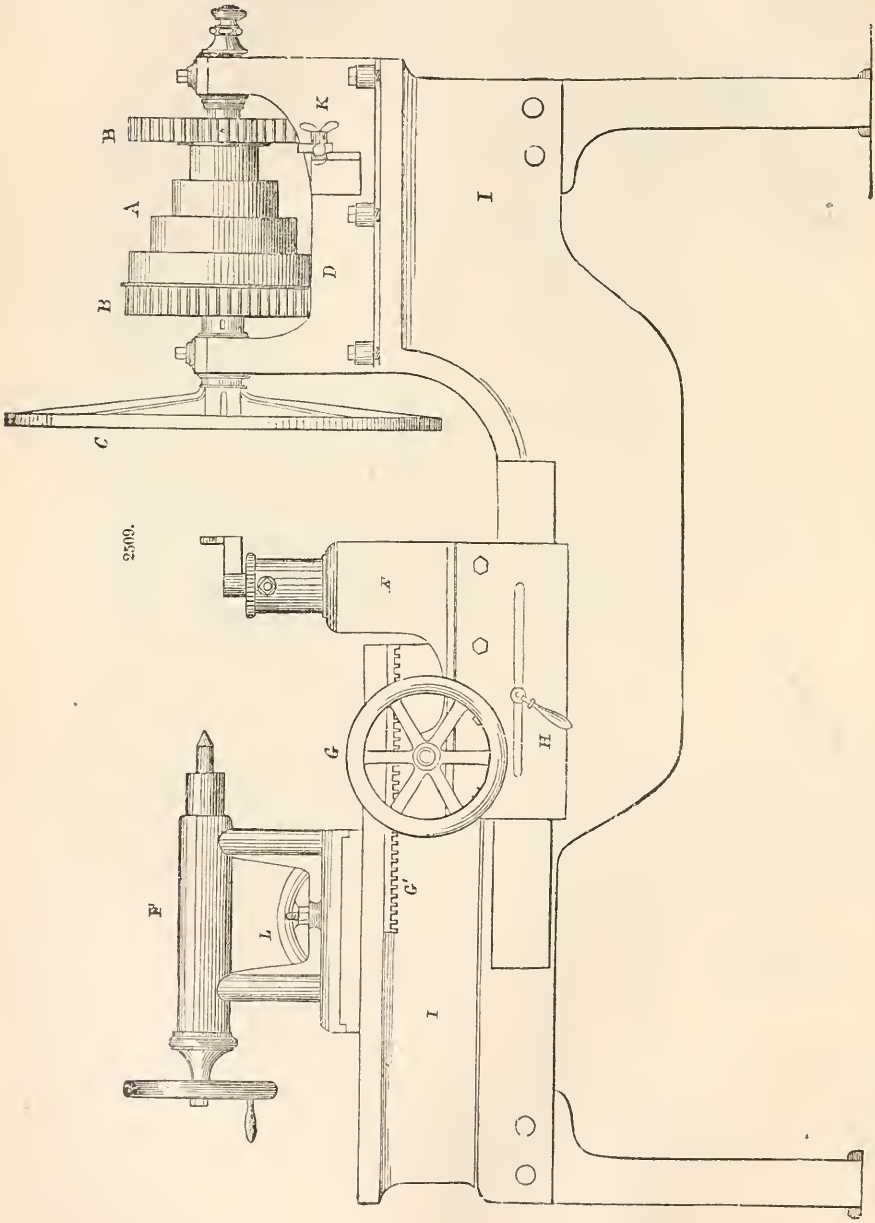
This lathe will swing 16 inches over the sills and 7 inches over the rest.



2507.

2508.

2509.

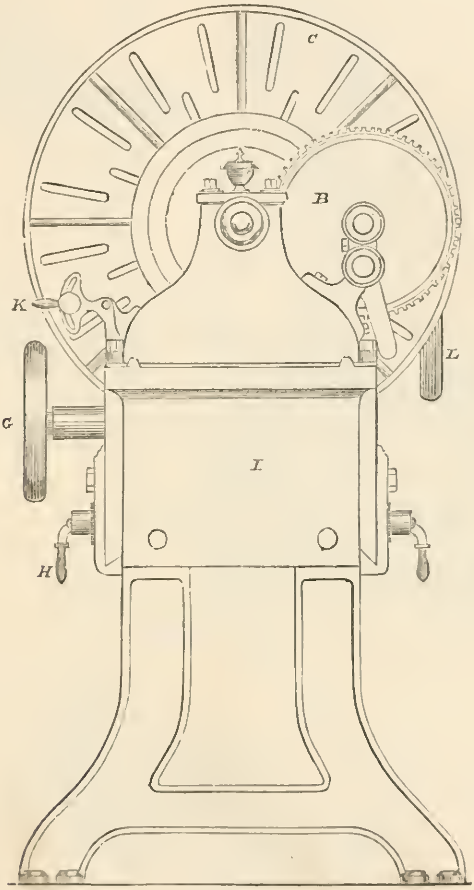


LATHE, BORING AND REAMING. Figs. 2509 and 2510. I, the main bed-piece, supported by two cast-iron standards.

D, head-stock, which carries the spindle and cone-pulleys A.

G, sliding-frame that supports rest P. This frame is traversed backward and forward by means of the hand-wheel R, which has a pinion on the other end geering into the rack G on side of the bed, (seen in Fig. 2509,) and is held down by the plates N, which hook under the slides S, and is secured by means of the nuts with handle H, one on each side.

2510.



C, face-plate on live spindle, to which the work is fastened by bolts when drilling or reaming.

F, tail-stock, with a traversing spindle, worked by the hand-wheel M, which turns a screw inside of spindle in the usual way, for pressing in the drills or reamers, &c.

L, hand-wheel on a screw for setting the tail-stock so as to make a tapering hole.

A, cone-pulleys on spindle.

U, geer on spindle.

b, pinion on spindle, playing into geer B.

B, geer on back shaft for reducing motion of spindle and increasing the power—same as is common in geered head-lathes.

K, handle for throwing the back geer-shaft out of or into geer.

This machine will bore out a hole 3 inches diameter in a wheel 3 feet diameter

LATHE, ENGINE. Figs. 2511, 2512, 2513. Will swing 50 inches in diameter over the ways, and 62 inches in diameter over the rest.

Fig. 2511 is a side elevation of the engine.

Fig. 2512 is an end elevation.

Fig. 2513 is a side elevation of the tail-stock.

P represents the bed piece which supports the head and tail stocks and rest.

C is the head-stock in which the live spindle runs; it is made in a saddle form, and very heavy; bolted to bed-piece by six bolts.

B B′ are the geers by which the motion of the spindle is reduced and the power increased.

D D′ are small cone-pulleys for driving the long feed-screw, which is on the inside of the bed-piece, and not shown in the drawing.

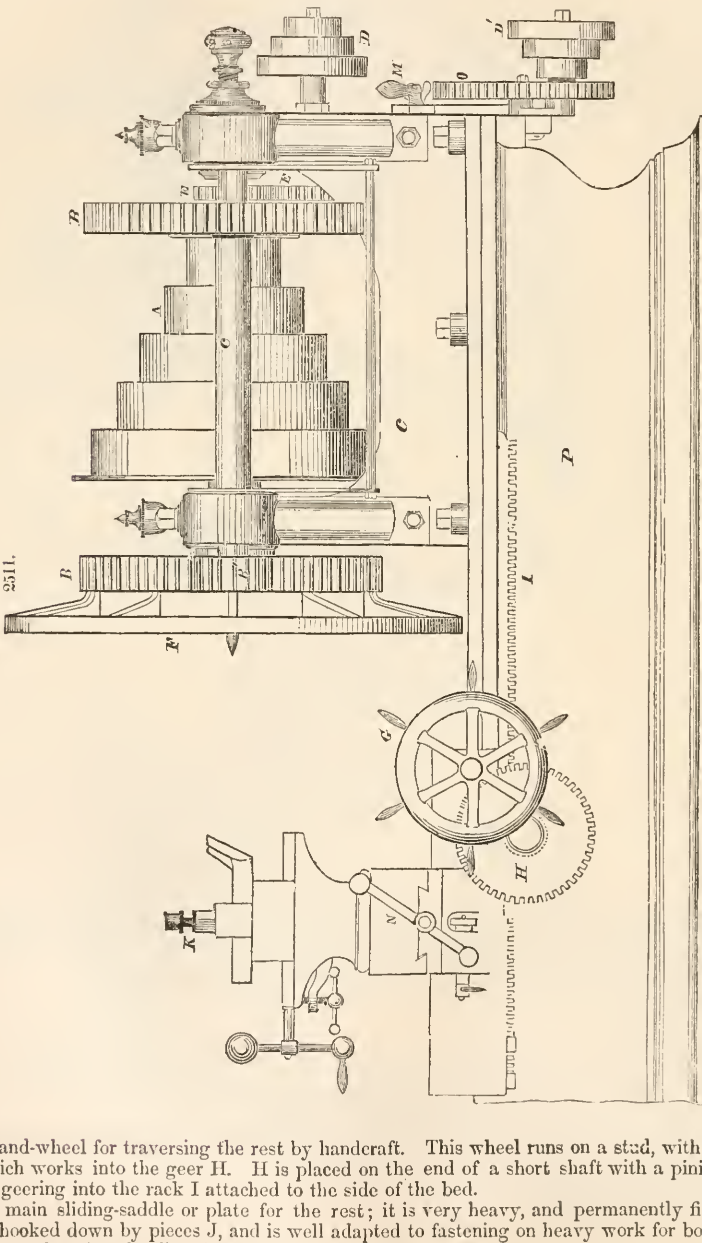
O, geer on end of feed-screw, driven by a pinion on the hub of the lower feed-cone D′.

A, cone-pulleys on spindle of cast-iron.

F, face-plate with geer B attached to the back side.

K, tool-holder, which slides upon a swivel-post S, that can be set at any angle and fastened by the lever and screw R to the block N, which slides crosswise of the bed-piece by means of the crank and screw with a balance bolt seen in Fig. 2511, and at N′ in Fig. 2512.

2511.



G is a hand-wheel for traversing the rest by handcraft. This wheel runs on a stud, with a pinion on its hub which works into the geer H. H is placed on the end of a short shaft with a pinion *h* on the other end, geering into the rack I attached to the side of the bed.

T is the main sliding-saddle or plate for the rest; it is very heavy, and permanently fitted to the slides and hooked down by pieces J, and is well adapted to fastening on heavy work for boring, &c.

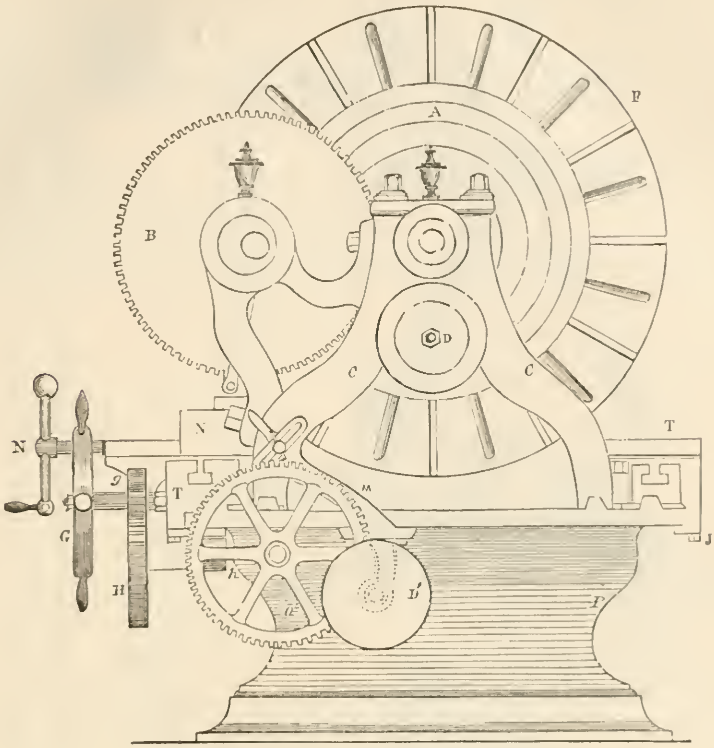
M, lever for changing the direction of the feed.

U, handle for stopping and starting feed.

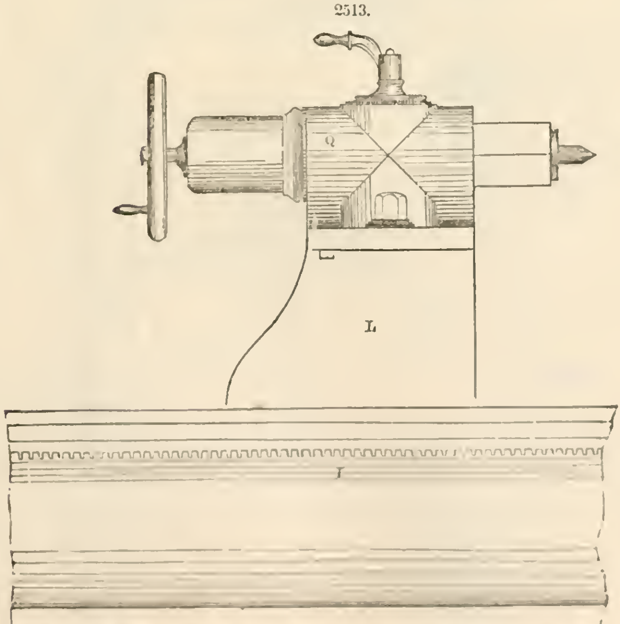
L is the lower part of tail-stock, which is notched on to the slides or ways of the bed-piece.

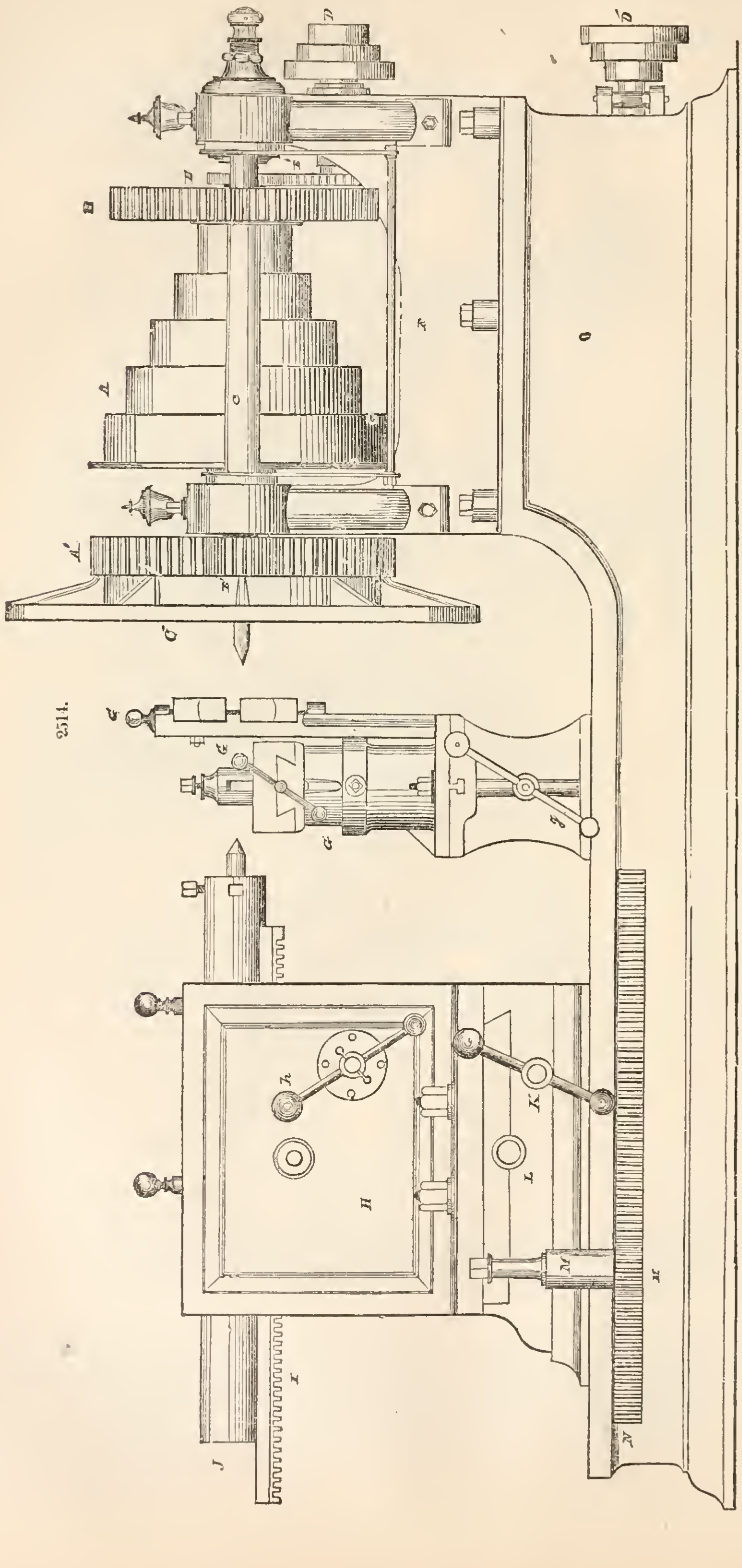
Q. upper part of the tail-stock, which is made to slide crosswise for tapering work, in the usual way

2512.



2513.





2514.

LATHE, LARGE BORING AND REAMING. A very convenient and useful tool for boring and reaming locomotive and car wheels, pulleys, geers, &c., &c. It will turn out a hole straight or tapering, and spline the same, without removing it from the chuck. It is adapted to turning or drilling out holes, or boring, by using the shell boring-tool; all self-feeding.

Fig. 2514 is a side elevation.

Fig. 2515, end elevation, looking towards the face-plate.

A, cone-pulley of cast-iron which runs on the live spindle. The spindle has strong journals, running in gun-metal boxes.

A′, geer on face-plate.

B, geer on front shaft.

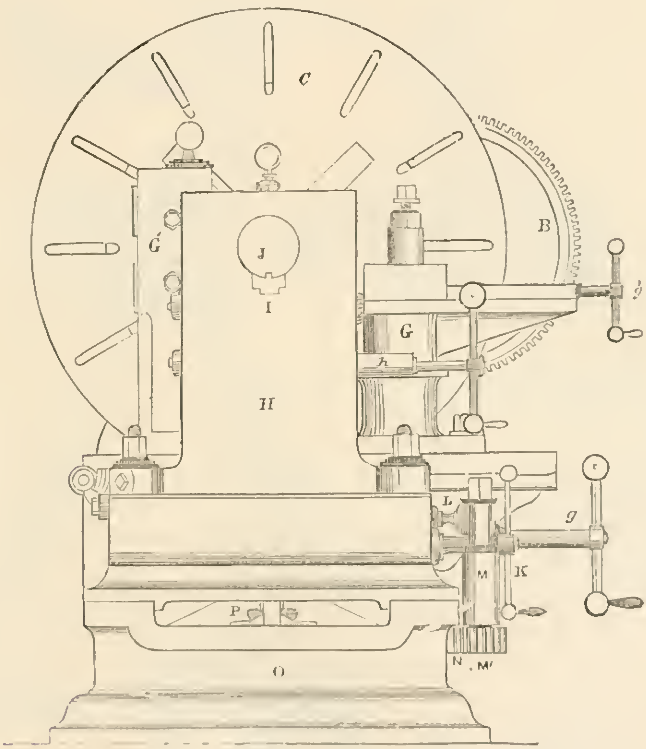
o, shaft, thrown out of and into geer by eccentrics.

C, face-plate, to which the work is fastened by means of bolts.

D, upper cone for driving the feed motion.

D′, lower cone on the splined shaft which passes through the centre of bed-piece, giving motion to the rack I, which can be connected with the spindle J, by the screw on top.

2515.



F, head-stock in which the live spindle rests.

G, swivel-post on which the tool-holder slides.

g, bed-piece on which G stands.

G′, rest, with jaws, for using flat drills and reamers, adjusted by the screw on top.

H, upper part of tail-stock, inside of which is the feeding apparatus. This piece rests upon a sliding plate that is traversed crosswise by the screw L.

S, worm which geers into a segment on side of tail stock for giving the proper angle when a hole is to be turned out tapering.

K, crank, with a bevel pinion on the inside end of its shaft, geering into a large bevel-wheel that has an internal screw cut through its hub for fastening down tail stock to the bed.

M, stand cast on the side of the lower piece of tail stock, carrying a shaft and pinion geering into a rack on side of bed-piece, for the purpose of moving tail stock by hand.

M′, pinion, geering into rack.

N, rack on side of bed piece.

O, bed piece, cast with cross pieces, and made very strong.

This lathe will admit a wheel 5½ feet in diameter, and is adapted to turning off the rims of pulleys, and for surface turning generally. These engines (pp. 168 to 172) are from the Lowell Machine Shop

LATHE, FOR GUN BORING, TURNING, AND PLANING, arranged for the Ordnance Department, U. S. Navy Yard, Washington, by Wm. M. Ellis, Engineer. Figs. 2516 to 2522.

Fig. 2519. *c*, rest for supporting the muzzle of the gun while boring.

d, pulley, with belt motion above, for drawing boring-bar.

When boring, the turning mandrel is taken out and the boring-bar put in its place; the back-head is forced up by feed-screws in the same manner as slide-rest for turning.

Fig. 2518. C, planing-head and tool-holder, bolted on slide-rest of lathe in place of tool-holder for turning.

h, slide of tool-holder.

i', cogged sector working in rack on bottom of drill of tool-holder.

i, shifting crank to convey motion to sector.

E, ratchet-wheel on main mandril of lathe, to give motion to gun on the centres while planing between the trunnions.

D, eccentric connection to give motion to feed-hand.

B, bevel-geer to work planing-head and feed-hand.

A, pulleys on bevel pinion-shaft.

2516.

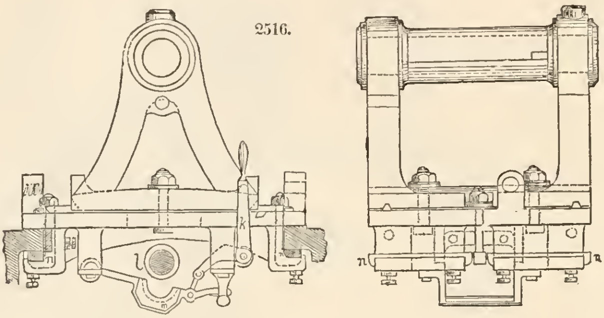


Fig. 2516. Back (sliding) head for turning or boring.

k, lever for throwing head out of geer.

l, feed-screw.

n, gibs.

Fig. 2520. *h*, lever for throwing slide-rest out of geer.

f, feed-screw.

m, half-rest for feed-screw.

n n, gibs on slide-rest.

Fig. 2521. *d*, pulley for drawing boring-bar.

e, ratchet-wheel.

f, lever on ratchet-wheel, for boring.

2517.

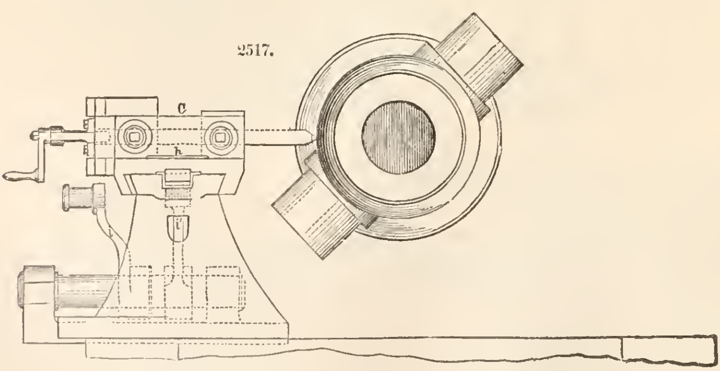


Fig. 2517. *c*, planing-head for planing between trunnions.

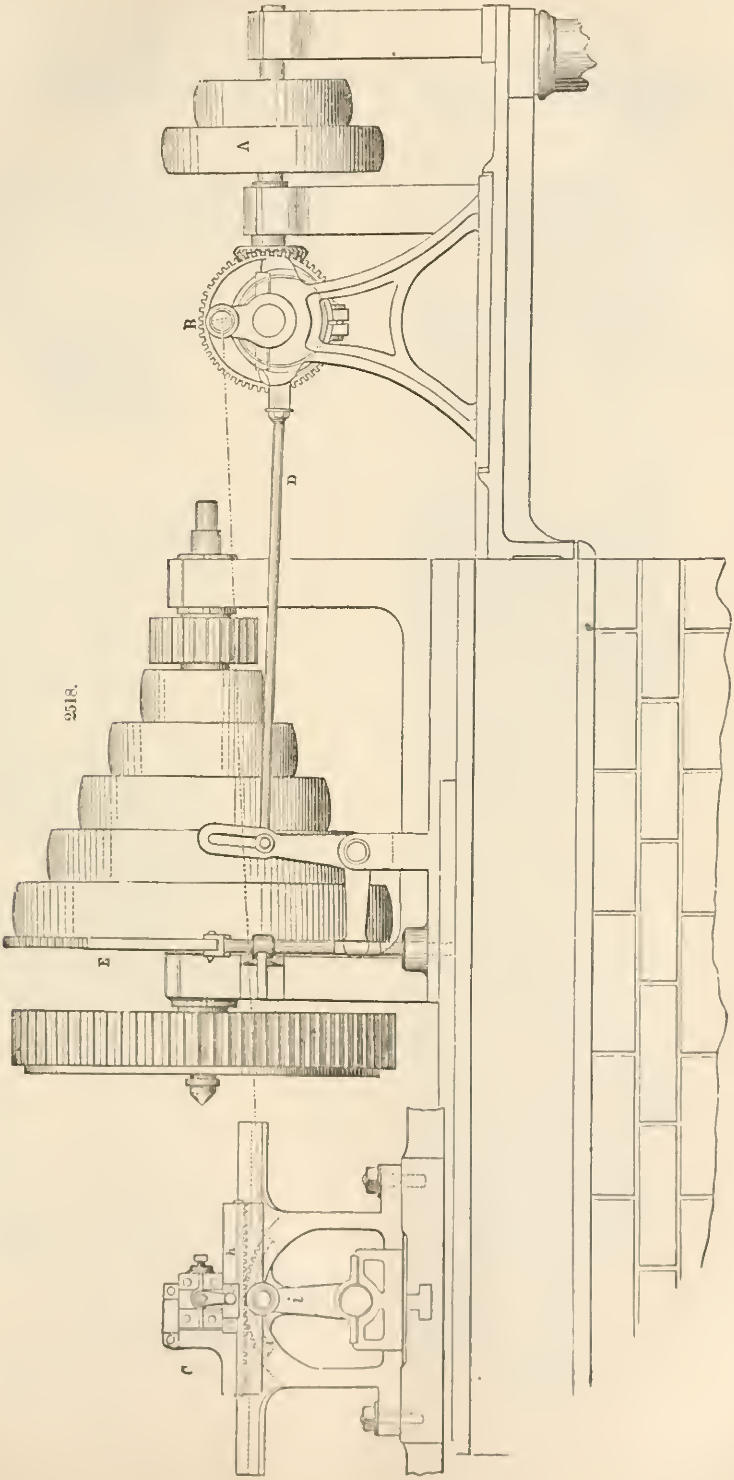
h, tool-holder.

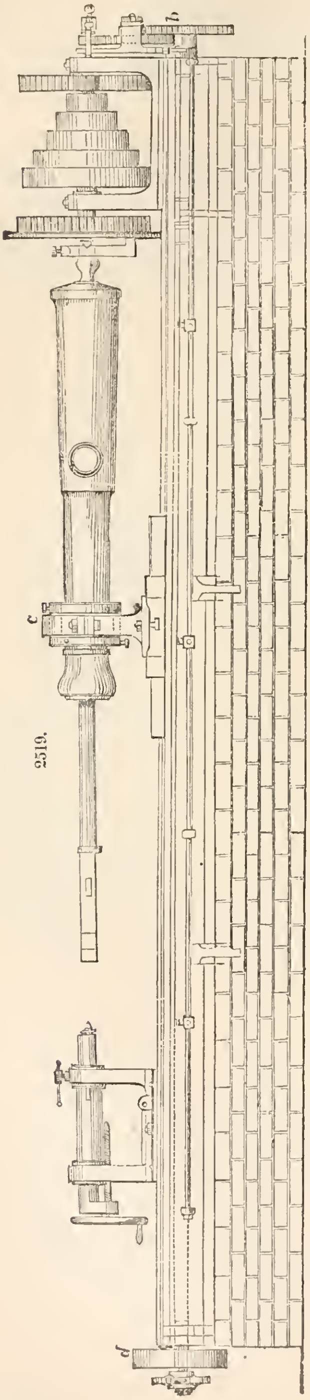
Fig. 2522. Standing-head.

b, feed-geer, (same in Fig. 2519.)

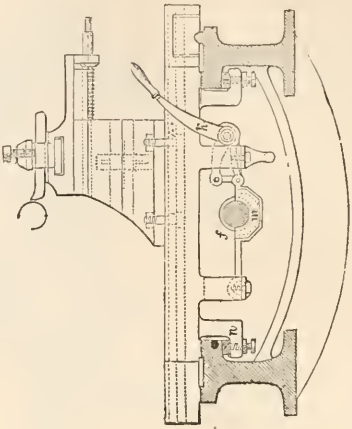
g, handle for changing feed-geer.

2518.

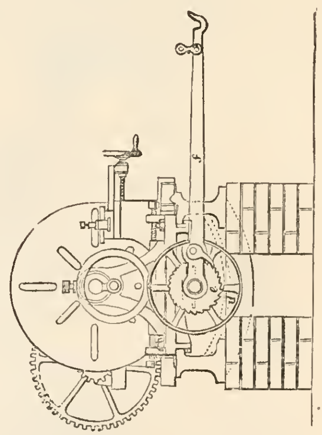




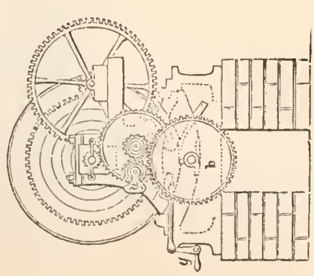
2519.



2520.



2521.



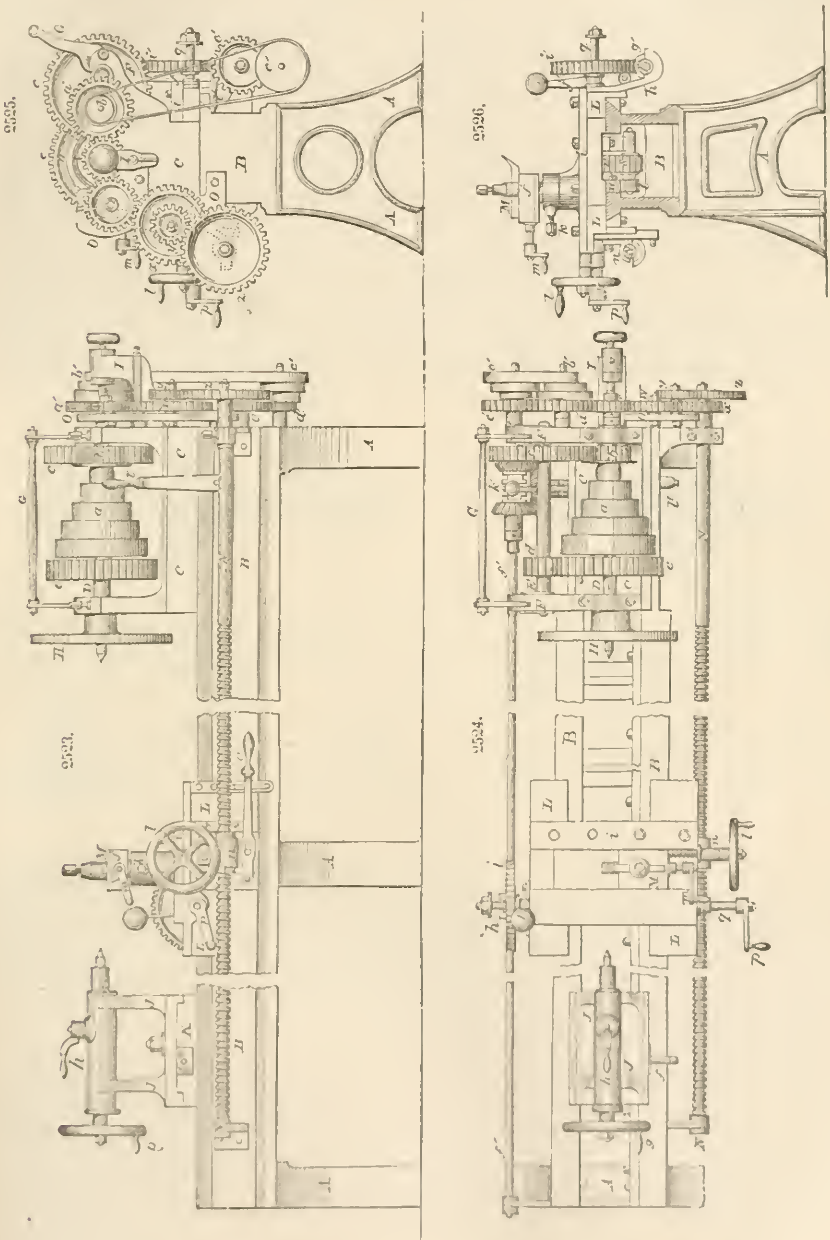
2522.

LATHE, SMALL SELF-ACTING AND SCREW-CUTTING, by CHARLES WALTON, Leeds, Eng
Fig 2523 is a general side elevation of the lathe, and

Fig. 2524 is a plan corresponding.

Fig. 2525 is an end elevation showing the geering.

Fig. 2526 is a transverse section taken between the fast-head and the slide-rest, showing the latter in elevation, as also the arrangement of the geering for traversing the same.



Figs. 2527, 2528, 2529, 2530, show details of the geering for working the slide-rest.

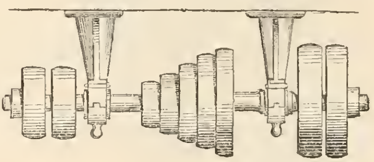
Fig. 2231 is an elevation of the top cone and driving pulleys: these consist of two sets, the smaller set being used for reversing the motion of the saddle when the lathe is employed in screw cutting, and the larger when the tool is in action, and a slower motion consequently necessary.

Fig. 2532 is a section through the driving-cone on the lathe-spindle.
Fig. 2533 is a front view of the chuck.
Fig. 2534 is a side elevation of the same; and
Fig. 2535 a vertical section in the plane of the lathe-spindle.

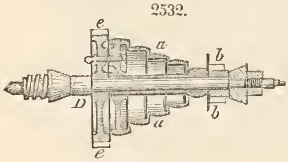
These figures exhibit in full detail the several parts of a very efficient, and, in many respects, convenient self-acting and screw-cutting lathe.

The machine is carried upon three standards marked A, and of which the general forms are shown in Figs. 2525 and 2526. These standards are planed on their upper surfaces to afford a solid rest for the bed B B, the upper surface of which is also planed. The exterior edges of the bed are bevelled in the usual way, as a means of retaining the saddle-plate L L of the slide-rest, as shown in the cross-section, Fig. 2526. The fast-head C C is fastened to the bed by means of bolts: it carries the main spindle D, upon which is the driving-cone *a*, a section of which, showing its relation to the spur-wheel *e* and pinion *b*, is the subject of Fig. 2532. The cone is as usual loose upon the spindle, and can be attached at pleasure to the wheel *e*, which is fast upon the spindle, when it is necessary to throw the back-speed shaft E out of geer. This is effected by the hand-rail G, which connects the two levers commanding the bearings of the shaft in the two standards of the fast-head, a method commonly adopted when the arrangement of the geering does not conveniently admit of the shaft being shifted longitudinally. The motion of the leading-screw N is derived from the cone-spindle through the train of wheels *v w x y z*, in screw-cutting; and in plain work the parallel motion of the tool is obtained through the train *v a′ e′ c*, and the band-pulleys *b′* and *c′*, to the traverse-spindle *f′ f′*, which, by means of the worm *g*, Figs. 2526 and 2530, and worm-wheel *i′* communicates through the intervening spur-pinions *r* and *s* with the pinion *t*, Fig. 2527, geering with the toothed-rack *u*, Figs. 2526 and 2529, attached to the under side of the saddle-plate L of the slide-rest. The geering for reversing the motion of the saddle consists of three meter-wheels and the clutch-box *k′*, arranged upon the traverse-rod *f′ f′*. The clutch *k′* communicates by means of a spanner fixed upon a horizontal shaft, passing through the

2531.



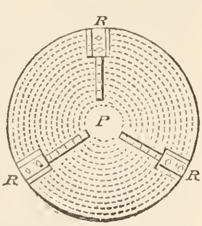
2532.



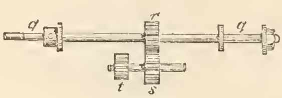
2535.

2534.

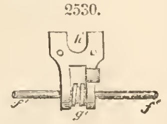
2533.



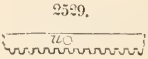
2527.



2530.



2529.



2528.

bed of the lathe, with the reversing-lever *l′* in front. By this means the shaft communicating with the train of wheels from the cone-spindle may be geered either directly with the traverse-rod *f′ f′*, or through the intervention of the meter-wheels at pleasure. A weighted lever *j′*, shown in Fig. 2526, serves the purpose of throwing the worm-wheel *i′* in or out of geer with the worm upon the traverse-rod, thereby connecting or disconnecting the lathe with the saddle of the slide-rest as may be required. The slide-rest can be relieved from connection with the leading-screw N by means of the handle *o* attached in front of the saddle: by pressing this handle down, it acts upon a stud in the plate, carrying the screw-box *n*, which is thereby opened, and the saddle relieved.

The movable head-stock J J is provided with a screw *f* for shifting it out of the line of the axis of the main spindle, thereby adapting the lathe to conical turning.

Action of the lathe.—The arrangement of the geering in the views given of the lathe in the plates, is that adapted to screw-cutting. The cone *a*, which is loose on the spindle, is fast to the pinion *b* of 13 teeth; this pinion geers with the wheel *c* of 52 teeth upon the back-speed spindle E, which also carries the pinion *d* of 13 teeth, geering with the wheel *e* of 52 teeth, fast upon the cone-spindle D. According to this arrangement, the ratio of the speed of the driving-cone to that of the main spindle is as 16 to 1.

The connection between the cone-spindle and the leading-screw N is accomplished by means of the wheel *v* of 40 teeth, fast upon the driving-cone spindle; this wheel is working into the wheel *w* of 60 teeth, upon a shifting-stud attached by means of a radial slot-bar to the bracket O, bolted upon the fast-head; this latter wheel again is in geer with the wheel *x* of 90 teeth, also upon a shifting-stud, and carrying a wheel *y* of 45 teeth, in geer with the wheel *z* of 90 teeth, fast upon the leading-screw shaft N. This train can, of course, be varied at pleasure to suit the particular pitch of screw to be cut, the positions of the radial slot-bars, carrying the studs of the carrier-wheels, being at the same time shifted to allow the wheels to come into geer.

To adapt the lathe for plain sliding, the back-speed shaft is put out of geer with the cone-spindle, by means of its hand-rail G; the wheel *v* upon the cone-spindle then geers with the wheel *a′*, working loose upon a stud attached to the head-stock, and carrying the cone-pulley b'. This last is connected by a band with the loose cone-pulley c', working likewise upon a stud fixed to the standard A, and carrying a wheel d', which geers into the wheel e', fast upon the end of the traverse-rod $f'f'$, on which are the three meter-wheels and clutch-box k', also the sliding-worm which works into the cone-wheel i' upon the shaft q. This shaft revolves in bearings attached to the saddle, and carries the pinion r, Fig. 2527, working into the wheel s, keyed upon the same spindle which carries the pinion t, also fast. This latter geers with the rack u bolted to the under surface of the saddle. By this arrangement motion is transferred from the cone to the traverse-rod $f'f'$, and thence to the slide-rest through the geering attached to the saddle.

Literal references.—A A A the standards upon which the lathe is supported.

B B the bed or shears having the upper ledges upon which the shifting head-stock and saddle rest, planed.

C C the fast-head, which is firmly bolted upon the bed.

D the main spindle, which is highly finished and case-hardened. It revolves in conical collars of hardened steel, and is further secured against end-long shift by a set-screw bearing against its outer end through the bracket I.

E the back-speed shaft revolving in bearings inserted in the projecting lugs F F, cast on the standards of the fast-head.

G hand-rail for throwing the back-speed shaft in and out of geer with the cone-spindle.

H the face-plate which is screwed upon the end of the main spindle.

I bracket bolted to the outer standard of the fast-head; see D.

J J the movable head-stock. It is planed and fitted upon a saddle K, both the upper and under surfaces of which are planed; on the upper to allow the head-stock to slide upon it transversely, and on the under to allow of its being travelled on the bed of the lathe.

L L the saddle-plate of the slide-rest. It is planed and fitted with bevelled pieces to retain it upon the bed of the lathe, as shown in Fig. 2526.

M the tool-holder of the slide-rest.

N the leading-screw, carried in bearings at its two extremities, attached in front of the lathe.

O the bracket for carrying the train of carrier-wheels by which the motion of the main spindle is transmitted from the leading-screw.

P, Figs. 2533, 2534, and 2535, the front plate of the universal chuck. And

Q the back plate of the same, showing the spiral groove for expanding and contracting the clutches or jaws.

R R R the clutches or jaws of the chuck. These are fixed upon separate soles through which one of the tails passes, while the other passes over the inner end of the sole; these tails slide between radial slots in the front plate P, and enter the spiral grooves formed in the face of the back plate Q. When the back plate is turned upon its axis, which coincides with the axis of the main spindle, the front plate being meantime held fast, the clutches or jaws will be guided simultaneously, further from, or nearer to the centre, and thereby be made to clutch the work in the usual way.*

a the driving-cone of the lathe; it is loose upon the main spindle, and fast to

b the first pinion of 13 teeth; it is fast to the driving-cone *a*.

c wheel of 52 teeth on the back-speed shaft E; and

d a pinion of 13 teeth on the same shaft.

e first wheel of 52 teeth on the main spindle of the lathe.

f screw for moving loose head-stock transversely for conical turning.

g hand-wheel for working the spindle of the loose head-stock; and

h a handle for tightening the pinching-screw of the same.

i adjustable check by which the slide-rest M is retained upon the saddle-plate L.

j rest-plate for the tool-carrier; and

k a screw for fixing the tool-holder upon the slide-rest.

l a hand-wheel and handle upon the end of the transverse-screw of the side rest. This screw works in plain collars attached to the saddle-plate, and in a nut attached to the sliding-sole of the rest, so that the screw being turned it carries the slide from or towards the axis of the lathe.

m a crank-handle upon the upper slide-screw, for putting the tool in and out of cut.

n the screw-box for the leading-screw. The under part is screwed internally to the same pitch as the leading-screw, and is carried upon a sliding-sole, into which is inserted a stud passing through a slot in

o the handle for connecting and disconnecting the screw-box of the leading screw. It acts as a lever of the second kind, the stud of the sliding-sole of the nut passing through a slot in it, between the fulcrum and the part acted on by the hand.

p the crank-handle for working the saddle plate by hand; it is placed upon

q the transverse-shaft upon which is the screw wheel i', working into the sliding-worm g', carried along the rod $f'f'$ by a fork h' attached to the saddle-plate.

r a spur-pinion keyed upon the transverse shaft *q*, and working into

s a small spur-wheel keyed upon a short spindle, attached by bearings on the bottom of the saddle-plate, and which geers with the pinion *r* on the transverse-shaft *q*.

t a spur-pinion keyed on the same spindle as *s*, and which geers with

u an inverted rack fast to the bed of the lathe.

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* This arrangement has an advantage over the mode of working the clutches by separate screws, in their being simultaneously expanded and contracted in respect of the centre; but it frequently happens that it is necessary to chuck articles which are not cylindrical, and in which it is more convenient to have the clutches movable, independently of one another. As a familiar example may be instanced half-lap coupling ends of shafts, which are semi-cylindrical, and must be made up by packing to the cylindrical form before they could be caught in a chuck of this kind.

v the first pinion in the trains of the head-geering of the lathe.

w a carrier-wheel which geers with the pinion *v*; it is loose upon a stud in the stud-plate O.

x a second carrier-wheel upon another stud in the stud-plate O, geering with the former.

y a third carrier-wheel on the same stud as the wheel *x*, and made fast to the latter.

z a wheel keyed upon the end of the leading-screw, and geering with the pinion *y*.

It is through this train that the leading-screw derives its motion from the main spindle of the lathe.

a' a wheel of the back-train geering with the pinion *v*, on the end of the main spindle; it is keyed upon a pap of

b the upper cone of the back-train, carried upon a stud in the standards of the fast-head. It is loose upon the stud, and has the eye prolonged into a pap upon which the wheel *a'* is keyed.

c' the lower of the two cones of the back-train. It is also loose upon its stud, and is connected by a band with the upper speed-cone *b'*.

d' a spur-pinion keyed upon the eye of the speed-cone *c'*, which is prolonged for that purpose, and which geers with

e' a spur-wheel on the end of the worm-shaft *f' f'*, geering with the pinion *d'*.

f' f' the traverse-rod or worm-shaft; a grooved rod passing at the back of the lathe, and having its bearings at the two extremities. It is also supported between by the fork which slides the worm *g'* along upon it, the projecting sides of which are formed into a species of double gallows, as shown in Figs. 2526 and 2530.

g' worm or endless screw upon the traverse-spindle, geering with the worm-wheel *i'*. It has a fixed key in the eye which slides in a groove in the rod *f' f'*.

i' worm-wheel on the end of the transverse-shaft *q*, worked by the worm *g'*.

j' a weighted lever for disconnecting the worm-wheel *i'*.

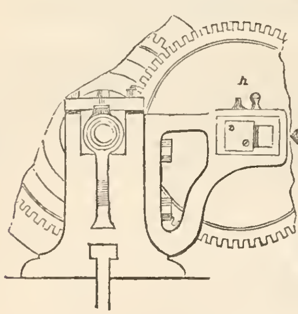
k' reversing-geer upon the worm-shaft *f' f'*, consisting of the three meter-wheels and clutch-box, arranged in the usual manner, and worked by

l' the lever of the reversing-geer *k'*; it acts by a spanner upon the clutch-box lever, bringing the clutch into geer with either of the wheels upon the worm-shaft at pleasure.

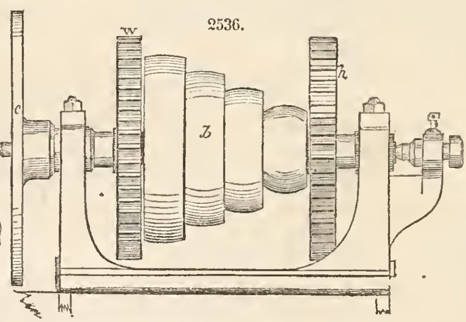
LATHE, BACK-GEER TURNING. This is a good specimen of a back-speed lathe.

Fig. 2536 is a side elevation of the fast-head; Fig. 2537 an end elevation of the same taken from the back, and Fig. 2538 is a plan of the fast-head. The same letters are used on each.

2537.

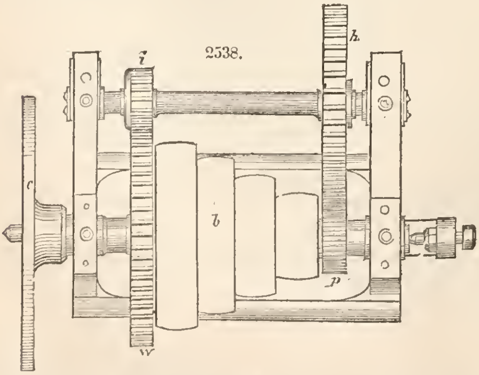


2536.

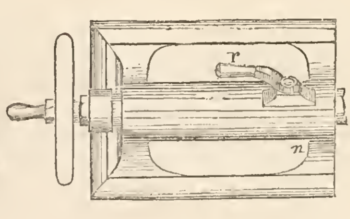


b, the driving cone-pulleys, loose on the spindle of the lathe and fast with the pinion *p*, Fig. 2538. *h*, a spur-wheel, fast on the back shaft, and *i* a pinion also fastened on the same. *w*, a wheel fast on the lathe-spindle, geering with the pinion *i*. *c*, is the chuck or face-plate; this admits of being taken off the lathe-spindle when not required. The spindle is kept forward by a back-centre pinching-screw.

2538.

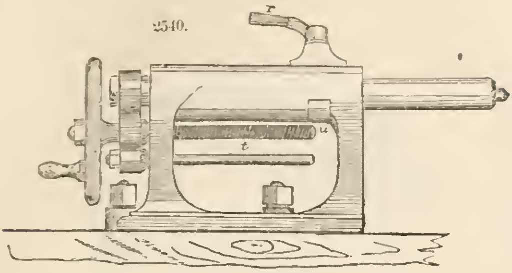


2539.



Figs. 2541 and 2540, are end and side elevations of the shifting-head of which Fig. 2539 is a plan. is a screw for shifting the spindle. A hand-wheel is placed on the outer end of it, which revolves in

2540.



2541.

a gland embracing the ends of the shifting-spindle and a guide-rod under the screw, Fig. 2540; by this means it is made to move horizontally, and to carry the shifting-spindle of the head along with it. *u* is an eye-bolt, tightened up by the traveller *r* on the spindle, to take the strain off the screw. When quicker speeds are wanted, the shaft carrying the wheels *h* and *i* is moved back by taking out a pin seen under *h* in Fig. 2537, and the cone is made fast to the wheel *w* by a latch in the usual way.

LATHE, BORING AND TURNING, by Mr. Kinmonds.

Fig. 2542 is a side elevation of the machine.

Fig. 2543 is a general plan corresponding.

Fig. 2544 is an end view from the left.

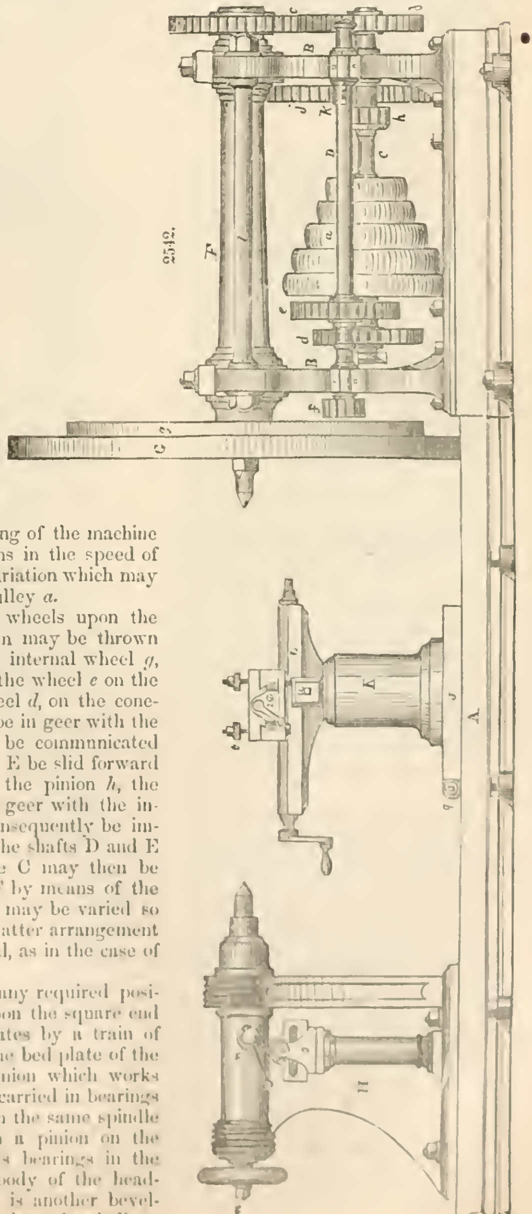
Fig. 2545 is a section taken in front of the shifting head-stock.

The fixed head-stock B B is provided with four bearings, cast in each of the two standards, for the purpose of receiving the cone-spindle C, the second motion shafts D and E, and the main spindle F, upon which the face-plate G is fixed. The geering of the machine is calculated to produce a series of variations in the speed of the main spindle F, independently of any variation which may be effected by means of the driving cone-pulley *a*.

To effect this the arrangement of the wheels upon the shafts D and E is such that either of them may be thrown into geer with the cone-spindle C, and the internal wheel *g*, on the back of the face-plate G. Thus, if the wheel *e* on the shaft D be brought into geer with the wheel *d*, on the cone-spindle, the pinion *f* will at the same time be in geer with the internal wheel *g*, and a quick motion will be communicated to the face-plate; but if the opposite shaft E be slid forward longitudinally till the wheel *j* geers with the pinion *h*, the pinion *f′* on that shaft will be thrown into geer with the internal wheel, and a slower motion will consequently be imparted to the face-plate. Again, let both the shafts D and E be thrown out of action; the cone-spindle C may then be directly connected with the main spindle F by means of the wheels *b* and *c*, the relative sizes of which may be varied so as to produce any required velocity; this latter arrangement is only employed for obtaining a high speed, as in the case of polishing.

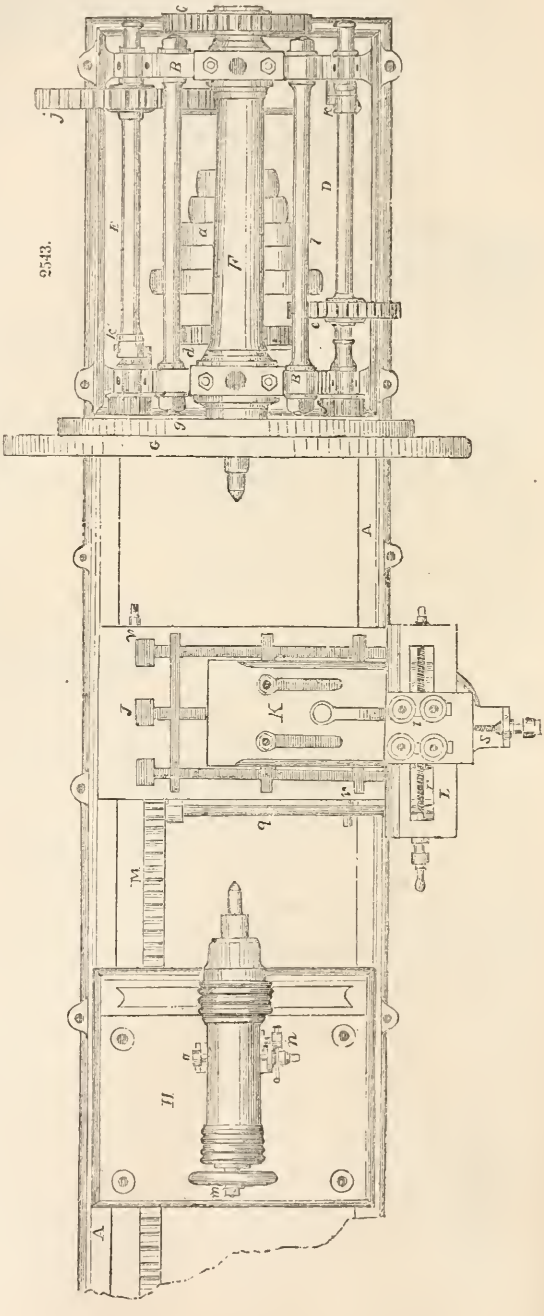
The loose head-stock H is adjustable to any required position by means of a crank-handle fitting upon the square end of the spindle marked *o*, which communicates by a train of toothed geer with the rack M, fixed upon the bed plate of the machine, as shown in Fig. 2546. The pinion which works into the rack is keyed upon the spindle *p*, carried in bearings attached to the sole of the head-stock. On the same spindle is a small bevel-wheel, which geers with a pinion on the lower end of a vertical spindle, having its bearings in the interior of a hollow column, cast in the body of the head-stock. On the upper end of this spindle is another bevel-wheel, which geers with a pinion on the horizontal spindle *o*

2542.



thereby completing the connection with the fixed rack M. This arrangement is fully exhibited in dotted lines in Fig. 2516.

The same rack M serves also for moving the side-rest K in a longitudinal direction, by means of a pinion keyed upon the shaft *q*, shown in Fig. 2543. This shaft is carried in bearings attached to the edge of the sole-plate of the slide J, and terminates in a *square*, to which a lever may be applied to give motion to the shaft. The sole-plate of the slide is provided with dovetail grooves in its under surface, to receive the correspondingly formed heads of two bolts, for the purpose of attaching and fixing to the saddle-plate J the sole of the bracket K, which carries the slide-rest L. To afford the utmost possible facility for adjustment, the bolt holes in the sole of the bracket K are slots of considerable length, and the fixing bolts hold the two plates firmly together, metal to metal, their surfaces of contact being planed true.



2543.

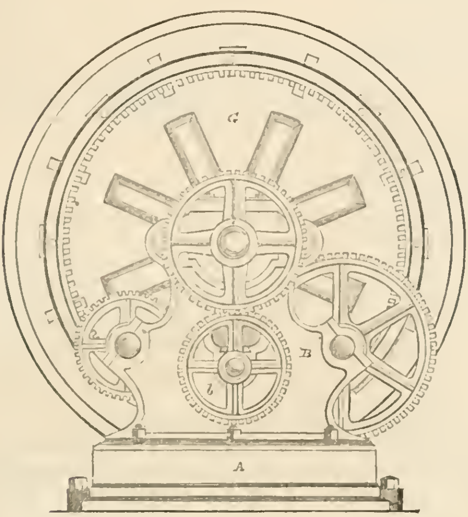
By this arrangement the slide may be made fast in any position upon the saddle-plate, which in turn is retained upon the bed-plate of the machine by wedge-pieces worked by means of two horizontal eccentric spindles *v v*, shown in Fig. 2543.

The longitudinal and transverse motions of the tool-holder, for the purposes of traversing the work, and placing the tool in and out of cut, are obtained by means of the screws *r* and *s*, which work at right angles to each other, in the usual manner; the tool is made fast on the tool-holder by means of the two clamps *t t*. In adjusting the slide primarily to the work the sole K is released from the saddle-plate J by relaxing the connecting bolts; the bracket K is then shifted to the required distance from the longitudinal axis of the machine, and also, to a certain extent, in the line of that axis by sliding the bolts in the dovetail grooves of the saddle-plate, should that operation be more convenient than moving the latter on the bed-frame of the machine. For transverse adjustment to a limited extent, the screw *s* can be used; for longitudinal adjustment, the tool-carrier may be set in a similar manner by the screw *r*.

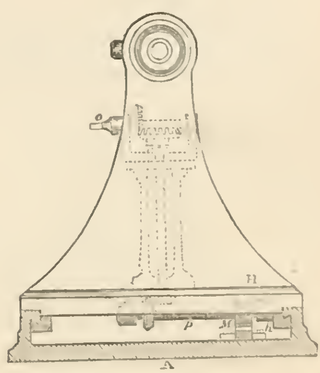
Action of the machine.—Supposing it is required to *face* a heavy piece of work by this machine, it is clamped to the face-plate by means of bolts which pass through radial slots formed in the latter. The wheel *c*, upon the end of the main spindle F, is then removed, and the shaft E is slid longitudinally in its bearings until the wheel *j* and the pinion *f'*, both keyed upon it, geer respectively with the pinion *h*, upon the cone-spindle, and the internal wheel *g*, which is fast upon the back of the face-plate. By this arrangement the slowest motion of the face-plate is obtained. If a quicker motion be required, as when the action of the tool is near the axis of the machine, the shaft E is thrown out of geer, (as shown in the views, Figs. 2542 and 2543,) and the shaft D is moved endways until the wheel *e* and pinion *f* upon it geer respectively with the wheel *d* upon the cone-spindle, and the internal wheel *g* upon the back of the face-plate. The speed is thus increased in the ratio of the number of teeth in the wheel *d* and pinion *h*; that is, as 51 to 15. A still higher speed, and indeed the highest, is obtained by arranging the geering of the machine as it is represented in the engravings. The shafts D and E, it will be observed, are both out of geer, (being retained in that position by the catches $k\,k'$,) and the wheel b upon the cone-spindle C is in geer with the wheel c, upon the end of the main spindle F, so that the speed of the cone is transmitted to the face-plate through the single pair of wheels b and c, which are to each other in the ratio of 51 to 66.

These three speeds, which are independent of the five speeds obtained by the cone, may be thus compared:—The numbers of teeth in the wheel j and pinion f, upon the back-shaft E, are respectively 78 and 13, and the numbers in the pinion h, upon the cone-spindle, and in the internal wheel g upon the back of the face-plates, are 15 and 119; consequently when the shaft E is in geer, the ratio of the speed between the cone-spindle and the face-plate is as $78 \times 119 : 13 \times 15$, or as 47·6 to 1, being the slowest motion of which the machine is capable. Again, the numbers of teeth in the wheel e and the pinion f, upon the shaft D, are respectively 51 and 13; and the numbers in the wheels d upon the cone-spindle, and the internal wheel g, being 51 and 119, therefore when the shaft D is in geer, the ratio of the speed of the cone-spindle to that of the face-plate is as 119 : 13, or as 9·15 to 1. And when both of these shafts are out of geer, and the wheel b upon the cone-spindle is working into the wheel c upon the main spindle, the numbers of teeth being respectively 51 and 66, the ratio of the speed is 1 to 1·3 nearly.

2545



2546.



The action of the machine in ordinary parallel turning is the same as in any common lathe. The mode of obtaining a self-acting longitudinal motion of the tool-carrier is by a stellar-plate fixed upon the end of the screw r, and which is worked by an arm bolted to the face-plate or to the object which is being turned, so as to come in contact with the plate, and cause it to advance one tooth at each revolution.

Application of this lathe to the boring of cylinders.—When the machine is to be used as a boring-mill, the slide-rest and shifting head-stock are removed, and a boring-bar is substituted; one end being supported by a standard fixed upon the bed-plate.

Literal References.

A A, the bed-plate of the machine.
B B, the fixed head-stock, bolted to the bed-plate.
C, the driving cone-spindle.
D E, the second motion shafts.
F, the main spindle carrying the face-plate G.
a, the driving cone-pulley with five speeds.
b, a wheel of 51 teeth working into
c, a wheel of 66 teeth on the main spindle.
d, a wheel of 51 teeth working into
e, an equal sized wheel on the second motion shaft D.
f f', pinions of 13 teeth on the shafts D and E, working into
g, the internal wheel of 119 teeth attached to the face-plate.
h, a pinion of 15 teeth working into
j, a wheel of 78 teeth upon the second motion shaft E.
k k', catches for retaining the shafts D and E when put in or out of geer.
l l, stay-rods for strengthening the fixed head-stock.
H, the shifting head-stock.
m, a screw-spindle with hand-wheel for adjusting the centre in the shifting head-stock.
n, a pinching-screw for fixing the centre when adjusted.
o, a spindle for moving the shifting head-stock longitudinally.
p, a transverse shaft forming part of the mechanism by which the shifting head stock is moved.
h' h', hooked bolts for fixing the shifting head-stock.
J, the saddle plate, forming a support for
K, a bracket for carrying the slide-rest.
L, the longitudinal carriage of the slide-rest.

M, the toothed rack, fixed to the bed-plate for the purpose of moving the slide-rest and shifting head-stock.
q, a shaft carrying a pinion which works into the rack M, for moving the slide-rest longitudinally.
r, longitudinal screw of the slide-rest.
s, transverse screw of do.
$t\,t$, clamps for fixing the tool upon the slide-rest.
u, screw for fixing the slide-rest.
$v\,v$, screws for fixing the saddle-plate.

LATHE, BORING MILL AND LARGE TURNING LATHE. This is an indispensable tool in works where engines of a large class are constructed. The plates exhibit a side elevation and plan, with the parts marked by the same letters of reference.

A, the boring-bar, having a recess in it to receive the feeding-screw; see Fig. 2547.

C C and D D, brackets for carrying bar.

B, bed-plate for fixing the work by T-headed bolts, passing through the longitudinal slots cast in it.

E, Fig. 2547, boring-block, fitting accurately on the bar; it is moved along it by the feed-screw working into the nut v, inserted into the boring-block.

H, main spindle carrying the driving cone-pulleys.

G, the face-plate for fixing the work to be turned.

S, Fig. 2548, a cylinder undergoing the process of boring.

t, bars for fixing the cylinder to the bed-plate.

y, a coupling bolted to the face-plate for the purpose of driving the boring-bar.

a, pinion fast to driving cone-pulleys and to the boss on the spindle H.

b, wheel fast on the shaft o, and geering with the pinion a.

e, pinion driving the wheel d, but which may be slid along the shaft on a sunk feather towards g, so as to be clear of d when required.

g, wheel fast on the shaft o.

h, wheel which geers with the wheel g, when required.

c, wheel on the shaft p, which geers with that marked b, on the shaft o.

k, internal wheel fast on the back of the face-plate G.

i, pinion fast on the shaft p, and geering with the internal wheel k, to communicate motion to the face-plate.

$s\,s$, planed rails for the brackets C and D, or other supports that may be used to carry lathe-heads.

w, x, boring-rings; the internal ring w is usually bored to fit E, and allowed to remain on the boring-block, the larger ones being keyed on it. The ring x, suited to bore the cylinder $s\,s$, has 24 slots in its circumference; 12 of these receive the cutters, which are adjusted and fixed by small wedges; sometimes they are bedded on paper. The other slots are fitted with pieces of hard wood driven tightly into them to form a general guiding surface.

l, wheel loose on the boring-bar, and having external and internal teeth. The internal teeth geer with those of a pinion on the end of the feed-screw; see Fig. 2549.

m, wheel fast on the boring-bar, and having the same number of teeth as the wheel l, (64.)

n, q, wheels fast on the small shaft u, and geering with m and l. The wheel q has one tooth less than n, (35 and 36,) so that one turn of the wheels n and q advances the wheel l one tooth on the bar, and (the internal wheel having the same number of teeth as the external) produces a motion of one tooth of the screw-pinion. The screw being $\frac{1}{2}$ inch pitch, and the piston 16 teeth, the feed motion of the boring-block will be $\frac{5\cdot}{16} = \cdot03125$ inch for each turn of the wheels n and q, or $\frac{\cdot03125 \times 64}{35} = .0571$ inch during one turn of the boring-bar.

The following table exhibits the various speeds of which the boring-bar is susceptible.

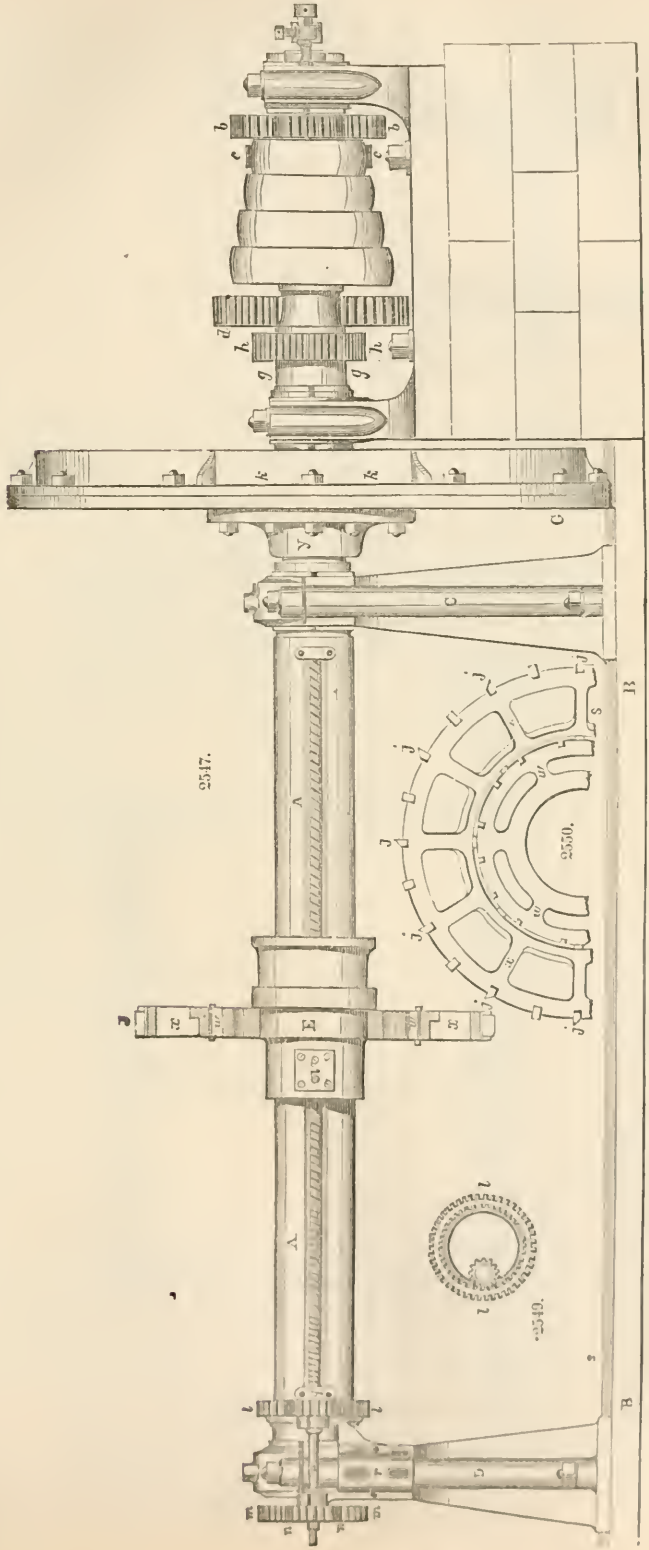
	Turns per minute.			Turns per minute.
1	·333 × 3 = 1		13	4·839
2	·416		14	6·049
3	·520		15	7·561
4	·650	$\sqrt{\cdot650} \times 3 = 1\cdot4$	16	9·451
5	·812	$\sqrt{\cdot812} \times 3 = 1\cdot56$	17	11·814
6	1·015		18	14·767
7	1·269		19	18·457
8	1·586		20	23·079
9	1·982	1·982 × 3 = 5·946	21	28·842
10	2·478		22	36·053
11	3·077		23	45·066
12	3·871		24	56·333

The speeds increase as 1 to 1¼, so that any speed within the range may be procured to within ⅛ of that required; that is, the boring speed being 7 feet per minute, the greatest deviation will be $\frac{84}{8} = 10\frac{1}{2}$ inches per minute.

The cone-pulleys of the machine are driven by a similar set of cone-pulleys on an intermediate shaft. This shaft is again driven from the main shaft by pulleys of the following relative diameters:

3 feet.	22½ in.
22½ in.	3 feet.

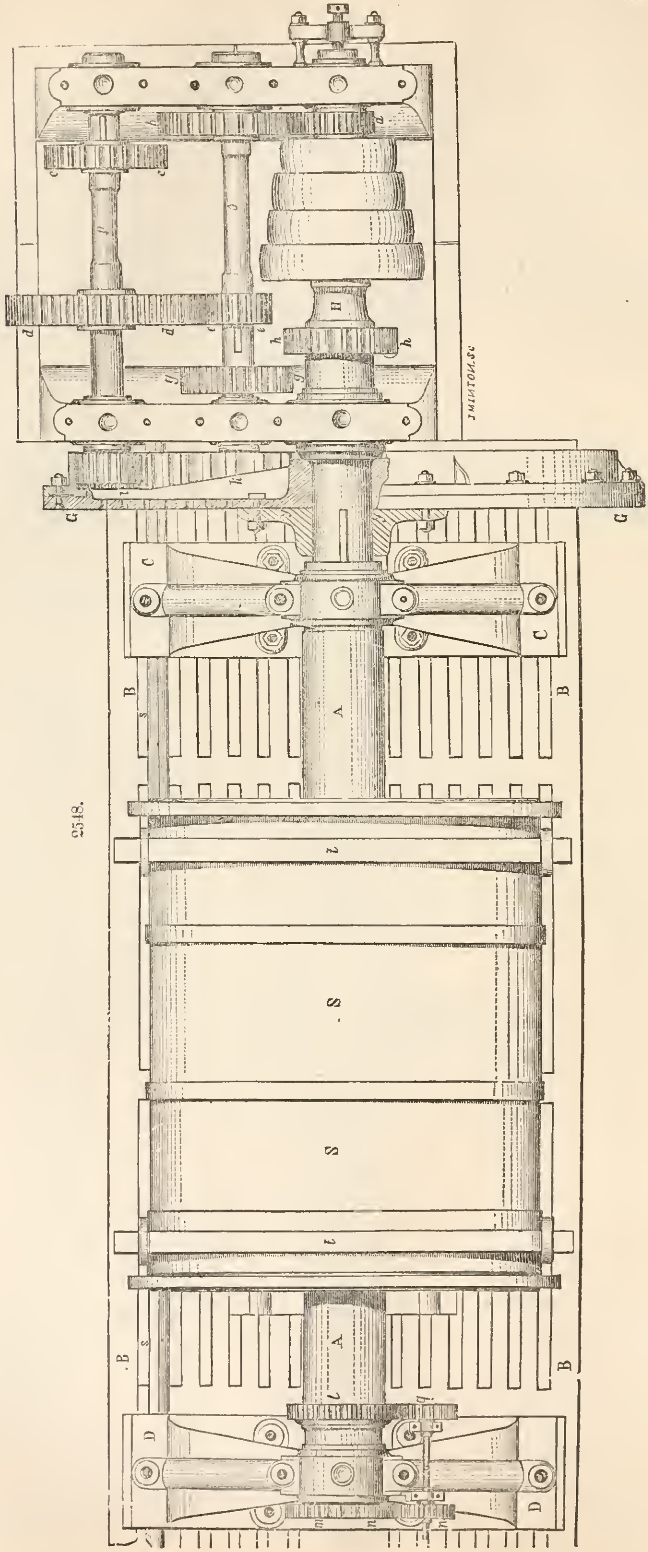
The diameters of these pulleys are to each other as the first to the fifth speed of the bar, so that the smaller is to the larger pulley as $\sqrt{\cdot333} : \sqrt{\cdot812} = 1 : 1\cdot56$. The increase of speed from the largest



2547.

2550.

2549.



2548.

to the smallest pulley on the spindle H is as the first to the fourth speed, and the diameters of the pulleys are $\sqrt{\cdot 333} : \sqrt{\cdot 650} = 19 : 26\frac{1}{2}$.

The first eight speeds are obtained with the wheels *d* and *c*, the second eight with the wheels *b* and *e*, and the third eight by geering *g* and *h*, disengaging *e* and *c*, and taking the pinion *i* out of geer with the large internal wheel on the face-plate by shifting the shaft *p* towards the shaft *o*.

Numbers of Teeth in Wheels.

Driving Wheels.	No. of Teeth.	Feed Wheels.	No. of Teeth.
a,	24	*l*, external,	64
b,	52	*l*, internal,	64
c,	40	*m*,	64
e,	14	*n*,	36
d,	64	*q*,	35
g,	34	Pinion on traverse screw,	16
h,	40		
i,	15		
k,	144		

The speeds produced by the wheels *e d* and *b c* are to each other as the first to the ninth speed of the chuck; therefore, $64 \times 52 \div 14 \times 40 = 5{\cdot}94$ nearly.

The boring speed being about 7 feet per minute, the slowest speed, viz., $\frac{1}{3}$ of a revolution per minute, would cut a cylinder of 80 inches diameter $\frac{84 \times 3}{3{\cdot}1416} = 80$. All the cylinder boring speeds are in the first eight of the table, the others are for turning and polishing heavy articles, such as large cylinder covers.

Another modification of the boring-lathe is seen in the vertical boring-mill of J. P. Morris & Co., of Philadelphia.

A modification of the reaming and boring-lathe may be seen in the vertical boring-mill built in the Washington Navy Yard, under the direction of Wm. M. Ellis. This is essentially the same as the boring-mill of J. P. Morris & Co., of Philadelphia.

Fig. 2551, elevation of the mill.

A, crane for lifting the work.

B, driver of boxing-shaft.

C, skeleton-frame to support cylinder.

D, frame to support upper end of cylinder.

E, horizontal chucking-plate.

F, cone of pulleys.

a, feed-geering for boring-head.

Fig. 2552, section.

E, chucking-plate.

F, cone of pulleys.

a, horizontal shaft transferring motion by bevel-pinion to upright shaft *b*, which drives the chucking-plate by a pinion.

c, small shaft for feed motion to slide-rest.

d, grooved pulleys for feed motion to the same.

e, expansion connection with universal joints at each end to convey motion of worm and rack to upright mandrel *i*.

f, brace to support counterbalance geering *g*.

h, cone supporting counterbalance.

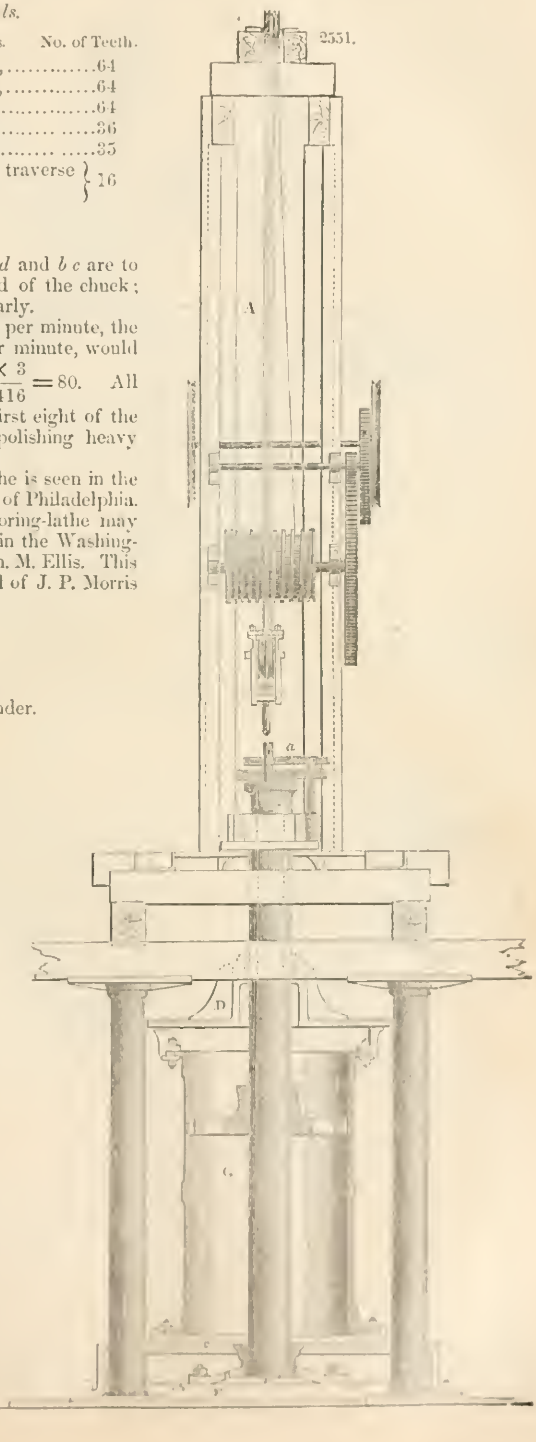
i, hexagon mandrel counterbalance.

Fig. 2554. G, cast-iron frame to support upper end of boring shaft.

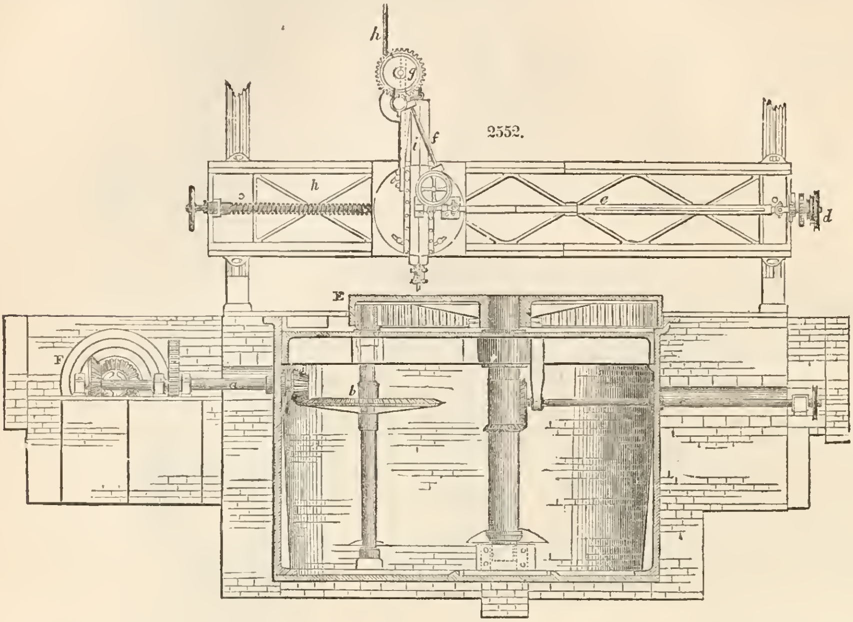
Fig. 2555 shows the stand or bed indicated by letter C, Fig. 2551, on which the cylinder rests which is to be bored out.

Fig. 2556 shows a guide, indicated by D, Fig. 2551, which is placed upon top of cylinder, and serves as guide for boring-bar. The boring-bar is then connected to the revolving-plate, as shown

2551.



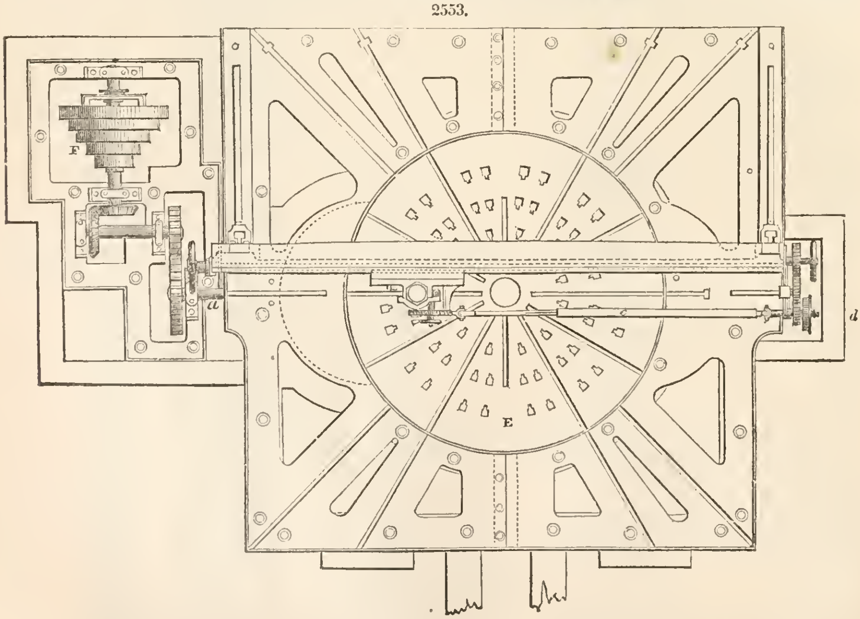
in B and E, Fig. 2551, and turns with it. The boring-head which holds the cutters is shown at G, and is connected with two screws nearly the whole length of boring-bar, set in grooves and moving with the bar and shown by dotted lines, which screws regulate the descent or feed, as it is termed, of the boring-head



2552.

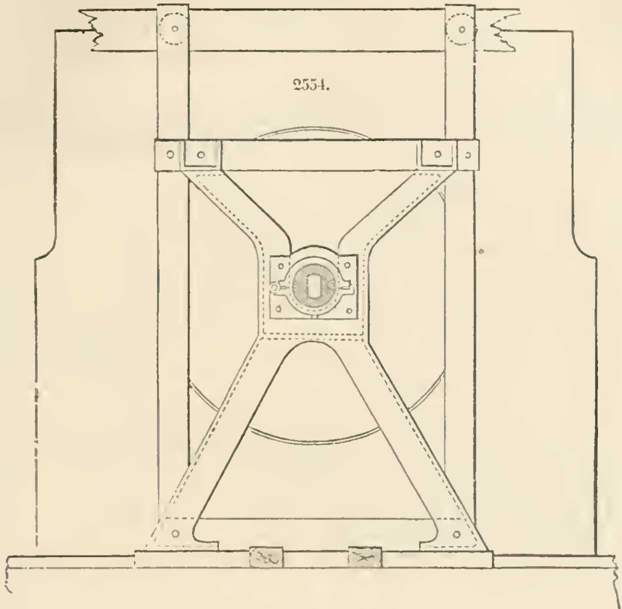
On the upper end of the boring-bar shown at *a*, Fig. 2552, is placed the geer by which the proper motion is given to the feeding-screws. On the end of each feeding-screw is placed a small pinion, which geers into the inner teeth of a wheel which is loose on the top of boring-bar, and of course does not turn

2553.



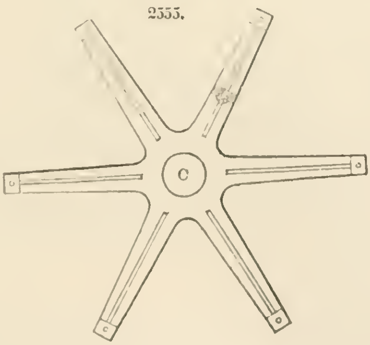
with it. This wheel has teeth on the inner and outer sides of its periphery; the outer teeth geer into one of a set of two wheels which turn together, and are placed on a fixed pivot, independent of the boring-bar. The upper wheel of this set geers into the upper wheel *a*, which is keyed to the boring-bar, and of course turns with it. The amount of feed, or the advance of the feeding-screw, is due to the difference of the velocities which are given to the wheels *a* and *m*. This difference of the velocities of these two wheels may be varied by varying the diameter of the wheels *a* and *m*.

2554.

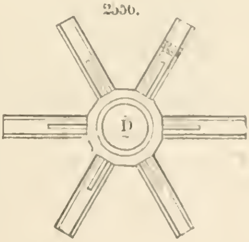


The geering shown above the top of the boring-bar is for hoisting up the boring-bar, when the machine is to be used for planing a flat, or turning a cylindrical or conical surface. The machine, as arranged for this purpose, is shown in Fig. 2552.

2555.

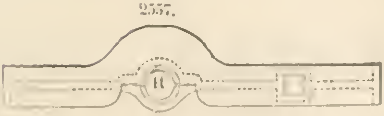


2556.



2558.

2557.



The cutting-tool is attached to the bar *i*, in which a rack is cut, into the teeth of which a pinion geers, which pinion is moved by a perpetual screw on the bar; by this arrangement the vertical motion is given to the tool. The method of producing the lateral motion of the tool by the screw *h* is shown by the figure, and does not need explanation.

Fig. 2557, H, cross-bar and bearing for upper end of shaft of chuck plate.

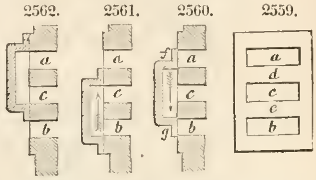
LAP AND LEAD OF THE SLIDE-VALVE. The slide-valve is that part of a steam-engine which causes the motion of the piston to be reciprocating. It is made to slide upon a smooth surface, called the cylinder face, in which there are three openings to as many pipes or passages: two for the admission of steam to the cylinder, above and below the piston, alternately; while the use of the third is to convey away the waste steam. The first two are, therefore, termed the induction or steam ports, and the remaining one the eduction or exhaustion port.

The slide is inclosed in a steam-tight case, called the slide-jacket; and motion is communicated to it by means of a rod working through a stuffing-box.

The steam from the boiler first enters the jacket, and thence passes into the cylinder, through either steam port, according to the position of the slide, which is so contrived that steam cannot pass from the jacket to the cylinder through both steam ports at the same time, or through the eduction port at any time.

CASE 1.—*When a Slide has neither Lead nor Lap.*—Fig. 2559 represents the cylinder face for a "Murray slide" without lap; *a* and *b* being the induction ports, and *c* the eduction.

2562. 2561. 2560. 2559.



Figs. 2560, 2561, and 2562, are similar sections of the nosle, showing the slide in its central and two extreme positions. It occupies the mid-position, Fig. 2560, when the piston is at either extremity of its stroke; the extreme position, Fig. 2561, when the piston is at half-stroke in its descent; and that shown in Fig. 2562, when the piston is at half-stroke in its ascent.

When a slide has no lap, the width of its facing, at *f* and *g*, Fig. 2560, equals that of the steam ports; the lap being any additional width whereby those ports are overlapped.

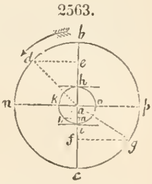
That the waste steam may have unobstructed egress, the exhaustion port *c* must be made of no less width than the steam ports; and, for the same reason, the bars *d* and *e* should correspond with the slide face at *f* and *g*. The three ports, together with the bars between and beyond them, are therefore drawn of equal width; the total length of the slide being equal to the distance between the steam sides of the steam ports.

The distance through which the slide moves, in passing from one extreme position to the other, is called its *travel;* which, in this case, equals *twice the port.*

When the motion of a slide is produced by means of an eccentric, keyed to the crank-shaft and revolving with it, the relative positions of the piston and slide depend upon the relative positions of the crank and eccentric.

Demonstration.

2563.



Let *a b*, Fig. 2563, represent the crank; then *b* being the crank-pin, and *a* the centre of motion, the larger circle represents the orbit of the crank, and its diameter *b c* the stroke of the piston. Supposing the cylinder to be an upright one, having the crank-shaft immediately above or below it, the connection between the piston-rod and crank being merely a connecting-rod, without the intervention of a beam, it is evident that when the position of the crank is *a b*, the piston will be at the top of the cylinder, and at the bottom when its position is *a c*. The relative positions of the crank and piston, at any point of the stroke between the two extremes, depend upon the length of the connecting-rod: for the present, however, let us suppose the connecting-rod to be of infinite length, and therefore always acting upon the crank in parallel lines, so that when the crank is at *d*, *e* will be the apparent position of the piston, and *f* the same when the crank is at *g*; the piston being represented by the sine of the arc described by the crank from either of the points *b* and *c*, in the direction of the arrow.

The diameter *h i*, of the inner circle of the figure, represents the travel of the slide, and its radius the eccentricity of the eccentric; or, regarding the eccentric as a crank, the radius may be said to represent that crank, as *a b* represents the main crank. The travel of a slide, without lap, being equal to twice the port, the two steam ports are represented by the spaces *a h* and *a i*, but transposed, *a i* being the passage to the top of the cylinder, and *a h* that to the bottom.

Supposing the piston to be at *b*, (the top of the cylinder,) the position of the slide will be that shown in Fig. 2560, the direction of its motion being downward, so that the port *a*, Fig. 2560, or *a i* in Fig. 2563, may be gradually opened for the admission of steam above the piston, until the piston has arrived at half-stroke, when it will be fully open, as shown in Fig. 2561. The direction of the slide's motion is then reversed, so that when the piston has completed its descent, the port *b*, Figs 2559 to 2562, or *a h* in the diagram, will begin to open for the admission of steam beneath it, and exhaustion will commence from above it through the port *a*, or *a i*, and exhaustion port *c*, the slide being again brought into its central position, Fig. 2560.

Now the slide being at half-stroke, when the piston is at either extremity of its stroke, if we make *a b* the position of the crank, *a k* will be that of the eccentric; and the axis of the crank being likewise that of the eccentric, they must necessarily revolve in equal times, and always at the same distance apart; therefore, when the crank has reached the point *d* (supposing it to move in the direction of the arrow) the eccentric will have advanced to *l*, and *c d* and *l m* represent the positions of the piston and slide respectively; showing, that when the piston has descended to *c*, the steam port *a i*, Fig. 2563, or *a*, Figs. 2559 to 2562, will be open to the extent *a m*. Again, when the crank is at *n*, and the piston consequently at half-stroke, *a i* will be the position of the eccentric, the port *a i* being fully open, and the slide occupying the extreme position shown in Fig. 2561. The direction of the slide's motion is now reversed, and the port is again gradually covered by the slide face until the positions of the crank and eccentric are *a c* and *a o*, when the piston will have completed its descent, and the port *a i* will be completely closed, the slide being again brought into its central position, Fig. 2560. The opposite steam port *a h* now begins to open for the admission of steam, and the direction of the piston's motion is reversed; the port continues to open until the crank and eccentric reach the points *p* and *h*, when the piston will again be at half-stroke, and the slide in its extreme position, Fig. 2562. Meanwhile, exhaustion from above the piston has been taking place, to the same extent, through the port *a i*. Finally, the piston having completed its ascent, the slide again occupies its original position, Fig. 2560, and, its course being downward, steam is again admitted into the cylinder, through the port *a*; the piston then begins to descend, and, at the same instant, exhaustion ceases from above, and commences from below it, through the port *b*.

It is sometimes urged against the use of the eccentric, as a means of actuating the slide, that the steam ports are opened and closed too slowly; but it must be remembered that the piston does not move at a uniform velocity, as the crank does; for example, while the crank describes the arc *b d*, the piston descends only from *b* to *e*, the versed sine of that arc; and its velocity is gradually increased as it approaches the middle of its stroke, where it is greatest, being equal to that of the crank. Again, as the piston approaches the end of its stroke, its velocity is diminished in the same ratio as that in which it had previously increased, until the completion of its stroke, where it remains stationary during the small space of time in which the direction of its motion is reversed.

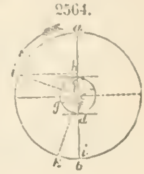
Now, it must be obvious that less steam is required to impel the piston at a slow rate than at a rapid one; and a glance at Fig. 2563 shows that the steam admitted into the cylinder, when the slide is actuated by an eccentric, is at all times proportioned to the velocity of the piston, the port being least open when the piston is near the end of its stroke, and fully open when it is at half-stroke.

When an eccentric, instead of being set, as in the preceding case, so that the steam port shall only begin to open when the piston commences its stroke, is so placed that the port shall be open to some extent prior to the commencement of the stroke, the width of that opening is termed

The Lead.—The non-use of lead is disadvantageous, chiefly because at the commencement of every stroke, the steam has to contend with the whole force of that which had impelled the piston during its previous stroke. But besides obviating that disadvantage, the lead is of essential service in locomotive engines, "where it is found necessary to let the steam on to the opposite side of the piston before the end of its stroke, in order to bring it up gradually to a stop, and diminish the violent jerk that is caused by its motion being changed so very rapidly as five times in a second. The steam let into the end of a cylinder before the piston arrives at it, acts as a spring cushion to assist in changing its motion; and if it were not applied, the piston could not be kept tight upon the piston-rod."

Case 2.—*When a slide has lead without lap.*—Let *a b*, Fig. 2564, represent the stroke of the piston; *c d* the travel of the slide; and *e f* the *lead;* then, supposing the piston to be at the top of the cylinder, *c a* is the position of the crank, and *e g* that of the eccentric. Following the course of the crank, in the direction of the arrow, we find the port *e d* fully open, not, as in the former case, when the piston is at half-stroke, but when it has descended to the point *h*,—the arc *a i*, described by the crank, being equal to the arc *g d*, described by the eccentric. Again, we find the port reclosed when the piston has descended to *i'*, at which point exhaustion commences from above the piston through *e d*, and steam enters below it through *c e*, for the return stroke, at the commencement of which the port *e c* is open to the extent *e l* (equal to *e f*) for the admission of steam, while *e d* is open to the same extent for exhaustion.

2564.



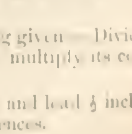
It is to be remarked, that the amount of *lead* is necessarily very limited in practice, its tendency being to arrest the progress of the piston before the completion of its stroke. The greatest possible amount of lead equals half the travel of the slide. The eccentric would in that case be set diametrically opposite to its first position, which would have the effect of reversing the direction of the piston's motion.

In the case of a slide having lead without lap, the distance of a piston from the end of its stroke, when the lead produces its effect, is proportional to the lead as the versed sine of an arc is to its sine, supposing the radii of the crank and eccentric to be equal.

Demonstration.

Let *a b*, Fig. 2565, represent both the travel of the slide and the piston's stroke; then *c a* and *c b* represent the steam ports. And let *c d* represent the lead; then *c a* and *c e* represent the crank and eccentric, the piston being at the top of the cylinder. Now, steam will enter the cylinder, below the piston, when the eccentric is at *f*, and the crank at *g*; for the arcs *a e g*, and *e b f* are equal. Again, the arc *g b* is equal to *h e*; therefore, *i g* is equal to *k e*, and *i b* to *k h*. Now, *k e* is the sine of the arc *h e*, and *k h* (equal to *i b*) is its versed sine: hence

2565.



Rule I.—To find the distance of the piston from the end of its stroke, when the lead produces its effect:—Divide the lead by the width of the steam port, both in inches, and call the quotient sine; multiply its corresponding versed sine, found in the table, by half the stroke, and the product will be the distance of the piston from the end of its stroke, when steam is admitted for the return stroke, and exhaustion commences. Or,

Rule II.—To find the lead, the distance of the piston from the end of its stroke being given:—Divide the distance in inches by half the stroke in inches, and call the quotient versed sine; multiply its corresponding sine by the width of steam port, and the product will be the lead.

Example 1.—The stroke of a piston is 48 inches; width of steam port 2½ inches; and lead ½ inch: required the distance of the piston from the end of its stroke, when exhaustion commences.

Here, ·5 ÷ 2·5 = ·2 = sine; and versed sine of sine ·2 = ·0202.

Then, ·0202 × 24 = ·4848 inches.

Example 2.—The stroke of a piston is 48 inches; width of steam port 2·5 inches; and distance of piston from the end of its stroke, when exhaustion commences, ·4848 inches: required the lead.

Here, $\cdot 4848 \div 24 = \cdot 0202 =$ versed sine;

and sine of versed sine $\cdot 0202 = \cdot 2$.

Then, $\cdot 2 \times 2\cdot 5 = \cdot 5 =$ lead.

When the lead of a slide is equal to the width of steam port multiplied by any number in the first column of the following table, the distance of the piston from the end of its stroke, when steam is admitted on the exhaust-side, will be equal to half the stroke multiplied by the corresponding number of the second column. Or, if the distance of the piston from the end of its stroke, when steam is admitted on the exhaust-side, be equal to half the stroke multiplied by any number in the second column, the width of steam port multiplied by the corresponding number of the first column equals the lead.

When the lead is equal to the width of steam port multiplied by		The distance of the piston from the end of its stroke, when steam is admitted on the exhaust-side, equals half the stroke multiplied by	
	·0625		·0019
	·09375		·0044
	·125		·0078
	·1875		·0176
	·21875		·0242
	·25		·0317
	·28125		·0403
	·3125		·0501
	·34375		·0609
	·375		·0730
	·40625		·0862
	·4375		·1008
	·46875		·1166
	·5		·1339

The Lap.—A slide is said to have *lap* when the width of its face is greater than that of the steam ports, the ports being thereby overlapped, as in Fig. 2569.

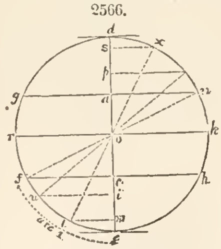
It is to be remarked that slides should have some degree of lap on both the steam and exhaustion sides of the passage, because, although in theory an aperture may be said to be completely closed when covered by a bar of similar width, yet, in the construction of a slide without lap, we cannot insure such accuracy of *fit* as to preclude the possibility of steam entering or leaving both steam ports at the same time.

Lap on the steam side has the effect of cutting off the steam from the cylinder, by closing the port before the completion of the stroke, the remainder of the stroke being effected by the expansion of the steam already admitted.

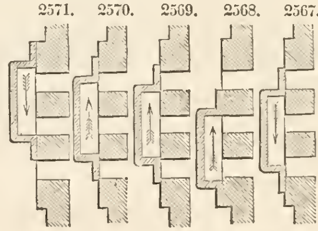
Demonstration.

Case 3.—*When a slide has lap on the steam side, without lead.*—Let *a b* and *b c*, Fig. 2566, represent the lap at both ends of the slide; and let *a d* and *c e* represent the two steam ports; then *d e* will represent the travel of the slide, which, in this case, equals twice the steam port, plus twice the lap.

2566.



2571. 2570. 2569. 2568. 2567.



Supposing *d e* also to represent the stroke of the piston, and that the piston is on the top stroke, then *b d* and *b f* are the respective positions of the crank and eccentric; for the slide, instead of occupying its central position, when the piston is at the end of its stroke, (as in Case 1,) must be set in advance of that position to the extent of the lap, that steam may enter the cylinder when the piston begins to move. See Fig. 2567.

When the eccentric has advanced from *f* to *e*, the crank will have reached the point *g*; the piston is therefore at *a* when the port *c e* is fully open, the slide being then in the position Fig. 2568. Again, when the eccentric has reached the point *h*, the port *c e* will be reclosed, Fig. 2567, and *i* will be the position of the piston; therefore, the distance of the piston from the end of its stroke, when the steam is cut off, is proportioned to the whole stroke, as *i e* is to *d e*.

When the eccentric arrives at *k*, the slide will occupy its central position, Fig. 2569, and the piston will be at *m*, where exhaustion commences from above it; but steam is not admitted below it, for the return stroke, until the eccentric has reached the point *n*, where the port *a d* begins to open, the position of the slide at that moment being that shown in Fig. 2570.

When the eccentric arrives at *d*, the port will be fully open, the slide being then in its extreme position, Fig. 2571; and it will be reclosed when the eccentric arrives at *g*, and the piston at *p*, where the steam is cut off, the position of the slide being again that shown in Fig. 2570. Again, when the eccentric reaches the point *r*, exhaustion ceases from above the piston, which is then at *s*, and commences from below it, the slide being then in its central position, Fig. 2569, and moving downward. Finally, the crank having arrived at *d*, and the eccentric at *f*, the piston will have completed its ascent, and the slide will occupy the position, Fig. 2567, as at starting.

The steam was shown to be cut off when the piston had descended from *d* to *i*, the crank having described the arc *d g u*, and the eccentric the arc *f e h*. Now, *d i* is the versed sine of *d g u*, and *c e* is the versed sine of half *f e h*; and *d g u* and *f e h* are equal arcs. Hence

Rule III.—To find at what part of the stroke steam will be cut off with a given amount of lap:—Divide the width of steam port, by itself, plus the lap, and call the quotient versed sine. Find its corresponding arc in degrees and minutes, and call it arc the first. If arc the first be less than 45 degrees, multiply the versed sine of twice that arc by half the stroke in inches, and the product will be the distance of the piston from the *commencement* of its stroke, when the steam is cut off.

If arc the first exceed 45 degrees, multiply the versed sine of the difference between double that arc and 180 degrees by half the stroke, and the product will be the distance of the piston from the *end* of its stroke when the steam is cut off.

Rule IV.—To find the amount of lap necessary to cut off the steam at any given part of the stroke:—

If it be required to cut off the steam before half-stroke, divide the distance the piston moves before steam is cut off, by half the stroke, and call the quotient versed sine. Find the arc of that versed sine, and also the versed sine of half that arc. Divide the difference between the versed sine last found and unity, by the versed sine, and multiply the width of steam port by the quotient; the product will be the lap.

If it be required to cut off the steam at a point beyond half-stroke, divide the distance of the piston from the end of its stroke, when steam is cut off, by half the length of stroke; call the quotient versed sine; find its corresponding arc, and abstract it from 180 degrees. Find the versed sine of half the remainder, and subtract it from unity. Divide the remainder by the versed sine, and multiply the width of the steam port by the quotient; the product will be the lap.

Example 3.—The stroke of a piston is 36 inches; width of steam port $1\frac{1}{2}$ inch; and lap 6 inches: required the point of the stroke at which steam will be cut off.

$$\text{Here } 1{\cdot}5 + 6 = 7{\cdot}5\text{; and } 1{\cdot}5 \div 7{\cdot}5 = {\cdot}2 = \text{versed sine;}$$

$$\text{arc of versed sine } {\cdot}2 = 36^\circ\ 52'\text{, (arc the first;)}$$

$$\text{and } 36^\circ\ 52' \times {\cdot}2 = 73^\circ\ 44' = \text{arc of versed sine, } {\cdot}7198.$$

Then $\cdot7198 \times 18 = 12{\cdot}95$ inches = distance of the piston from the commencement of its stroke when the steam is cut off.

Example 4.—The stroke of a piston is 36 inches; width of steam port $1\frac{1}{2}$ inch; and extent of lap $1\frac{1}{4}$ inch: required the point of the stroke at which steam is cut off.

Here $1{\cdot}5 + 1{\cdot}25 = 2{\cdot}75$; and $1{\cdot}5 \div 2{\cdot}75 = {\cdot}5454$ = versed sine of arc $62^\circ\ 58'$ (arc the first.)

Then $62^\circ\ 58' \times 2 = 125^\circ\ 56'$; and $180^\circ - 125^\circ\ 56' = 54^\circ\ 4'$ = arc of versed sine, $\cdot4131$; $\cdot4131 \times 18 = 7{\cdot}43$ inches = distance of the piston from the end of its stroke when the steam is cut off.

Example 5.—The stroke of a piston is 36 inches; width of steam port 1·5 inches; and distance of the piston from the commencement of its stroke, when the steam is cut off, 12·95 inches: required the lap.

$$\text{Here } 12{\cdot}95 \div 18 = {\cdot}7198 = \text{versed sine of arc } 73^\circ\ 44'\text{;}$$

$$73^\circ\ 44' \div 2 = 36^\circ\ 52' = \text{arc of versed sine } {\cdot}2.$$

$$\text{Then } 1 - {\cdot}2 = {\cdot}8\text{; and } {\cdot}8 \div 2 = 4\text{; } 1{\cdot}5 \times 4 = 6 \text{ inches} = \text{lap.}$$

The Lead and Lap.—Having separately investigated the two cases of a slide having lead without lap, and lap without lead, we now proceed to consider the effect of both in combination, together with that of lap on the exhaustion side.

Demonstration.

Case 4.—*When a slide has lap on both the steam and exhaustion sides, together with lead.*—Let *a b* and *a c*, Fig. 2572, represent the double lap on the steam side; *a f* and *a g*, the same on the exhaustion side; *b e* and *c d* the steam ports; and the line *c d* both the travel of the slide and stroke of the piston. Then, supposing *c h* to represent the lead of the slide, *a i* will be the position of the eccentric when that of the crank is *a e*; the slide occupying the position shown in Fig. 2573, and the piston being at the top of its downward stroke.

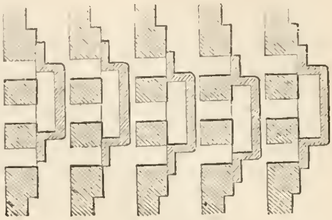
2572.

When the eccentric reaches the point *k*, the port *c d* will be fully closed, as shown in Fig. 2574, and the piston will have descended to *l*, the arc *e m* being equal to the arc *i k*. Again, when the eccentric arrives at *n*, the slide being then brought into the position Fig. 2575, exhaustion commences from above the piston, which has descended to *o*; the arc *e m p* being equal to the arc *i k n*. When the eccentric arrives at *q*, the port *b e* begins to open for the admission of steam beneath the piston, (see Fig. 2576,) which has then descended to *r*; the arc *e m s* being equal to the arc *i k q*. When the eccentric has reached the point *i'*, opposite to *i*, the port *b e* will be open to the extent of the lead *b h'*, equal to *c h*, and the piston will have completed its descent.

Steam continues to enter the port *b e* during the ascent of the piston, until the eccentric reaches the point *k'*, when the port *b e* will be reclosed, Fig. 2576, the direction of the slide's motion being downward, and the piston having ascended to *l'*. Exhaustion ceases from above the piston when the eccentric reaches the point *t*, the piston being then at *u*, and the slide again in the position Fig. 2575

When the eccentric reaches the point n', opposite to n, exhaustion commences below the piston, the slide being then in the position Fig. 2577, and the piston at o'. Finally, when the eccentric reaches the point q', and the crank the point s', opposite to s, steam begins to enter the port $c\,d$ for the return stroke, at the commencement of which the port $c\,d$ will be open to the extent of the lead $c\,h$; the crank and eccentric occupying their original positions $a\,c$ and $a\,i$.

2573. 2574. 2575. 2576. 2577.



It is here shown that four distinct circumstances result from the use of a slide having lap on both sides of the port, with lead, during a single stroke of the piston. These are—

First: The cutting off the steam, for the purpose of expansion.

Second: The cessation of exhaustion on the exhaustion side.

Third: The commencement of exhaustion on the steam side.

Fourth: The readmission of steam for the return stroke.

With regard to the first of these results, we found the steam port $c\,d$ closed, when the crank and eccentric had described the equal arcs $c\,m$ and $i\,d\,k$. Now, $c\,d$, the steam port, is the versed sine of $d\,k$; and $h\,d$, the steam port *minus the lead*, is the versed sine of $i\,d$. Hence,

Rule V.—To find the point of the stroke at which steam will be cut off:

Divide the width of the steam port, and also that width minus the lead, by half the slide's travel, and call the quotients versed sines. Find their corresponding arcs, and call them arc the first, and arc the second, respectively. Then, if the sum of those arcs be less than 90 degrees, multiply the versed sine of their sum by half the stroke, in inches, and the product will be the distance of the piston from the *commencement* of its stroke, when the steam is cut off.

If the sum of arcs the first and second exceed 90 degrees, subtract it from 180 degrees; and the versed sine of the difference, multiplied by half the stroke, equals the distance of the piston from the *end* of its stroke, when the steam is cut off.

Example 8.—The stroke of a piston is 60 inches; the width of steam port 3 inches; lap on the steam side $2\frac{1}{2}$ inches; lap on the exhaust side $\frac{1}{8}$th inch; and lead $\frac{1}{2}$ inch: required the point of the stroke at which steam will be cut off.

$$\text{Here } \frac{3}{3+2{\cdot}5} = {\cdot}5454 = \text{versed sine of } 62^\circ\ 58' \text{ (arc the first;)}$$

$$\text{and } \frac{3-{\cdot}5}{3+2{\cdot}5} = {\cdot}4545 = \text{versed sine of } 56^\circ\ 57' \text{ (arc the second.)}$$

Then $62^\circ\ 58' + 56^\circ\ 57' = 119^\circ\ 55'$; and $180^\circ - 119^\circ\ 55' = 60\ 5' =$ arc of versed sine, ·5012. $\cdot5012 \times 30 = 15{\cdot}036$ inches = distance of the piston from the *end* of its stroke when the steam is cut off.

Exhaustion was shown to cease, during the ascent of the piston, when the eccentric had reached the point t, and the crank the point x; the crank having described the arc $d\,k\,x$, equal to $i'\,c\,t$ described by the eccentric.

Now $i'\,c$ is equal to *arc the second*, (Rule V.;) and $c\,t$ is equal to 90 degrees minus $t\,t'$, or the arc of versed sine $e\,f$; and $e\,f$ is half the slide's travel minus the lap on the exhaust side. Hence,

To find the point of the stroke at which exhaustion ceases:

Divide half the slide's travel, minus the exhaustion lap, by half the travel, call the quotient versed sine, and add its corresponding arc, calling it arc the third, to arc the second. The versed sine of the difference between their sum and 180 degrees, multiplied by half the stroke, equals the distance of the piston from the end of its stroke when exhaustion ceases.

Example 9.—The several proportions being as in the preceding example.

$$\text{Here } 3 + 2{\cdot}5 = 5{\cdot}5 = \text{half the slide's travel;}$$

$$\text{and } \frac{5{\cdot}5 - {\cdot}125}{5{\cdot}5} = {\cdot}9772 = \text{versed sine of arc } 88^\circ\ 42' = \text{(arc the third.)}$$

Then $88^\circ\ 42' + 56^\circ\ 57'$ (arc the second) $= 145^\circ\ 39'$; and $180^\circ - 145^\circ\ 39' = 34^\circ\ 21' =$ arc of versed sine, ·1743. $\cdot1743 \times 30 = 5{\cdot}229$ inches = the distance of the piston from the end of its stroke when exhaustion ceases.

Exhaustion was shown to commence from above the piston when the crank and eccentric had described the equal arcs $c\,k'\,p$ and $i\,d\,n$.

Now $i\,d\,n$ is equal to 180 degrees minus $n\,i'$; $n\,i'$ is equal to $n'\,i$; and $n'\,d$ is equal to arc the third. Hence,

To find the distance of the piston from the end of its stroke when exhaustion commences:

Subtract arc the second from arc the third, and multiply the versed sine of their difference by half the stroke. The product will be the distance required.

Example 10.—The proportions being as in the two preceding examples.

Here $88^\circ\ 42' - 56^\circ\ 57' = 31^\circ\ 45' =$ arc of versed sine, ·1496; and $\cdot1496 \times 30 = 4{\cdot}488$ inches, the distance required.

Steam was found to be readmitted, for the return stroke, when the piston had reached the point r in its descent, the crank and eccentric having described the equal arcs $c\,k'\,s$ and $i\,d\,q$.

Now $i\,d\,q$ is equal to 180 degrees minus $q\,i'$; i' being diametrically opposed to i. And $q\,i'$ is equal to $i\,q'$, the difference between arcs the first and second. Hence,

To find the distance of the piston from the end of its stroke when steam is readmitted for the return stroke:

Multiply the versed sine of the difference between arcs the first and second by half the stroke, and the product will be the distance required.

Example 11.—The proportions being as before.

$$\text{Here } 62^\circ\ 58' - 56^\circ\ 57' = 6^\circ\ 1' = \text{arc of versed sine } {\cdot}0055.$$

$$\text{Then } {\cdot}0055 \times 30 = {\cdot}165 \text{ inches} = \text{the distance required.}$$

Rule VI.—To find the proportions of the steam lap and lead; the points of the stroke where steam is cut off, and readmitted for the return stroke, being known:

When the steam is cut off before half-stroke, divide the portion of the stroke performed by the piston by half the stroke, and call the quotient versed sine. Likewise, divide the distance of the piston from the end of its stroke when steam is readmitted for the return stroke, by half the stroke, and call that quotient versed sine. Find their respective arcs, and also the versed sines of half their sum and half their difference. The width of the steam port in inches, divided by the versed sine of half their sum, equals half the travel of the slide: and half the travel, minus the width of port, equals the lap. The difference of the two versed sines last found, multiplied by half the travel of the slide, equals the lead.

When the steam is to be cut off after half-stroke, divide the distance of the piston from the end of its stroke by half the stroke; call the quotient versed sine, and subtract its corresponding arc from 180 degrees. Divide the distance the piston has to move when the steam is admitted for the return stroke, by half the stroke; call the quotient versed sine, and find its corresponding arc. Then proceed with the two arcs thus found, as in the former case.

Example 12.—The stroke of a piston is 60 inches; the width of steam port 3 inches; distance of the piston from the end of its stroke when steam is cut off 15·036 inches; and when steam is admitted for the return stroke ·165 inches: required the lap and lead.

$$\text{Here } 15{\cdot}036 \div 30 = {\cdot}5012 = \text{versed sine of arc } 60^\circ\ 5';$$

$$\text{and } 180^\circ - 60^\circ\ 5' = 119^\circ\ 55'.$$

$$\text{Then } {\cdot}165 \div 30 = {\cdot}0055 = \text{versed sine of } 6^\circ\ 1'.$$

$$119^\circ\ 55' + 6^\circ\ 1' = 125^\circ\ 56'; \qquad 119^\circ\ 55' - 6^\circ\ 1' = 113^\circ\ 54'.$$

$$\frac{125^\circ\ 56'}{2} = 62^\circ\ 58' = \text{arc of versed sine } {\cdot}5454;$$

$$\frac{113^\circ\ 54'}{2} = 56^\circ\ 57' = \text{arc of versed sine } {\cdot}4545.$$

$$3 \div {\cdot}5454 = 5{\cdot}5 \text{ inches} = \text{half the slide's travel};$$

$$\text{and } 5{\cdot}5 - 3 = 2{\cdot}5 = \text{lap}.$$

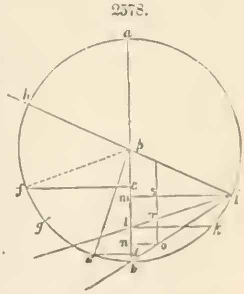
$${\cdot}5454 - {\cdot}4545 = {\cdot}0909; \text{ and } {\cdot}0909 \times 5{\cdot}5 = {\cdot}5 \text{ inches} = \text{lead}.$$

To find the lap and lead by construction.

The stroke of the piston; width of steam port; and distances of the piston from the end of its stroke when the steam is cut off, and when it is readmitted for the return stroke, being known:

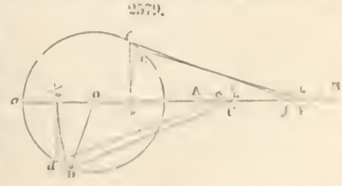
Let the circle, Fig. 2578, represent the crank's orbit, and its diameter *a b* the stroke of the piston, to some known scale. Make *a c* equal to the part of the stroke performed before the steam is cut off; and *b d* equal to the distance of the piston from the end of its stroke when steam is readmitted for the return stroke. Draw *d e* and *c f* at right angles to *a b*, and mark the point *g* at the distance *b e* from *f*. Bisect the arc *a g*, and from the point of bisection, *h*, draw the diameter *h i*. Make *i k* equal to *b e*; draw *i m* and *k l* at right angles to *a b*; and draw *i l* and *i b* indefinitely. From the point *m* set off *m n* equal to the width of steam port, full size; from *n* draw *n o* parallel to *i m*, and meeting *i b*, and also *o p* parallel to *a b*, and meeting *h i*; then will *s p* equal the lap, and *s r* the lead.

2578.



In all the foregoing cases, we have taken the versed sine of the arc described by the crank, from either extremity of the stroke, as the portion of the stroke performed by the piston; but, as has been already observed, the relative positions of the piston and crank depend upon the length of the connecting-rod, which will be seen by reference to Fig. 2579, where A B represents the stroke of the piston, C D the connecting-rod, and D O the crank. Now, by supposing *a d* to be the arc described by the crank when the piston has performed one-fourth of its stroke, and from the length of that arc, calculating the amount of lap required to cut off the steam at that part of the stroke, we appear to be in error—for, from the oblique action of the connecting-rod, the piston would have descended only to the point *c*. But the engine being double-acting, we have to take into consideration the position of the crank when the piston has performed one-fourth of its stroke in the opposite direction from the point B; and here we find, that by supposing the crank to have described the arc *b e*, (equal to *a d*,) instead of the true arc *b* E, we cause the steam to be cut off when the piston has reached the point *f*; and the distance B *f* being precisely as much more than B F as A *c* is less than A C, the seeming error is self-corrective.

2579.



A Table of Multipliers to find the Lap and Lead, when the Steam is to be cut off at ½ to ⅞ths of the Stroke.

The lap must be equal to the width of the steam port multiplied by col. 1.
The lead must be equal to the width of the steam port multiplied by col. 2.

Half-Stroke.		Five-Eighths of the Stroke.		Three-Fourths of the Stroke.		Seven-Eighths of the Stroke.		
1	2	1	2	1	2	1	2	The distance of the Piston from the end of its stroke when steam is readmitted for the return stroke being equal to half the stroke multiplied by
Lap	Lead	Lap	Lead	Lap	Lead	Lap	Lead	
2·41	·000	1·58	·000	1.000	·000	·540	·000	·00000
2·16	·145	1·41	·124	·893	·105	·477	·089	·00208
2·06	·198	1·35	·170	·851	·146	·450	·123	·00416
1·94	·268	1·27	·231	·795	·200	·413	·170	·00833
1·84	·318	1·21	·276	·754	·240	·385	·204	·01250
1·77	·358	1·16	·312	·723	·271	·363	·232	·01666
1·71	·391	1·12	·342	·691	·299	·344	·257	·02083
1·65	·420	1·08	·368	·668	·322	·327	·277	·02500
1·60	·444	1·05	·391	·644	·343	·313	·296	·02916
1·56	·467	1·02	·412	·623	·362	·298	·313	·03333
1·48	·505	·968	·449	·586	·396	·273	·343	·04166
1·41	·540	·921	·480	·554	·425	·251	·370	·05000
1·35	·570	·881	·508	·526	·451	·232	·393	·05833
1·30	·595	·844	·532	500	·473	·215	·414	·06666
1·25	·617	·810	·554	·476	·495	·198	·434	·07500
1·21	·638	·779	·572	·454	·514	·183	·452	·08333
1.17	·657	·751	·592	·434	·532	·160	·468	·09166
1·13	·674	·724	·607	·415	·548	·156	·483	·10000

Example of its application.—Stroke 36 inches; width of port 2 inches; steam to be cut off at half-stroke; distance of the piston from the end of its stroke when steam is readmitted for the return stroke, 1·5 inch.

$\frac{1·5}{18} = 0833.$ Find that number, or the one nearest to it, in the right hand, or last column, and take out the multipliers on the same line under the head Half-stroke.

Then $2 \times 1·21 = 2·42$ inches = the lap.

And $2 \times ·638 = 1·276$ inches = the lead.

LEAD—A well-known metal much used in the arts. Lead unites with most of the metals, has little elasticity, and is the softest of them all. Gold and silver are dissolved by it in a slight red heat, but when the heat is much increased the lead separates, and rises to the surface of the gold, combined with all heterogeneous matters; hence lead is made use of in the art of refining the precious metals. If lead be heated so as to boil and smoke, it soon dissolves pieces of copper thrown into it; the mixture, when cold, being brittle. The union of these two metals is remarkably slight, for upon exposing the mass to a heat no greater than that in which lead melts, the lead almost entirely runs off by itself.

Among the ores of lead some have a metallic aspect; are black in substance, as well as when pulverized; others have a stony appearance, and are variously colored, with usually a vitreous or greasy lustre. The specific gravity of the latter ores is always less than 5. The whole of them, excepting the chloride, become more or less speedily black, with sulphureted hydrogen or with hydrosulphurets; and are easily reduced to the metallic state upon charcoal, with a flux of carbonate of soda, after they have been properly roasted. They diffuse a whitish or yellowish powder over the charcoal, which, according to the manner in which the flame of the blowpipe is directed upon it, becomes yellow or red; thus indicating the two characteristic colors of the oxides of lead.

The lead ores most interesting to the arts are:

1. *Galena*, sulphuret of lead. This ore has the metallic lustre of lead, with a crystalline structure derivable from the cube. When heated cautiously at the blowpipe it is decomposed, the sulphur flies off, and the lead is left alone in fusion; but if the heat be continued, the colored surface of the charcoal indicates the conversion of the lead into its oxides. Galena is a compound of lead and sulphur, in equivalent proportions, and therefore consists, in 100 parts, of 86⅔ of metal, and 13⅓ of sulphur, with which numbers the analysis of the galena of Clausthal by Westrumb exactly agrees. Its specific gravity, when pure, is 7·56. Its color is blackish gray, without any shade of red, and its powder is black—characters which distinguish it from *blende*, or sulphuret of zinc.

2. The *seleniuret of lead* resembles galena, but its tint is bluer. Its chemical characters are the only ones which can be depended on for distinguishing it. At the blowpipe it exhales a very perceptible smell of putrid radishes. Nitric acid liberates the selenium. When heated in a tube, oxide of selenium of a carmine red rises along with selenic acid, white and deliquescent. The specific gravity of this ore varies from 6·8 to 7·69.

3. *Native minium* or *red lead* has an earthy aspect, of a lively and nearly pure red color, but sometimes inclining to orange. It occurs pulverulent, and also compact, with a fracture somewhat lamellar. When heated at the blowpipe upon charcoal, it is readily reduced to metallic lead. Its specific gravity varies from 4·6 to 8·9. This ore is rare.

4. *Plomb-gomme.*—This lead ore, as singular in appearance as in composition, is of a dirty brownish or orange-yellow, and occurs under the form of globular or gum-like concretions. It has also the lustre and translucency of gum, with somewhat of a pearly aspect at times. It is harder than fluor spar. It consists of oxide of lead, 40; alumina, 37; water, 18·8; foreign matters and loss, 4·06; in 100. Hitherto it has been found only at Huelgoet, near Poullaouen, in Brittany, covering with its tears, or small concretions, the ores of white lead and galena which compose the veins of that lead mine.

5. *White lead, carbonate of lead.*—This ore, in its purest state, is colorless and transparent, like glass, with an adamantine lustre. It may be recognized by the following characters:

Its specific gravity is from 6 to 6·7; it dissolves with more or less ease, and with effervescence, in nitric acid; becomes immediately black by the action of sulphureted hydrogen, and melts on charcoal before the blowpipe into a button of lead. According to Klaproth, the carbonate of Leadhills contains 82 parts of oxide of lead, and 16 of carbonic acid, in 98 parts. This mineral is tender, scarcely scratches calc-spar, and breaks easily, with a waved conchoidal fracture. It possesses the double refracting property in a very high degree; the double image being very visible on looking through the flat faces of the prismatic crystals. Its crystalline forms are very numerous, and are referrible to the octahedron, and the pyramidal prism.

6. *Vitreous lead*, or *sulphate of lead.*—This mineral closely resembles carbonate of lead; so that the external characters are inadequate to distinguish the two. But the following are sufficient. When pure, it has the same transparency and lustre. It does not effervesce with nitric acid; it is but feebly blackened by sulphureted hydrogen; it first decrepitates and then melts before the blowpipe into a transparent glass, which becomes milky as it cools. By the combined action of heat and charcoal, it passes first into a red pulverulent oxide, and then into metallic lead. It consists, according to Klaproth, of 71 oxide of lead, 25 sulphuric acid, 2 water, and 1 iron. That specimen was from Anglesea; the Wanlockhead mineral is free from iron. The prevailing form of crystallization is the rectangular octahedron, whose angles and edges are variously modified. The sulphato-carbonate, and sulphato tri-carbonate of lead, now called *Leadhillite*, are rare minerals which belong to this head.

7. *Phosphate of lead.*—This, like all the combinations of lead with an acid, exhibits no metallic lustre, but a variety of colors. Before the blowpipe upon charcoal, it melts into a globule externally crystalline, which, by a continuance of the heat, with the addition of iron and boracic acid, affords metallic lead. Its constituents are 80 oxide of lead, 18 phosphoric acid, and 1·6 muriatic acid, according to Klaproth's analysis of the mineral from Wanlockhead. The constant presence of muriatic acid in the various specimens examined is a remarkable circumstance. The crystalline forms are derived from an obtuse rhomboid. Phosphate of lead is a little harder than white lead; it is easily scratched, and its powder is always gray. Its specific gravity is 6·9. It has a vitreous lustre, somewhat adamantine. Its lamellar texture is not very distinct; its fracture is wavy, and it is easily frangible. The phosphoric and arsenic acids being, according to M. Mitscherlich, isomorphous bodies, may replace each other in chemical combinations in every proportion, so that the phosphate of lead may include any proportion, from the smallest fraction of arsenic acid to the smallest fraction of phosphoric acid, thus graduating indefinitely into arseniate of lead. The yellowish variety indicates, for the most part, the presence of arsenic acid.

8. *Muriate of lead. Horn-lead*, or *murio-carbonate.*—This ore has a pale yellow color, is reducible to metallic lead by the agency of soda, and is not altered by the hydrosulphurets. At the blowpipe it melts first into a pale yellow transparent globule, with salt of phosphorus and oxide of copper; and it manifests the presence of muriatic acid by a bluish flame. It is fragile, tender, softer than carbonate of lead, and is sometimes almost colorless, with an adamantine lustre. Specific gravity, 606. Its constituents, according to Berzelius, are lead, 25·84; oxide of lead, 57·07; carbonate of lead, 6·25; chlorine, 8·84; silica, 1·46; water, 0·54; in 100 parts. The carbonate is an accidental ingredient, not being in equivalent proportion. Klaproth found chlorine, 13·67; lead, 39·98; oxide of lead, 22·57; carbonate of lead, 23·78.

9. *Arseniate of lead.*—Its color of a pretty pure yellow, bordering slightly on the greenish, and its property of exhaling by the joint action of fire and charcoal a very distinct arsenical odor, are the only characters which distinguish this ore from the phosphate of lead. The form of the arseniate of lead, when it is crystallized, is a prism with six faces, of the same dimensions as that of phosphate of lead. When pure, it is reducible upon charcoal, before the blowpipe, into metallic lead, with the copious exhalation of arsenical fumes; but only in part, and leaving a crystalline globule, when it contains any phosphate of lead. The arseniate of lead is tender, friable, sometimes even pulverulent, and of specific gravity 5·04. That of Johann-Georgenstadt consists, according to Rose, of oxide of lead, 77·5; arsenic acid, 12·5; phosphoric acid, 7·5, and muriatic acid, 1·5.

10. *Red lead*, or *chromate of lead.*—This mineral is too rare to require consideration in the present work.

11. *Plomb vauquelinite. Chromate of lead and copper.*

12. *Yellow lead. Molybdate of lead.*

13. *Tungstate of lead.*

Having thus enumerated the several species of lead ore, we may remark that galena is the only one which occurs in sufficiently great masses to become the object of mining and metallurgy. This mineral is found in small quantity among the crystalline primitive rocks, as granite. It is, however, among the oldest talc-schists and clay slates that it usually occurs.

Treatment of the ores of lead.—The mechanical operations performed upon the lead ores, to bring them to the degree of purity necessary for their metallurgic treatment, may be divided into three classes, whose objects are:

1. *The sorting and cleansing of the ores;*
2. *The grinding;*
3. *The washing, properly so called.*

The apparatus subservient to the first objects are sieves, running buddles, and gratings. The large sieves employed for sorting the ore at the mouth of the mine, into coarse and fine pieces, is a wire gauze of iron; its meshes are square, and an inch long in each side. There is a lighter sieve of wire gauze, similar to the preceding, for washing the mud from the ore, by agitating the fragments in a tub filled with water. But instead of using this sieve, the pieces of ore are sometimes merely stirred about with a shovel, in a trough filled with water.

The method of sorting and cleansing the ore consists in using a plane surface made of slabs or planks, very slightly inclined forwards, and provided behind and on the sides with upright ledges, the back one having a notch to admit a stream of water. The ore is merely stirred about with a shovel, and exposed on the slope to the stream. For this apparatus, formerly the only one used, the following has been substituted, called the *grate*. It is a *grid*, composed of square bars of iron, an inch thick, by from 24 to 32 inches long, placed horizontally and parallelly to each other, an inch apart. There is a wooden canal above the grate, which conducts a stream of water over its middle; and an inclined plane is set beneath it, which leads to a hemispherical basin, about 24 inches in diameter, for collecting the metallic powder washed out of the ore.

The apparatus subservient to grinding the ore are:

1. The beater, formed of a cast-iron plate, 3 inches square, with a socket in its upper surface, for receiving a wooden handle. In some localities crushing cylinders have been substituted for the beater

At the mines, the *knocker's* workshop, or *striking floor*, is provided either with a strong stool, or a wall 3 feet high, beyond which there is a flat area 4 feet broad, and a little raised behind. On this area, bounded, except in front, by small walls, the ore to be bruised is placed. On the stool, or wall, a very hard stone slab, or cast-iron plate is laid, 7 feet long, 7 inches broad, and $1\frac{1}{2}$ inches thick, called a *knok-stone*. The workmen, seated before it, break the pieces of mixed ore with the beater.

Crushing machines are in general use in England, to break the mingled ores, which they perform with great economy of time and labor. They have been employed there for nearly forty years.

This machine is composed of one pair of fluted cylinders, and of two pairs of smooth cylinders, which serve altogether for crushing the ore. The two cylinders of each of the three pairs turn simultaneously in an inverse direction, by means of two toothed-wheels upon the shaft of every cylinder, which work by pairs in one another. The motion is given by a single water-wheel. One of the fluted cylinders is placed in the prolongation of the shaft of this wheel, which carries besides a cast-iron toothed-wheel, geared with the toothed-wheels fixed upon the ends of two of the smooth cylinders. Above the fluted cylinders, there is a hopper, which discharges down between them the ore brought forwards by the wagons. These wagons advance upon a railway, stop above the hopper, and empty their contents into it through a trap-hole, which opens outwardly in the middle of their bottom. Below the hopper there is a small bucket called a shoe, into which the ore is shaken down, and which throws it without ceasing upon the cylinders. The shoe is so regulated that too much ore can never fall upon the cylinders, and obstruct their movement. A small stream of water is likewise led into the shoe, which spreads over the cylinders, and prevents them from growing hot. The ore, after passing between the fluted rollers, falls upon inclined planes, which turn it over to one or other of the pairs of smooth rolls.

These are the essential parts of this machine; they are made of iron, and the smooth ones are case-hardened, or *chilled*, by being cast in iron moulds. The gudgeons of both kinds move in brass brushes fixed upon iron supports made fast by bolts to the strong wood-work base of the whole machine. Each of the horizontal bars has an oblong slot, at one of whose ends is solidly fixed one of the plummer-blocks or bearers of one of the cylinders, and in the rest of the slot the plummer-block of the other cylinder slides; a construction which permits the two cylinders to come into contact, or to recede to such a distance from each other as circumstances may require. The movable cylinder is approximated to the fixed one by means of iron levers, which carry at their ends weights, and rest upon wedges susceptible of adjustment. These wedges press the iron bar, and make it approach the movable cylinder by advancing the plummer-block which supports its axis. When matters are so arranged, should a very large or hard piece present itself to one of the pairs of cylinders, one of the rollers would move away and let the piece pass without doing injury to the mechanism.

Besides the three pairs of cylinders which constitute essentially each crushing machine, there is sometimes a fourth, which serves to crush the ore when not in large fragments.

The *stamp-mill* is employed in concurrence with the crushing cylinders. It serves particularly to pulverize those ores whose gangue is too hard to yield readily to the rollers, and also those which being already pulverized to a certain degree, require to be ground still more finely. (See Stampers.)

The sifting meshes of the sieve are made of strong iron wire, three-eighths of an inch square. This sieve is suspended at the extremity of a forked lever, or brake, turning upon an axis by means of two upright arms about 5 feet long, which are pierced with holes for connecting them with bolts or pins, both to the sieve-frame and to the ends of the two branches of the lever. These two arms are made of wrought iron, but the lever is made of wood, as it receives the jolt. Each jolt not only makes the fine parts pass through the meshes, but changes the relative position of those which remain on the wires, bringing the purer and heavier pieces eventually to the bottom. The mingled fragments of galena, and the stony substances lie above them; while the poor and light pieces are at top. These are first scraped off, next the mixed lumps, and lastly the pure ore, which is carried to the *heap*.

The poor ore is carried to a crushing machine, where it is bruised between two cylinders appropriated to this purpose; after which it is sifted afresh.

Washing apparatus.—For washing the ore after sifting it, the machine already described is employed

Smelting of lead ores.—The lead ores of England were anciently smelted in very rude furnaces, or *boles*, urged by the natural force of the wind, and were therefore placed on the summits or western slopes of the highest hills. More recently these furnaces were replaced by blast hearths, resembling smiths' forges, but larger, and were blown by strong bellows, moved by men or water-wheels. The principal operation of smelting is at present always executed there in *reverberatory furnaces*, and in furnaces similar to those known in France by the name of Scotch furnaces

The reverberatory furnaces called cupola are now exclusively used in Derbyshire for the smelting of lead ores. In the works where the construction of these furnaces is most improved, they are interiorly 8 feet long by 6 wide in the middle, and 2 feet high at the centre. The fire, placed at one of the extremities, is separated from the body of the furnace by a body of masonry, called the *fire-bridge*, which is two feet thick, leaving only from 14 to 18 inches between its upper surface and the vault. From this, the highest point, the vault gradually sinks towards the further end, where it stands only 6 inches above the sole. At this extremity of the furnace, there are two openings separated by a triangular prism of *fire-stone*, which lead to a flue, a foot and a half wide, and 10 feet long, which is recurved towards the top, and runs into an upright chimney 55 feet high. The above flue is covered with stone slabs, carefully jointed with fire-clay, which may be removed when the deposit formed under them (which is apt to melt) requires to be cleaned out. One of the sides of the furnace is called the laborers' side. It has a door for throwing coal upon the fire-grate, besides three small apertures each about 6 inches square. These are closed with movable plates of cast-iron, which are taken off when the working requires a freer circulation of air, or for the stirring up of the materials upon the hearth. On the opposite side, called the working side, there are five apertures; namely, three equal and opposite to those just described, shutting in like manner with cast-iron plates, and beneath them two other openings, one of which is for running out the lead, and another for the scoriæ. The ash-pit is also on this side, covered with a little water, and so disposed as that the grate-bars may be easily cleared from the cinder slag.

The hearth of the furnace is composed of the reverberatory furnace slags, to which a proper shape has been given by beating them with a strong iron rake, before their entire solidification. On the laborers' side, this hearth rises nearly to the surface of the three openings, and falls towards the working side, so as to be 18 inches below the middle aperture. In this point, the lowest of the furnace, there is a tap-hole, through which the lead is run off into a large iron boiler, (lea-pan,) placed in a recess left outside in the masonry. From that lowest point, the sole gradually rises in all directions, forming thus an inside basin, into which the lead runs down as it is melted. At the usual level of the metal bath, there is on the working side, at the end furthest from the fire, an aperture for letting off the slag.

In the middle of the arched roof there is a small aperture, called the *crown-hole*, which is covered up during the working with a thick cast-iron plate. Above this aperture a large wooden or iron hopper stands, leading beneath into an iron cylinder, through which the contents of the hopper may fall into the furnace when a trap or valve is opened.

Roasting.—The ordinary charge of ore for one smelting operation is 20 cwts., and it is introduced through the hopper. An assistant placed at the back doors spreads it equally over the whole hearth with a rake; the furnace being meanwhile heated only with the declining fire of the preceding operation. No regular fire is made during the first two hours, but a gentle heat merely is kept up by throwing one or two shovelfuls of small coal upon the grate from time to time. All the doors are closed, and the register plate of the chimney is lowered.

The outer basin in front of the furnace is at this time filled with the lead derived from a former process, the metal being covered with slags. A rectangular slit above the tap-hole is left open, and remains so during the whole time of the operation, unless the lead should rise in the interior basin above the level of that orifice; in which case a little mound must be raised before it.

The two doors in front furthest from the fire being opened, the head smelter throws in through them, upon the sole of the furnace, the slags swimming upon the bath of lead, and a little while afterwards he opens the tap-hole, and runs off the metallic lead reduced from these slags. At the same time his assistant turns over the ore through the back doors. These being again closed, while the above two front doors are open, the smelter throws a shovelful of small coal or coke cinder upon the lead-bath, and works the whole together, turning over the ore with the paddle or iron oar. About three-quarters of an hour after the commencement of the operation, he throws back upon the sole of the hearth the fresh slags which then float upon the bath of the outer basin, and which are mixed with coaly matter. He next turns over these slags, as well as the ore, with the paddle, and shuts all the doors. At this time the smelter runs off the lead into the pig-moulds.

The assistant now turns over the ore once more through the back doors. A little more than an hour after the operation began, a quantity of lead, proceeding from the slag last remelted, is run off by the tap; being usually in such quantity as to fill one-half of the outer basin. Both the workmen then turn over the ore with the paddles, at the several doors of the furnace. Its interior is at this time of a dull red heat: the roasting being carried on rather by the combustion of the sulphurous ingredients, than by the action of the small quantity of coal in the grate. The smelter, after shutting the front doors, with the exception of that next the fire-bridge, lifts off the fresh slags lying upon the surface of the outside bath, drains them, and throws them back into the furnace.

An hour and a half after the commencement, the lead begins to ooze out in small quantities from the ore; but little should be suffered to flow before two hours have expired. About this time the two workmen open all the doors, and turn over the ore, each at his own side of the furnace. An hour and three-quarters after the beginning, there are few vapors in the furnace, its temperature being very moderate. No more lead is then seen to flow upon the sloping hearth. A little coal being thrown into the grate to raise the heat slightly, the workmen turn over the ore, and then close all the doors.

At the end of two hours, the *first fire* or roasting being completed, and the doors shut, the register is to be lifted a little, and coal thrown upon the grate to give the *second fire*, which lasts during 25 minutes. When the doors are now opened the inside of the furnace is of a pretty vivid red, and the lead flows down from every side towards the inner basin. The smelter, with his rake or paddle, pushes the slags upon that basin back towards the upper part of the sole, and his assistant spreads them uniformly over the surface through the back doors. The smelter next throws in, by his middle door, a few shovelfuls of quick-lime upon the lead-bath. The assistant meanwhile, for a quarter of an hour, works the ore and the slags together through the three back doors, and then spreads them out, while the smelter pushes the slags from the surface of the inner basin back to the upper parts of the sole. The doors being now left open for a little, while the interior remains in repose, the metallic lead, which had been pushed back with the slags, flows down into the basin. This occasional *cooling* of the furnace is thought to be necessary for the better separation of the products, especially of the slags, from the lead-bath.

In a short time the workmen resume their rakes, and turn over the slags along with the ore. Three hours after the commencement, a little more fuel is put into the grate, merely to keep up a moderate heat of the furnace during the paddling. After three hours and ten minutes, the grate being charged with fuel for the *third fire*, the register is completely opened, the doors are all shut, and the furnace is left in this state for three-quarters of an hour. In nearly four hours from the commencement, all the doors being opened, the assistant levels the surfaces with his rake, in order to favor the descent of any drops of lead; and then spreads the slags, which are pushed back towards him by the smelter. The latter now throws in a fresh quantity of lime, with the view, not merely of covering the lead-bath and preventing its oxydizement, but of rendering the slags less fluid.

Ten minutes after the third fire is completed, the smelter puts a new charge of fuel in the grate, and shuts the doors of the furnace to give it the *fourth fire.* In four hours and forty minutes from the commencement, this fire being finished, the doors are opened, the smelter pierces the tap-hole to discharge the lead into the outer basin, and throws some quick-lime upon the slags in the inner basin. He then pushes the slags thus *dried up* towards the upper part of the hearth, and his assistant rakes them out by the back doors.

The whole operation of a *smelting shift* takes about four hours and a half, or at most five hours, in which four periods may be distinguished.

1. The *first fire* for roasting the ores, requires very moderate firing, and lasts two hours.

2. The *second fire*, or the smelting, requires a higher heat, with shut doors; at the end the slags are *dried up* with lime, and the furnace is also allowed to cool a little.

3, 4. The last two periods, or the *third* and *fourth fires*, are likewise two smeltings or foundings, and differ from the first only in requiring a higher temperature. The heat is greatest in the last. The form and dimensions of the furnace are calculated to cause a uniform distribution of heat over the whole surface of the hearth. See article METALLURGY.

The lead is brought from the smelting works to any place where it is to be manufactured in the form of "pigs," each of which is an oblong mass, about three feet long, six inches wide, and weighing about one hundred weight and a half. As for the philosophy of the word "pig," applied to the masses of lead, we may remark that it forms another curious instance of the phraseology used in manufacture. It appears that in the iron-manufacture, when the metal flows from the furnace in which it has been reduced from the ore, it passes into a large trough excavated in sand, and from thence into smaller lateral channels on each side. This arrangement has been suggestive of a sort of simile: for the larger trough is called by the workmen the "sow," and the smaller the "pigs," who suck the metal from the "sow;" hence proceeded the names of "sow-metal" and "pig-metal;" and hence, in all probability, the name of "pig" is applied to the saleable masses both of iron and of lead.

The two principal articles into which lead is manufactured are *sheet-lead* and *water-pipes;* or at least they are the only two which need here be noticed, since the comparatively low temperature at which the metal fuses, and the ease with which it is beaten into various forms, enable the plumber to modify it in various ways. The sheet-lead here spoken of is that with which roofs and terraces are covered, and cisterns lined. It is sometimes made, and used formerly to be wholly made, by pouring the melted metal on a flat surface of sand, in a stratum of any required thickness; but the more modern method is that of rolling, or "milling," which we proceed to describe.

A furnace is provided consisting of a hemispherical melting-pot, four or five feet in diameter, and nearly as much in depth, heated by a fire beneath, and covered with an inclosed cap or chimney reaching above the roof of the building, for the purpose of conveying away the deleterious gases engendered during the melting of lead. Into this melting-pot is put about six tons (thirteen thousand pounds) of lead, new and old, which remains there till thoroughly melted. During this time all the impurities, being lighter than the metal, rise to the surface. Immediately adjoining the furnace is a cast-iron frame, called the "mould," being a flat vessel about six or seven feet square, and six inches deep. The bottom of this mould is also of iron, and the melted metal is allowed to flow into it from an opened valve near the bottom of the melting-pot. A shoot or trough conveys the metal from the furnace to the mould. The glistening liquid mass soon flows out, to the weight of about ten or eleven thousand pounds, the dross and impurities being for the most part left behind in the melting-pot. As, however, some impurities or oxidized portions enter the mould, a subsequent removal becomes necessary; and this is effected by drawing the edge of a board carefully over the surface of the hot and liquid metal, the board urging before it all the floating impurities, and leaving a surface very silvery and clear.

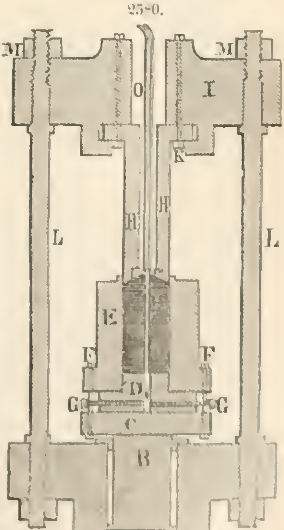
After some hours the mass of lead, technically called a "plate," is lifted out of the mould by a powerful crane, and placed upon the machine where it is to be rolled into the form of sheets. This machine is very peculiar in its action. It consists of a long frame or bench, about a yard in height, seven or eight feet wide, and probably seventy feet in length. At intervals of every foot or two are transverse rollers, all placed on the same level, so that a heavy body may be rolled from one end of the frame to the other with great facility. About midway along the frame is the milling or rolling machine, consisting mainly of two ponderous rollers, between which the lead is passed: these are made of iron, the upper one being fifteen or sixteen inches in diameter, with a weight of three tons, the under one being the same. The two rollers are placed at any required distance apart, the one above the other, and are also made to revolve in either direction. These being the mechanical arrangements, the process of milling proceeds thus: The plate of lead is brought between the rollers, which are opened so as only to receive the lead by compressing it; and the rollers being made to rotate, the plate is drawn in between them. This process is repeated over and over again, the plate passing first from right to left, and then from left to right, the opening between the rollers being gradually reduced by means of an index and graduated dial-plate. The small wooden rollers facilitate the motion of the elongated lead to and fro; and when the length, obtained by reducing the thickness, has become inconveniently great, the piece is cut into two, and each half milled in a similar manner. Thus the lead continues to pass between the rollers to the number of seven or eight hundred times, having its thickness diminished and its length increased by regular degrees. From 300 to 400 feet in length, with a width of seven or eight, is the average quantity of roofing-lead produced by these means from one of the plates. The lead is then coiled up in a roll, and in that form is sold to the plumber, who adapts it to his various purposes.

The manufacture of lead-pipe, like that of sheet-lead, combines the processes both of casting and elongating, or drawing. Whatever be the required diameter and thickness of the pipe, it is first cast in a short piece of great thickness, and then elongated, by which the thickness becomes reduced. The diameter of the cast piece is, internally, the same as that of the required pipe, the external diameter being that which undergoes reduction. The first process is, therefore, to cast the short pieces of pipe. These moulds measure from two to four feet in height, and are fitted for casting pipe whose diameter varies externally from two to six inches, and internally from half an inch to four inches. The mould consists of two semi-cylindrical halves, which, on being brought together, form the external contour of the pipe, while a spindle or steel core, running down the centre of the hollow cavity, regulates the internal diameter of the pipe.

A small melting-furnace is appropriated for the pipe-casting, the lead being carefully skimmed from dross while melting; and when the fusion is complete the melted metal is poured into the mould, the upper end of which is open and the lower end closed. The quantity of lead required for each mould varies from about 24 to 200 pounds, according to the thickness of the pipe. The metal being solidified and sufficiently cool for handling, the two halves of the mould are drawn asunder and the lead removed, the technical name of the "plug" being applied to the short thick piece of pipe thus produced.

Next ensues the very singular method whereby the plug is elongated to the required dimensions. The "drawing-bench" is a frame about thirty feet long and three in height, having in the middle of its length mechanism for producing the elongation. An endless chain is kept in constant motion round two wheels or rollers, one near the end and the other near the middle of the draw-bench, insomuch that a hook or a clasp connected with one of the links would be forcibly drawn along the bench. A mandril, or steel rod, corresponding in size with the internal diameter of the pipe, is inserted into one of the short pipes or plugs, and then so connected with the endless chain as to be drawn along the bench; but in its progress the pipe has to pass through a hole in a steel plate, or die, rather smaller than the diameter of the lead itself, by which its external diameter becomes somewhat reduced and its length increased. Again and again is the pipe, with its contained mandril, drawn along the frame, the die being exchanged after each drawing and replaced by one of smaller diameter. In producing a two-inch pipe no fewer than sixteen dies are employed, the diameters of which descend in a regular series. The hole through the die is conical, that is, larger on one side of the die than on the other, and the lead enters the hole at the widest part, whereby a process of compression is undergone; but at a certain point in the operations a "cutting-die" is introduced, that is, one wherein the lead is at once exposed to a cutting edge, the result of which is that a thin film is cut or scraped from the whole surface of the pipe. By the time that all this routine is undergone the metal has become more dense and compact, the temperature so high as scarcely to be bearable by the hand, the length greatly increased, and the external diameter proportionably diminished. After this the elongated pipe is removed from the mandril, and is then ready for disposal to the plumber.

2580.



Lead-pipe is also manufactured by forcing it through dies, and the process, as improved by Mr. Cornell, of New York, is thus described by him in the specifications of his patent:

My invention consists of certain improvements in the arrangement and combination of the machinery or apparatus heretofore used for similar purposes, and in the construction and application of certain additional machinery or apparatus, and the combination thereof with the other apparatus, as herein described.

My machine is applicable to the manufacture of pipes and tubes of lead, and such other metals and their alloys as are capable of being squeezed or forced by means of great pressure from a cylinder or receiver through or between apertures, dies, cores, or mandrils, when in a solid or semi-fluid state, and is mainly referable in its general construction and purposes to the machine patented by Thomas Burr in Great Britain, and described in the first volume of the first series of the "London Journal of Arts and Sciences."

In my machine I use the hydraulic press, the lead cylinder or receiver, the columns or pillars connecting the hydraulic press with the lead cylinder, the movable ram for pressing the piston upon the lead in the cylinder or receiver, the dies and cores to give the pipes the required form, and calibre, and dimensions, and such other parts of the old machines as may be necessary, substantially similar to the machine of the said Thomas Burr.

Fig. 2580 represents my invention, showing how, by different arrangements of the machinery, the power may be applied to the lead cylinder, which in this case is movable, while the piston is stationary.

This figure is a sectional view of the hydraulic press and pipe machinery in which the long movable core is used. In the figure, A is the hydraulic cylinder, and B the ram rising therefrom. A cross-head is attached to the hydraulic cylinder in the usual manner, and is connected with the upper cross-head I, by means of the rods L L, which are secured at the top and bottom by the nuts M M M M, turned on the screws at the ends of the rods. On the top of the ram a head-block C is placed, and there secured. A foot-block D is attached to the bottom of the lead cylinder E, and the head-block, the foot-block, and the lead cylinder are secured firmly together by the bolts F F. By this arrangement the lead cylinder will be moved upwards and downwards by the ram of the hydraulic press. To the upper cross-head I the hollow piston H is attached, and secured by means of the bolts K K having screws and nuts at the ends. The die P is placed in the lower end of the piston, which is hollowed throughout, and communicates with the aperture O made through the upper cross head. The long movable core N which is used in this case, is firmly secured to the head-block of the ram, extending upwards through the centre of the lead cylinder, and a short distance above it, to be inserted through the die in the end of the piston. The position of the core is regulated by means of the set-screws G G, four in number, which move the core laterally, and set it centrally in the die. When all the parts are thus arranged, the lead cylinder is raised up to the lower end of the piston, the end of the core passing through the die, and being there adjusted centrally by the set-screws, the lead cylinder is charged, and the power of the press applied.

The ram is forced upwards, carrying the lead cylinder before it, which passes over the piston. The pipe is formed at the point of pressure, as before, passing through the hollow piston through the aperture O, and out at the top of the machine. The core in this arrangement moves upwards with the lead cylinder through the die and the hollow piston. A strong metallic ring is placed and firmly secured on the lower cross-head, encircling the ram B, to act as a guide for the ram, keeping it steady and giving it the precise direction.

LENS. In optics, a piece of glass, or other transparent substance, having its two surfaces so formed that the rays of light have their direction changed by passing through it; so that they either converge, tending to a point beyond the lens, or diverge, as if they proceeded from a point before the lens; or become parallel, after converging or diverging.

A double convex lens, Fig. 2581, is bounded by two convex spherical surfaces, whose centres are on opposite sides of the lens. It is equally convex when the radii of both surfaces (that is, the distances from the centres to the circumferences of the circle they belong to) are equal, and unequally convex when their radii or distances are unequal.

A plano-convex lens, Fig. 2582, is bounded by a plane surface on one side, and by a convex one on the other.

A double concave lens, Fig. 2583, is bounded by two concave spherical surfaces whose centres are on opposite sides of the lens.

A plano-concave lens, Fig. 2584, is bounded by a plane surface on one side, and a concave one on the other.

A meniscus, Fig. 2585, is bounded by a concave and a convex spherical surface; and these two surfaces meet, if continued.

2581.

2582.

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2584.

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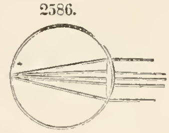
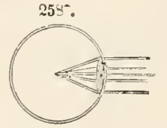
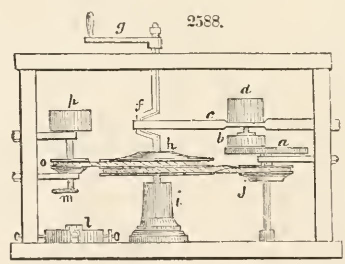
2586.



2587.



2588.



The focal distance, or distance of the focus from the surface of the lens, depends both upon the form of the lens and of the refractive power of the substance of which it is made; in a glass lens, both sides of which are equally convex, the focus is situated nearly at the centre of the sphere of which the surface of the lens forms a portion; it is at the distance, therefore, of the radius of the sphere. Fig. 2587.

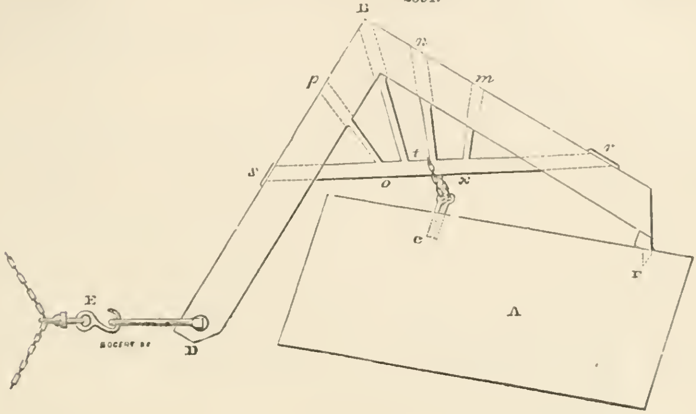
Plano-convex lens and rays converging.—Fig. 2586. Lenses that have one side flat and the other convex, (plano-convex,) have their focus at the distance of the diameter of a sphere, of which the convex surface of the lens forms a portion, as represented in the figure.

According to some opticians, the greatest diameter of a lens is half an inch; if it exceed that thickness they do not call it a lens, but a lenticular glass. Lenses are made either by blowing or grinding. Blown lenses are small globules of glass melted in the flame of a lamp; ground lenses are reduced by grinding and polishing. A variety of simple apparatus is employed in the processes of grinding and polishing lenses, among which the one shown in Fig. 2588 is much used. *a* shows the edge of a circular lap or slab, used for grinding flat glasses upon; *b* a circular tool or block, upon the under surface of which the glasses to be ground are cemented; *c* is a reciprocating bar; *d* a box containing any weighty matter; *e* a long mortised aperture in the frame, through which the bar *c* freely works; *f* a crank; *g* a winch; *h* a double pulley-wheel, the axis of which rests in the block *i*; *j* a single pulley-wheel. Now on turning the crank by the winch *g*, the bar *c* gives to *b* an eccentric motion; the attrition of *b* on the surface of the lap *a* being increased or diminished at pleasure by increasing or diminishing the load in the box *d*. It should be noticed that the cord which passes round the pulley *h* is crossed previous to its embracing the periphery of the pulley *i*, consequently a motion is given to the lap *a* the reverse of that given to *b*, which is considered to produce the best effect of grinding. The apparatus described is devoted to the producing of plane surfaces to optical glasses; but the apparatus on the other side of the machine is, at the same time, by similar arrangements, employed in grinding concave or convex surfaces. For this purpose a variety of laps and other tools are so made as to fit on the bed *l*, which bed is adjustable by four equidistant screws. The pulley *o* is driven by another band on the pulley *h*, and the required pressure given by another loaded box *p*. The several tools used are screwed on at *m*, and are adapted for ready changing, that the operations may be performed with celerity.

LEVER. One of the MECHANICAL POWERS, which see.

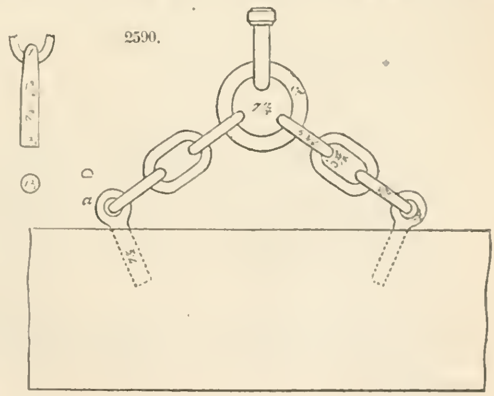
LEWIS. When stone are to be laid into masonry, that are too heavy for the workmen to handle

2591.



without resort to machinery, it becomes necessary to provide means for suspending them so as to leave the lower surface and two of the joints unobstructed. This is usually done by drilling a hole in the upper surface, in which is placed an iron bolt secured by a key. The bolt has an eye or ring, by which it may be attached to the machine which is to suspend the stone. This bolt and key is called a "Lewis," from the name of the inventor.

2590.

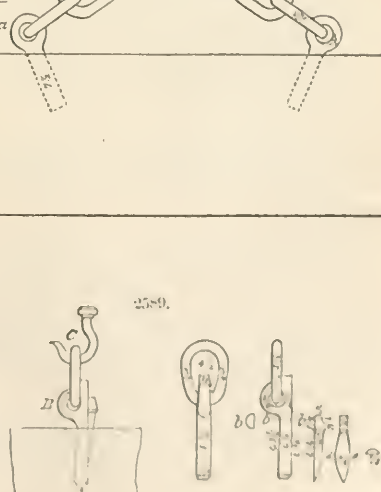


The single lewis is in the form of Fig. 2589, and is generally used to suspend stone not exceeding 500 pounds weight.

The double, or chain lewis, is in the form of Fig. 2590. This was the form of the lewis which was chiefly used on the U. S. Dry Dock at Brooklyn, for suspending stone from 500 pounds to 10,000 pounds; and stone of twice this weight were suspended with two lewises of this description.

The floor of this dock is an inverted arch, and the sides are made up of alter courses, the top surface of which show as coping stone. To suspend stone of this description, as well as steps and coping, without marring the upper surface, has been long a desideratum.

2589.



In Fig. 2591 is exhibited a drawing of Lidgewood's lever lewis, by means of which all this description of stone were set on the dock—some of them weighing seven tons.

The mitre sills on the same work were enormously heavy: the centre stone weighed nearly twenty-five tons, and two others over twenty tons, and several others nearly as large. These stone were suspended by a frame, as shown in Fig. 2591.

LIGHT. The cause of those sensations which we refer to the eyes, or that which produces the sense of seeing. The phenomena of light and vision have always been regarded as one of the most interesting branches of natural science; though it is only since the days of Newton that they have been examined with such care as to afford grounds for any safe speculation respecting the nature of light, and the mode of its propagation through space.

Experiments of the simplest and most familiar kind suffice to show that light is propagated from luminous bodies in all directions. Provided nothing intervenes to intercept the light, they are seen in all situations of the eye.

Another property of light is, that it requires time for its propagation. The velocity with which it passes from one point to another is, however, so great, that, with respect to any terrestrial distances, the passage may be considered as instantaneous. But astronomy furnishes the means, not only of detecting its propagation, but of measuring its velocity with great precision. The eclipses and emersions of Jupiter's satellites become visible about 16 min. 26 sec. earlier when the earth is at its least distance from Jupiter, than when it is at its greatest. Light, therefore, occupies above a quarter of an hour in passing through the diameter of the earth's orbit. Now the sun's distance from the earth being nearly 95,000,000 of miles, it follows that light must travel through space with the prodigious, though finite, velocity of 192,500, or nearly 200,000 miles in a second of time, and consequently would pass round the earth in the eighth part of a second. Astounding as this conclusion is, no result of science rests on more certain evidence. It is also proved, by the phenomena of aberration, that the light of the sun, planets, and all the fixed stars, travels with one and the same velocity.

Theories of light.—Two different theories have long divided the opinion of philosophers respecting the nature and propagation of light. One of these consists in supposing it to be composed of particles of excessive minuteness, projected from the luminous body with a velocity equal to nearly 200,000 miles in a second. This hypothesis was adopted by Newton, and, till recently, has been acquiesced in by the greater number of writers on optics. The other hypothesis supposes light to be produced by the vibrations or undulations of an ethereal fluid of great elasticity, which pervades all space and penetrates all substances, and to which the luminous body gives an impulse which is propagated with inconceivable rapidity, in spherical superficies, by a sort of tremor or undulation, as sound is conveyed through the atmosphere, or a wave along the surface of water. Both of these hypotheses are rendered probable by the great number of phenomena of which they afford a mechanical explanation; but they are both, also, attended with very great difficulties. Other theories have also been proposed; but they have not met with such general attention from philosophers as to make it necessary to explain them in this place.

Corpuscular theory of light.—Sir John Herschel, in his admirable *Essay on Light*, in the *Encyclopædia Metropolitana*, states the principles of the Newtonian or Corpuscular theory as follows:

1. "That light consists of particles of matter possessed of inertia, and endowed with attractive and repulsive forces, and projected or emitted from all luminous bodies with nearly the same velocity, about 200,000 miles per second.

2. That these particles differ from each other by the intensity of the attractive and repulsive forces which reside in them; and in their relations to the material world; and also in their actual masses, or inertia.

3. That these particles, impinging on the retina, stimulate and excite vision: the particles whose inertia is greatest, producing the sensation of red; those of the least inertia, of violet; and those in which it is intermediate, the intermediate colors.

4. That the molecules of material bodies and those of light exert a mutual action on each other, which consists in attraction and repulsion, according to some law or function of the distance between them; that this law is such as to admit, perhaps, of several alternations or changes from repulsive to attractive force; but that when the distance is below a certain very small limit it is always attractive up to actual contact; and that beyond this limit resides at least one sphere of repulsion. This repulsive force is that which causes the reflection of light at the external surfaces of dense media; and the interior attraction that which produces the refraction and interior reflection of light.

5. That these forces have different absolute values or intensities, not only for all different material bodies, but for every different species of the luminous molecules, being of a nature analogous to chemical affinities or electric attractions; and that hence arises the different refrangibilities of the rays of light.

6. That the motion of a particle of light, under the influence of these forces and its own velocity, is regulated by the same mechanical laws which govern the motions of ordinary matter; and that therefore each particle describes a trajectory, capable of strict calculation as soon as the forces which act on it are assigned.

7. That the distance between the molecules of material bodies is exceedingly small in comparison with the extent of their spheres of attraction and repulsion on the particles of light.

8. That the forces which produce the reflection and refraction of light are, nevertheless, absolutely insensible at all measurable or appreciable distances from the molecules which exert them.

9. That every luminous molecule, during the whole of its progress through space, is continually passing through certain periodically recurring states, called by Newton fits of easy reflection and easy transmission, in virtue of which they are more disposed, when in the former states or phases of their periods, to obey the influence of the repulsive or reflective forces of the molecules of a medium; and when in the latter, of the attractive."

Such are the postulates on which the corpuscular theory of light depends. Most of them may be admitted without difficulty; and they afford data for the application of mathematical reasoning to the phenomena, which may be investigated by the same sort of analysis with which mathematicians are already familiar in the theories of heat, capillary attraction, and other molecular forces.

Undulatory theory.—The principles of the undulatory theory are thus stated by Sir J. Herschel:

1. "That an excessively rare, subtle, and elastic medium, or *ether*, fills all space, and pervades all material bodies, occupying the intervals between their molecules; and either by passing freely among them, or by its extreme rarity, offering no resistance to the motion of the earth, the planets, or comets, in their orbits, appreciable by the most delicate astronomical observations; and having inertia, but not gravity.

2. That the molecules of the ether are susceptible of being set in motion by the agitation of the particles of ponderable matter; and that when any one is thus set in motion it communicates a similar

motion to those adjacent to it; and thus the motion is propagated further and further in all directions, according to the same mechanical laws which regulate the propagation of undulations in other elastic media, as air, water, or solids, according to their respective constitutions.

3. That in the interior of refracting media the ether exists in a state of less elasticity, compared with its density, than in vacuo, (*i. e.*, in space empty of all other matter;) and that the more refractive the medium, the less, relatively speaking, is the elasticity of the ether in its interior.

4. That vibrations communicated to the ether in free space are propagated through refractive media by means of the ether in their interior, but with a velocity corresponding to its inferior degree of elasticity.

5. That when regular vibratory motions of a proper kind are propagated through the ether, and, passing through our eyes, reach and agitate the nerves of our retina, they produce in us the sensation of light, in a manner bearing a more or less close analogy to that in which the vibrations of the air affect our auditory nerves with that of sound.

6. That as, in the doctrine of sound, the frequency of the aerial pulses, or the number of excursions to and fro from the point of rest made by each molecule of the air, determines the pitch or note; so, in the theory of light, the frequency of the pulses, or number of impulses made on our nerves in a given time by the ethereal molecules next in contact with them, determines the *color* of the light; and that as the absolute extent of the motion to and fro of the particles of air determines the *loudness* of the sound, so the *amplitude* or extent of the excursions of the ethereal molecules from their points of rest determines the brightness or intensity of the light."

Whichever theory we adopt to explain the phenomena of light, we are led to conclusions which strike the mind with astonishment. According to the corpuscular theory, the molecules of light are supposed to be endowed with attractive and repulsive forces, to have poles, to balance themselves about their centres of gravity, and to possess other physical properties which we can only ascribe to ponderable matter. In speaking of these properties it is difficult to divest one's self of the idea of sensible magnitude, or by any strain of the imagination to conceive that particles to which they belong can be so amazingly small as those of light demonstrably are. If a molecule of light weighed a single grain, its momentum (by reason of the enormous velocity with which it moves) would be such that its effect would be equal to that of a cannon-ball of 150 pounds, projected with a velocity of 1000 feet per second. How inconceivably small must they, therefore, be, when millions of molecules, collected by lenses or mirrors, have never been found to produce the slightest effect on the most delicate apparatus contrived expressly for the purpose of rendering their materiality sensible!

If the corpuscular theory astonishes us by the extreme minuteness and prodigious velocity of the luminous molecules, the numerical results deduced from the undulatory theory are not less overwhelming. The extreme smallness of the amplitude of the vibrations, and the almost inconceivable, but still measurable rapidity with which they succeed each other, were computed by Dr. Young, and are exhibited by Sir J. Herschel in the following table:

Colors.	Length of undulation in parts of an inch.	Number of undulations in an inch.	Number of undulations per second.
Extreme Red	0·0000266	37640	458,000000,000000
Red	0·0000256	39180	477,000000,000000
Orange	0·0000240	41610	506,000000,000000
Yellow	0·0000227	44000	535,000000,000000
Green	0·0000211	47460	577,000000,000000
Blue	0·0000196	51110	622,000000,000000
Indigo	0·0000185	54070	658,000000,000000
Violet	0·0000174	57490	699,000000,000000
Extreme Violet	0·0000167	59750	727,000000,000000
			The velocity of light being assumed at 192,000 miles per second.

On a cursory view, it must appear singular that two hypotheses, founded on assumptions so essentially different, should concur in affording the means of explaining so great a number of facts with equal precision and almost equal facility. This, however, is the case with respect to the corpuscular and undulatory theories of light, from both of which the mathematical laws to which the phenomena are subject may be deduced, though not in all cases with the same degree of facility.

LIGHT, ARTIFICIAL. The importance of obtaining a brilliant and economical light for public and domestic purposes, has exercised the ingenuity and scientific research of eminent men for a century past. And although their labors have resulted in discoveries of great value, the desideratum so steadily sought after has not yet been attained.

The introduction of coal-gas, in 1798, by Mr. William Murdock, engineer to Messrs. Bolton and Watt, was an invention of the highest order, and one that has conferred most important benefits upon society. The subsequent use of oil and resin, as substitutes for coal, to avoid the difficulties of purification required by the latter, did not result in any improvement of economy or illuminating power. The discovery of the voltaic and oxy-hydrogen lime light was a brilliant addition to our stock of chemical science, but neither of them have yet been reduced to any thing like a practical form suited to public or domestic uses.

The requirements of the case may be stated thus: 1st, intense illuminating power; 2d, economy; 3d, portability; 4th, small radiation of heat; 5th, perfect ventilation; 6th, simplicity in the production and steadiness of combustion, so as to insure uniform power of light.

To obtain an artificial light combining all these requisites, is now one of the most interesting problems of this era of useful inventions, and its solution will place the discoverer on the same eminence with Newton, Watt, Fulton, and Morse. There is, therefore, no field of research that promises more substantial rewards to the successful than the invention of a simple, economical, and powerful light, as the want of it is felt by the whole civilized world.

That this subject has already attracted the attention of both scientific and practical men in this country, as well as abroad, we have abundant proofs in the frequent announcement of grand discoveries in the production of artificial light, that, upon investigation, prove to be either new discoveries of old chemical experiments, by some tyro or quack, or else are of no value practically, owing to the chemical or mechanical cost of production.

It is very easy to assure the public that water can be made to burn, or that a whole city is about to be completely illuminated with a single gas-light. The demonstration of such wonders is, however, probably reserved for a future age. At present we would only direct the attention of our ingenious countrymen to the simple fact, that this subject is one of universal public importance, presenting a broad scope for the exercise of their inventive faculties.

LIGHT-HOUSES. See SEA-LIGHTS, under which head the subject should be treated.

LIGHTNING CONDUCTORS are pointed metallic rods, fixed to the upper parts of buildings to secure them from strokes of lightning. They were invented and proposed by Dr. FRANKLIN for this purpose, and they exhibit a very important and useful application of modern discoveries in the science of electricity. See ELECTRICITY.

LIFE-BOAT. A boat originally made at Shields, in 1789, by Mr. Greathead, for saving the crews of shipwrecked vessels. The following are the general principles: The boat is wide and shallow; the head and stern are alike, for pulling in either direction, and raised, to meet the waves; it pulls double-banked, the oars being fir, for lightness, and fitted with thole-pins and grummets, and is steered with an oar. The boat is cased round inside, on the upper part, with cork, in order to secure her buoyancy with as many persons as she can carry, even though full of water; the cork likewise assists in maintaining, or, if overset, in recovering, the position of stable equilibrium. The boat is painted white, to be conspicuous in emerging from the hollow of the sea. It is a curious fact that the smugglers paint their boats white for the contrary reason, because dark-colored objects alone are discernible in dark nights.

The loss by fire constantly occurring on the western waters is a proof of the necessity for greater and more effective means of saving life, than are yet adopted in our mercantile marine of all classes nearly. That this should be so is doubly surprising, when, in our very midst, we have the remedy in Francis's galvanized iron life-boat, of which it may be stated, they are never leaky. They may be thrown overboard without injury, or lessening their usefulness; they right themselves, if swamped; and, when full of water, a thirty-foot boat will sustain forty people, so long as they can hold on to the beckets, with which each boat is provided. The non-inflammable material of their construction is another great safety on going alongside a burning wreck; and in a heavy sea their elasticity and buoyancy preserves them alongside a sinking wreck, in circumstances which invariably destroy a wood-boat at the time when she is most needed. These boats are manufactured by Mr. Francis, at the Novelty Works of Stillman, Allen & Co., on the East River.

LIME. Carbonate of lime is the substance forming the principal ingredient of all natural limestones, which may be classified, from their outward mineralogical characters, under the following arrangement:

Granular limestone, with a decidedly crystalline grain: the different varieties of marble, (Parian, Carrara,) and particularly the old mountain limestone, belong to this class.

Compact limestone occurs in quite as great a variety of colored species as the foregoing, but is never so white. It is found in all geological formations, and is named according to its age, or from the formations of which it is a member; we thus have transition limestone, graywacke limestone, carboniferous limestone, mountain limestone, shell limestone, lias limestone, fresh-water limestone, &c.

Limestone Breccia, consisting of lumps of limestone, cemented together by another limestone mass.

Limestone marl, more or less uniformly mixed with clay, of a dense earthy fracture. This and the foregoing variety belong to no particular member of the stratified rocks, exclusively.

Silicious limestone contains numerous silicious minerals, as quartz, hornestone, chalcedony, opal, &c. This variety is dense, and interspersed often with cavities; it is gray, or yellowish-white.

Fetid limestone is characterized by the bitumen which it contains, and which is rendered perceptible to the smell by friction. It is generally dense, and exhibits stratification. It is called *friable marl* when it occurs as a disconnected earthy mass, and is of a dark color.

Chalk is a dense, earthy rock, imparting color when rubbed, seldom other than of a white color. It is distinguished as being the matrix of flints.

Coarse lime is dense, earthy, approaching sandstone in appearance, and contains a large proportion of quartz-sand and clay, and is stratified.

Calcareous tufa consists of layers of lime which are pretty free from foreign matters, and is still in the process of formation. Generally unstratified. In some parts it is loose, porous, and earthy; in others dense, passing into a variety of dense limestone.

Calcareous tufa and Travertin belong to this class. Lime of similar origin is called calcareous sinter when the stratification contains crystalline particles (calcareous spar or arragonite) arranged like layers of bark, one above the other, often in the form of columns.

[These formations are produced by the solvent action of water containing carbonic acid upon carbonate of lime.

The *stalactites* and *stalagmites* which frequently cover the roofs and floors of certain caverns, are also due to the same cause. The water which permeates the rocks above them dissolves the carbonate of lime, by reason of the carbonic acid which it contains. In dropping from the roof, however, it remains suspended for some time, and, losing a certain part of the acid, deposits also a portion of the carbonate of lime, previously held in solution. The accumulation of these minute portions of lime gradually form the stalactites. The same takes place on the floors of the caverns, giving rise to the formation of the stalagmites.]

Dolomite is characterized by a large amount of magnesia; it is generally granular, and seldom earthy or massive. It is not distinctly stratified, but sometimes bituminous.

The characters of limestone which stand in connection with the theory of the earth's formation, the geological characters, therefore, lead to a totally different classification. The examination of a limestone in one point of view only, must therefore lead to a very imperfect knowledge of its nature. The mere study of its chemical constitution, would also afford but a very partial means of judging it.

Many limestones exhibit clear indications of having been put in motion in the liquid state. Limestone of this kind must possess a high degree of purity, as, if this were not the case, (and clay or other substances were present,) the result of the fusion would certainly have been different, and would not have ended in the formation of crystals of pure carbonate of lime.

Other limestones, which have been formed by precipitation from soluble salts of lime, are more likely to contain foreign admixtures, which have been deposited by chemical or mechanical agency. Thus, some contain magnesia, iron, and manganese uniformly disseminated through them; others are mixed in the same manner with aluminous or silicious particles, or these are interstratified with them.

Others, again, and a whole series of limestones, have obviously been formed with the concurrence of the animal creation, and it is of importance to ascertain what part the living beings have performed in this general development. Thus, at the present moment, whole islands are being raised up in certain latitudes and oceans, from the calcareous coverings of the coralline animals, just as in former ages the range of the Jura and other mountains have been produced from the same agency. There are likewise limestones, as the shell limestones, which are composed of masses of shells of crustaceous animals. The shells of these animals have been filled with lime, and cemented together so as to form a more or less solid rock. The bodies of the animals have not, however, disappeared without leaving a trace behind them; for that which is denominated *bituminous* in these rocks, is generally the residue of decomposed animal matter permeating the entire mass of the stone.

While many limestone formations have been deposited from sea-water, others appear to have been decidedly formed in fresh water. Calcareous tufa is still being deposited in numerous places from springs, the carbonic acid in which, under greater pressure, dissolves lime, which is again precipitated, when the carbonic acid is evolved under the lesser pressure of the atmosphere.

Pure burnt lime absorbs water with great avidity, and occasions a great disengagement of heat, forming a dense, very soft paste, or, as it is called, becoming *fat;* the limestones containing magnesia are poorer in proportion as they approach to the composition of dolomite. The oxides of manganese and iron which are so frequently found in the limestones, have probably been formed by the action of the atmosphere upon the protoxides of these metals.

Besides the carbonates, the silica and alumina contained in the limestone rocks are also of interest. They exist in the most variable proportions, often combined in the form of clay, sometimes associated with magnesia, sometimes alone. The silica is often, but the alumina never in excess, so that both remain undissolved in acids. Their presence is without any perceptible influence when they are present in small quantity; but when their amount exceeds 10 per cent., the limestones are slaked very slowly and with difficulty after burning, their affinity for water is diminished, and they are then applicable to very different purposes. Of these we shall have occasion to speak under the head of *hydraulic lime.*

Lime burning—Chemical process.—Carbonate of lime is not decomposed at a low red-heat, but is converted at a bright red-heat into carbonic acid and lime. The temperature at which the decomposition is effected is, however, influenced by circumstances, or rather depends entirely upon the facility afforded the carbonic acid for escape when it has been expelled from the lime. If the limestones are constantly surrounded with an atmosphere of carbonic acid, the further evolution of carbonic acid from them is, according to Faraday, very much impeded; but if the gaseous acid is removed as quickly as it is expelled from the lime, the process of removing the future portions of acid is much accelerated. In close vessels, the decomposition is stopped as soon as the space not occupied by the lime has become filled with carbonic acid.

It will be proper to explain the processes employed in burning lime, which must be viewed as a preparation of the limestone for its numerous applications in the arts. The burning of lime is accomplished in three modes: 1. Without a kiln; 2. By an intermittent kiln; and 3. By a kiln in constant operation, or, as it is called, a *perpetual kiln.*

1. *Without a kiln.*—In Wales and Belgium lime is burnt precisely as we burn charcoal; the pile of limestone and fuel mixed is covered with turf, making a heap of about 16 feet in diameter at the base, and 12 feet at the summit, which occupies in burning from six to seven days.

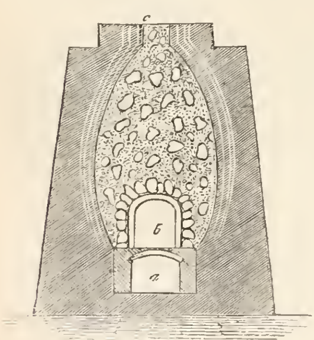
Intermittent kiln.—One of the simplest, but at the same time crudest arrangements, is the following: The kiln is perpendicular, and constructed of the same limestone (in the dry state and without mortar) as that which it is intended to burn. It is placed at the side of a steep hill or declivity, so that the mouth is equally accessible for charging the kiln, as the fire place for introducing the fuel. The shaft is round throughout, six feet in diameter at the top, and gradually expands to ten feet at about one-third from the bottom. A sudden contraction of the diameter is there introduced, forming a sort of projection inwards of one foot in width, and the size of the kiln then diminishes until it acquires a diameter of about 6½ feet at the bottom. A projection or ledge is carried in the form of a ring all round the interior of the furnace, but not at the same height from the ground, inclining towards the stoking hole. The charging is carried on upon a certain fixed plan. The lime-burner begins by constructing a pointed arch upon the ledge, with the large pieces of limestone which are selected expressly for this purpose. He forms in this manner a kind of support or foundation, upon which the other limestones are thrown in, at random, from above, the largest first and the smaller pieces afterwards, which are also piled up above the mouth of the kiln. When the charge has been thus arranged, a pile of wood is erected in the space below the arch, and ignited. The regulation of the fire is by no means an unimportant point, as the possibility of completing the burning depends upon the length of time that the arch, which acts as a support, will endure. The stones composing this arch being unconnected by any cement and unhewn, and only touching in a few places so as to leave a free ingress for the flames, a slight shock will often cause the downfall of the whole, and put a stop to the operation. The sudden and powerful action of the fire, by expanding the stones very rapidly, and driving out the moisture with such force as to rupture the stones, will often produce a sufficient shock to create a catastrophe of this kind. The art of burning lime, therefore, consists in bringing the mass of limestone as gradually as possible to a red-heat. The first period is called *the smoking*, because the gases evolved from the fuel, being too much cooled, are imperfectly burnt, and pass off in the form of a thick smoke. The temperature generally increases in a kiln of this kind during the first two-thirds of the time, until it attains a white-heat, and diminishes again in the last third. The firing must, however, be kept up until the uppermost stones have been completely burnt. During the firing the bulk of the stones is much diminished, and the heap above the mouth of the furnace sinks gradually down.

The evils of such a system of burning, which involves an enormous waste of fuel, (the loss of time not being taken into consideration,) are obvious. The furnace must be allowed to cool each time it is discharged, and the entire amount of heat, or, what is the same thing, the whole of the wood employed for raising the very extensive sides of the kiln to the temperature at which lime is burnt, must be sacrificed. It is also evident that, in such a system of burning, the lower half of the limestone must be thoroughly caustic, while the upper portions are still in the mild state. The upper part is at a very considerable distance from the fire, and removed from the direct action of the flames, is burnt, consequently, at a much greater cost of fuel than would otherwise be necessary. At the same time the lower layers in the kiln are exposed to the constant danger of becoming over-burnt, which very much injures the quality of the lime.

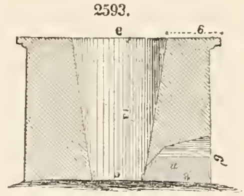
A great advantage is gained by constructing the kilns of brick-work, in a more solid manner, giving the shaft more appropriate dimensions and shape, and building the kilns in situations less subject to be obstructed in working by moisture, &c.

These improvements have been carried out in the kiln shown in Fig. 2592. Instead of a rudely constructed wall, an outer wall is erected in these furnaces, with an internal one of solid brick-work. The fire is placed upon the grate which separates the ash-pit *a* from the fireplace *b*. The grate is really a permeated brick arch.

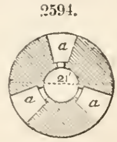
2592.



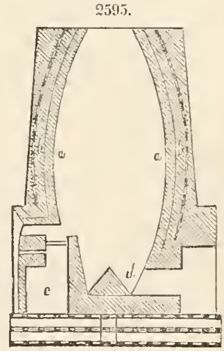
2593.



2594.



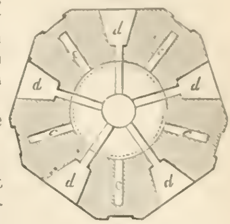
2595.



The *perpetual* or *draw kilns* are constructed as follows: Fig. 2593 represents a vertical section of a common form of perpetual kiln constructed for a coal-fire; Fig. 2594 is a horizontal section of the same through the drawing-holes. The actual burning-space is a shaft in the form of an inverted cone, wide at the top and narrow at the bottom. There is no separate hearth, the apertures *a a a*, of which there are three, serving only for drawing out the lime. A layer of brushwood is first placed at the bottom of the kiln, upon this some coal, then a layer of limestone, which is again covered with coal, and then another layer of limestone, and so on until the kiln is filled. The last layer of stone is heaped up above the mouth of the kiln, and the progress of the firing is judged of by the manner in which it sinks down; the sinking in this case being due, not only to the diminution in bulk of the stones, but also to the consumption of the fuel. As soon as the uppermost layer has sunk down to the level of the top of the kiln, another charge of coal and limestone is thrown upon it. In the mean time, at intervals of one-half to one-quarter of an hour, the lime which has sunk to the bottom of the kiln is drawn out through the holes. The lower the charges sink in the kiln the more the coal is consumed, and the less space they will occupy; for this reason the inverted conical form of the kiln is the most appropriate. The intensity of the fire can be regulated with perfect ease by adding more or less coal with each charge of limestone. The draught may be impeded by stopping the apertures entirely or in part. In a kiln of the above dimensions, 500 cubic feet of lime are drawn in twenty-four hours, and the consumption of coal is about two tons.

Fig. 2595 represents a section, and Fig. 2596 a plan of one of the most approved forms of perpetual kilns in use in Prussia, in which one part of wood and four parts of peat are used. *d d d d d* are openings at bottom for drawing the lime as it is burnt; *c c c c c* fire-furnace for the fuel, whose mode of connection with the cavity where the limestone is placed may be seen at *c* in the vertical section, which also shows at *d* the manner in which the lime may be drawn. At *a a* is shown a lining of fire-brick, back of which is a cavity *b b* filled with cinders, which act as a non-conductor of heat.

2596.



The outside is built of rough stone. It produces about 250 bushels of lime daily.

Scale, 12 feet to ½ inch.

Coal is a kind of fuel that is easily broken in small pieces, in a convenient state for spreading about between the layers of limestone. Another advantage arising from the use of coal is the small quantity of ash which it leaves, and which is easily removed from the kiln with the burnt lime. These remarks do not apply to wood which is reduced with difficulty into small pieces, and not being equally distributed amongst the lime stone, impedes the regular burning and delivery of the lime; nor to peat, which in general leaves so large a proportion of ash as to subject the kiln to the danger of becoming stopped. In those cases where a perpetual process must be combined with the use of wood and peat as fuel, the construction of the kiln must undergo a suitable modification. While the kiln retains its character as a perpendicular or shaft furnace, the fuel, instead of being interstratified with the limestone, is burnt on separate hearths at the sides of the shaft, and the flame is conducted into the latter, which, in this case, contains nothing but the material to be burnt. The number of the fires, which must always be symmetrically arranged round the circumference of the shaft, is regulated by the size of the kiln, so that kilns with three, four, and five fires are met with. The fuel consumed in furnaces of this construction must, of course, yield a long and lively flame, as from wood, peat, or coal; but for the latter, the arrangement is not so economical as the plan of stratification previously described.

Fig. 2597 is a vertical section of a plain perpetual kiln, built in Berkshire, Mass. It is 25 feet high, and built of alternate layers of fire-brick and stone. It is four-sided; consisting of a single chimney 4 feet square on the inside, and 8 feet on the outside, making the walls 2 feet thick. To the height of 7 feet from the bottom it is 12 feet in one direction, for the purpose of making room for the furnaces *d d*, in which wood only is burnt, and which are 2 feet high and 20 inches wide. For the passage of the heat into the limestone in the chimney the bricks are laid up like a grate; *a a* are ash-pits beneath the fires, *b* an opening for clearing the lime from the bottom of the chimney—being about 18 inches square. The kiln consumes from 2 to 2½ cords of wood daily, and produces 75 bushels of lime, which is drawn out at intervals of 8 hours. Scale, 12 feet to a half inch.

2597.

Consumption of fuel.—Notwithstanding the great saving of fuel, which is effected in perpetual kilns, yet it must be borne in mind, that these kilns demand the entire attention of the workman, and cannot be well attended to as a casual occupation, or as a secondary branch of husbandry, for instance; it must also be remembered that perpetual furnaces are always yielding, that is, they produce, in the same time, a much larger amount of burnt lime, and are, consequently, only economical where there is a large and constant demand for the produce. Every improvement in the construction of lime-kilns would be a great boon to the public, for they must be decidedly classed amongst the chief sources of the waste of fuel. The best mode of arriving at some sure foundation from which to calculate the amount of this waste, will no doubt be, by ascertaining the theoretical amount of fuel that is necessary to burn a given weight of lime, and making this result the standard by which to compare the real loss. It may be stated that 1 lb. of wood fuel is capable of heating 26 lbs. of water 100° C. If the specific heat of limestone and carbonic acid is taken at ⅓ that of water, and the temperature at which lime is rendered caustic is calculated at 800° C., it results, first, that 1 lb. of wood will heat $3 \times 26 = 78$ lbs. of lime to 100°, and consequently $\frac{78}{8} = 9{\cdot}75$ lbs. of limestone to 800°; or in other words and round numbers, only $\frac{1}{10}$ of the weight of the lime is requisite. In practice from 4 to 6 times as much is consumed. The limestone, it is true, does not lose its carbonic acid all at once, as the calculation presupposes, even when it has acquired the proper heat, but the acid is evolved very gradually; it is, consequently, not only necessary to heat the kiln for a single instant to the proper temperature, but to keep up that temperature for a considerable time. But, even if the quantity of wood calculated as necessary be doubled, on account of this latter circumstance, yet there still remains a loss of an equal quantity, and it may be positively asserted, that the quantity of wood consumed in the lime kilns is about as much again as it should be. The heating power of coal being to that of wood as 60 : 26, for every 10 lbs. of lime burnt there should be 0·43 lbs. of coal consumed. But, as was stated above, for every cubic foot of lime, from ¼ to ⅓ cubic foot of coal is burnt, which is equivalent to from 2·4 to 3 lbs. of coal for 10 lbs. of lime, and consequently a very much greater waste.

Lime may be burnt, like bricks, in mounds; but the irregular form of the pieces, and the contraction which ensues, renders the process difficult, and it is consequently seldom practised.

Produce.—Chemically, pure carbonate of lime loses 44 per cent. of carbonic acid, and yields, after burning, 56 per cent. of caustic lime. The produce from the kilns upon a large scale is much less when the limestone is very moist, and greater when it contains a large proportion of clay, which loses nothing in the kiln. The average amount of produce obtained, ranges between 45 and 77 per cent., the ordinary quantity being about 54 per cent. The contraction is not so considerable as might be expected, as the burnt lime is very porous. The specific gravity of limestone is diminished from $\frac{1}{3}$ to $\frac{1}{2}$ by burning, and its volume is reduced from 10 to 20 per cent. Triest found, by direct experiment, the weight of a solid cubic foot (Hessian) of Rüdersdorf limestone = 93 lbs., after burning = 48 lbs.; the loss was, therefore, = 45 lbs. or 48 per cent. 100 lbs. of fresh Rodheim limestone, to give another example, occupy a space = 209, after burning, (when they ought to weigh 60 lbs.) the space which they occupy is reduced to 183; the contraction, therefore, amounts to 12½ per cent.

Besides the lumps or shells of lime, there is always a portion leaves the kiln in the state of powder, which is in consequence of the stones splitting in the fire, or is due to the friction in charging and discharging the kiln.

Action of aqueous vapor in the kiln.—Moist limestone is said by old lime-burners to burn much more easily than dry limestone. This fact, which is so well established among them that they prefer burning stones fresh from the pit, or even moisten those which have become dry in the air with water before putting them into the kiln, is not without a true foundation, although it is often misunderstood in practice.

When, on the one hand, it cannot be denied that limestone is more easily burnt under the influence of a current of steam, yet on the other, it is very questionable whether the practice of burning moist stones is really advantageous. The practice of bringing moist stones into the kiln is equivalent to the exposure of limestone very much below a red-heat to the action of a current of vapor, as far the greater part of the water must be uselessly expelled (with a proportionate waste of fuel) before the stones acquire a red-heat.

Burnt lime.—Lime, when burnt, combines with the free silica at a red-heat, or enters as a constituent into the compound silicate of lime and alamina which is formed. It will be obvious from these facts, that the foreign substances must exercise considerable influence upon the quality of the burnt lime. In the purer varieties of limestone that contain but very little foreign matter, the influence is imperceptible. As the clay and silica are less prominent in these instances, the action of the magnesia is rendered still more obvious, and when present to the amount of 10 per cent., affects the heating of the lime, and diminishes its property of slaking and forming a soft impalpable paste; in short, renders it poor. When the amount of magnesia exceeds $\frac{1}{3}$, the poorness of the lime is so great as to render it useless. The nature of the limestones is not solely dependent upon the foreign substances which they contain, but also upon the mode of regulating the furnace; while one portion of the shells exhibits the proper amount of heat when slaked, other pieces will slake very slowly, and the water will often hardly act at all upon them; they are then said to be *dead-burnt.*

To convert oyster and muscle shells into lime, requires a higher temperature in the kiln than ordinary limestone, and they have a great tendency to produce a badly slaking lime. The gelatin in the shells is converted into charcoal which burns with difficulty, and is long retained in the interior of the stones while the lime is burnt. Now, if burnt lime is heated for some time intimately mixed with charcoal, the basic carbonate is produced—according to Fuchs.

The slaking.—Burnt lime is of a whitish-gray color, or often dirty white, seldom pure white; it is much more friable than fresh limestone, but yet sufficiently solid to bear carriage. The crystalline structure of many varieties of lime is often distinguishable after burning. It is light and excessively porous. In consequence of its porosity, burnt lime absorbs water (about 18 per cent.) with the greatest avidity, during which operation the air contained in the pores is evolved with considerable noise. In a few minutes (but much later with poor lime) the saturated lime is observed to become hot, and from that moment the combination of lime and water proceeds. The lumps of lime fall to pieces with a crackling sound, and the smaller pieces are reduced to powder with the evolution of much steam, until at last the whole is converted, with a greatly increased volume, into a soft uniform white powder, *i. e.*, into *hydrate of lime.* For building, it is customary to place the lime in *slaking tubs*, or into flat boxes constructed of boards, with a spout, and to pour as much water into them as will nearly cover the lime. During the slaking of the lime, the excess of water is heated to lively ebullition, and the workmen endeavor to mix the lime and water in a uniform manner with a hoe. If the proportion of water was correctly estimated, a uniformly thick semi-liquid mass results. In the formation of hydrate of lime, 100 parts of pure lime combine with 32 parts of water, or nearly $\frac{1}{3}$.

The conversion of liquid into solid water may be viewed as the proximate cause of the great evolution of heat which accompanies the slaking of lime, inasmuch as the water must be contained in this state in the solid hydrate of lime. Suppose 3 lbs. of lime to be slaked, these will combine with 1 lb. of water, for instance, and convert it into the solid form. In this process, a quantity of heat is liberated sufficient to bring 0·79 or $\frac{4}{5}$ lbs. of water to the boiling point. In practice the amount of heat is much greater, for a boiling temperature is attained when the lime is covered with three times the quantity of water. The conversion of water from the liquid to the solid state is, consequently, not the only source of the heat, the remainder must be accounted for by the chemical action which ensues. As a proof of this, the fact may be adduced that lime heats with snow or ice. When a large excess of water is used, the heat evolved is more diffused and less intense; it increases with a lesser quantity, and attains a maximum when no more is added than enters into combination with the lime. The heat has then been observed to attain the temperature required to ignite sulphur and gunpowder, or even wood. If the lime is moistened with water in the dark, it becomes red-hot and emits a lively luminous appearance; in this case, the heat is concentrated by the surrounding lime which is not in the act of being slaked. The heat is in general so much the more intense the more rapidly the lime is slaked; or, is in proportion to its purity and the proper degree of causticity attained in the kiln. The temperature of slaking must always be attended to, as it influences the quality of the lime, and must be regulated by a cautious addition of water; when no more water is added to the lime than it can absorb, it does not form a soft, but a sandy (coarsely crystalline) powder, and is said to have been rendered *poor by slaking.* The builders have, therefore, a good reason for slaking the lime at once to the form of an impalpable, and not a coarse powder. Rather more than 3 parts of water are required for this purpose. If lime is only speedily dipped in water in a basket, so that it falls to powder, and is afterwards mixed with more water, it does not increase more than to 2½ volumes; if allowed to fall to powder, exposed to the air, and then made into a paste with water, it will only yield 1·7 volumes.

Influence of the air.—Exposed to the air, burnt lime is converted very slowly and without any elevation of temperature into a rough, coarse powder, containing small angular pieces; it then effervesces vigorously with acids.

As large quantities of lime must be kept ready slaked for the purposes of the builder, and it is necessary to protect it from the action of the atmosphere which would render it useless as mortar, it is customary to preserve it in deep pits. The slaking-tub is placed in front of a pit into which the slaked lime in the semi-liquid state is allowed to flow until the pit is filled. The lime becomes fatter and tougher in the pit, those pieces becoming gradually slaked which resisted the first action of the water. The excess of water collects on the surface and can be removed; the pit is then covered with a layer of sand two or three inches in thickness, and the lime is thus preserved totally unchanged. In removing the ruins of the castle of Landsberg in order to lay the foundations for a new building, it is stated by Jahn, that a lime-pit of considerable dimensions was found in one of the vaults. The surface of this mass of lime was carbonated to the depth of a few inches, but all below that was in the state of freshly slaked lime, only somewhat more dry. This lime, which was certainly more than 300 years old, and valued at several hundred florins, was consequently used in constructing the new building.

Hydraulic lime.—Those varieties of lime which contain about 10 per cent. of silica or silicates, assume different properties, and although they are only slowly slaked after burning and poor, yet when made into a dough with water, they soon become solid, and exposed in this state to the constant action of water, acquire a high degree of consistence, and are rendered hard, like stone, without being subsequently loosened or eaten away by the water, and are very appropriately called *hydraulic*. As the hydraulic property is solely due to a chemical process, it can only be explained and understood by reference to the chemical nature of the stones. The following are the results of Berthier's analyses, with the exception of the last number, which was analyzed by Kersten:

The fresh Limestones contained in 100 *parts:*

	1	2	3	4	5	6	7	8	9
Carb. of lime	90·0	89·0	89·0	89·0	85·8	82·5	80·0	79·2	76·5
" " magnesia	5·0	3·2	2·0	2·0	0·4	4·1	1·5	2·5	3·0
" " protox. iron	—	—	—	—	6·2	—	—	6·0	3·0
" " protox. mang.	—	—	—	—	—	—	—	—	1·5
Silica	—	—	—	—	—	—	17·0	6·5	11·6
Alumina	—	—	—	—	—	—	1·0	3·3	3·6
Oxide of iron	5·0	7·8	9·0	9·0	5·4	13.4	—	—	—
Carbon	—	—	—	—	—	—	—	2·0	—
Water	—	—	—	—	—	—	1·0	—	—

The Lime obtained by burning the above contained in 100 *parts:*

	1	2	3	4	5	6	7	8	9
Lime	87·0	84·0	82·0	82·0	83·0	79·3	70·0	74·0	68·3
Magnesia	4·0	2·5	1·5	1·5	—	3·5	1·0	2·0	2·0
Clay	9·0	13·5	16·5	16·5	7·0	16·7	29·0	17·0	24·0
Oxide of iron	—	—	—	—	10·0	—	—	7·0	5·7

The first five numbers yield lime of very moderate, the last four, of a very marked hydraulic character. It will be seen by the table below, that this property increases with the quantity of matter insoluble in muriatic acid. This substance consists chiefly of a combination of silica and alumina, but is often composed nearly entirely of silica in the soluble modification. It becomes of great importance to obtain a knowledge of this insoluble portion, as upon it the hydraulic properties depend. This has consequently received more attention in recent analyses, as will be seen by the following examples:

Burnt hydraulic lime is (with few exceptions) soluble in acids; and, in proof of the presence of a silicate that can be decomposed by acids, a thick jelly of silica is produced. This property of yielding gelatinous silica stands, therefore, in intimate connection with the property of becoming hard under water. Unburnt, pulverized stones do not harden, as is well known; and hydraulic lime, mixed with water, acquires a certain consistence much before it becomes hard. Moistened hydraulic lime produces, in the first instance, a connected, very soft, friable mass, which is easily scratched by the nail; at a much later period, this mass, when covered with water, acquires a hardness which is quite equal to, and often exceeds that of, the limestone itself. As a general fact, the time in which different hydraulic limestones become hard is very variable, and the chemical action, which is the cause of the hardening, is consequently very unequal. The degree of hardness which they acquire is also not the same; those that harden slowly are often more compact than those which harden in a shorter time. The time required for hardening varies from a few minutes to weeks and months, and bears some relation to the amount of the aluminous constituent in the lime. The more the limestones contain of this ingredient, the more quickly they harden. The hardening and solidification of the hydraulic stones being, therefore, dependent upon the chemical reaction of their two ingredients, the relative proportions of these cannot be a matter of indifference; and as there are varieties which, from the smaller quantity of the silicious constituents contained in them, approach the ordinary limestones in properties, so there are others, in which this ingredient obtains so great a preponderance, and in which the amount of carbonate of lime is so small, that they no longer exhibit the hydraulic property. All mineral substances which possess the property of rendering ordinary limestone hydraulic, are very appropriately called *cements.*

Contains silicious clay.	Moderately good hydraulic lime.	Ordinary hydraulic lime.	Best hydraulic lime.	Intermediate lime.	Bad intermediate cement.	Ordinary cement.	Best intermediate cement.	Transition to Puzzolana.
Before burning (to 100 carbonate of lime.)	12	20	25	30	37	56	156	510
After burning (to 100 caustic lime.)	22	36	44	53	65	100	273	900

This division is of course quite arbitrary, no classes existing in nature, but only transitions; it is, however, convenient when its true signification is borne in mind. There must necessarily be numerous exceptions, for this reason, that the property of hardening in one and the same specimen of lime varies with the temperature at which it has been burnt; thus several varieties belonging to the third class, when imperfectly burnt (*i. e.*, when the whole of their carbonic acid has not been expelled) yield an hydraulic lime of the second best quality. Vicat has determined in single cases the amount of imperfect calcination by the amount of carbonic acid not expelled from the lime, and has tested the property of hardening in these different gradations. Thus one variety of limestone in which the carbonic acid remaining in it

amounted to	30 per cent.	27 per cent.	26 per cent.	23 per cent.	20 per cent.	10 per cent.
yielded a mortar which hardened in	15 minutes	12 minutes	7 minutes	9 days	30 days	9 days.

whence it is obvious, that in the course of calcination, and with the increase in the amount of caustic lime, a great diversity of relations between it and the aluminous constituent are created, upon one of which, or upon several at once, the property of rapidly hardening is chiefly dependent. Too much heat in the kiln and incipient fusion, renders the lime very much weaker than it should be when the process is properly conducted, and at last disqualifies it completely. It must be noticed lastly, that hydraulic lime never hardens, when it is immediately immersed in water, before having acquired a certain consistence. In this case, the particles never agglutinate properly together, but form a porous mass.

Many limestones, particularly those which form the boundary between the hydraulic limestones and the cements, possess the very objectionable property of containing portions which slake at a subsequent period, when the greater bulk has already solidified and become hard. The mortar then falls to pieces and is rendered perfectly useless. It would appear as if particles of lime were in this case so enveloped, as only to become penetrated by the water in the course of the process of hardening.

Calcination.—Hydraulic lime is burnt in a similar manner to ordinary limestone; a much less degree of heat, however, is required. Perpetual kilns are used; the burnt stones are reduced to powder under stampers or ground in a mill; the powder is passed through a sieve, and is then in a fit state for use.

Those varieties of hydraulic lime which slake easily, need not even be reduced to powder. A great error is, however, committed in exposing the hydraulic lime (particularly in the state of powder) for any length of time, during carriage, or in warehouses, to the moisture in the atmosphere; the greater part of its good properties are thus gradually destroyed, and it afterwards hardens very slowly or not at all. It need hardly be mentioned, that a larger stock of hydraulic lime should never be made than is intended for immediate consumption. With reference to this point, Vicat has shown, that hydraulic lime which has once attracted moisture, may be made to set, by renewed pulverization and mixture with water; but the action is much slower, and it is converted into an article of the worst quality.

Theory of hardening or solidification.—The solidification of hydraulic lime is supposed to be due to the presence and mutual action of the *silica* and *caustic lime* contained in it. The final result is derived from two operations. During *calcination*, the lime is rendered caustic by the evolution of carbonic acid, and this caustic lime then reacts upon the silicious clay, converting it into a compound that is easily decomposed by acids. The excess of caustic lime, as well as the compound into which the silicious clay has been converted, then react upon each other, when mortar is prepared from the ground burnt lime, in such a manner, that a *solid stone-like silicate* is produced in the *humid way.* The water here obviously has a double action. Dry substances, like lime and the silicate of alumina, act very little, or, under certain circumstances, not at all, upon each other, unless the solvent power of water is employed to bring them into intimate contact. During solidification, the water will constantly transfer the lime which it has dissolved, to the silicious particles; it will then dissolve fresh lime, which is again employed in the production of the silicate, and so on. The process of solidification is not so much the conversion of a ready formed silicate into a hydrate, as the *formation of a hydrated silicate in one and the same operation.*

The action of the clay.—The silica may be replaced, as is indeed the case in the greater number of dydraulic limestones, by different silicates. Amongst these, the clays are the most important.

The great diversity in the nature of the clays does not admit of the supposition that their action is always the same, but nevertheless they all yield a substance with lime which hardens well, and in some cases affords excellent mortar. All must be previously burnt, particularly potter's-clay. In some cases, it is necessary to calcine the clay with lime. The common ferruginous brick-earth hardly binds at all with lime when only slightly burnt, but when strongly heated, to the point of incipient fusion, the oxide of iron enters into combination with the clay, and a very powerful solidification then ensues with lime.

Artificial hydraulic lime.—Artificial mixtures of appropriate silicates with lime, under proper treatment, possess the hydraulic property in quite as eminent a degree as the natural productions. Experience has indeed anticipated theory in this fact by several centuries. The Romans were well acquainted with the use of lime-mortar, and applied it both in the construction of buildings and roads; they also soon made the important discovery that a certain soft, porous, almost earthy rock, containing pumice-stone, and resembling this in composition, and which was found on the coasts of the Bay of Bayæ and Naples, particularly in the neighborhood of Puteoli, possessed the valuable property of forming an hydraulic mortar with burnt lime. They called the rock *pulvis Puteolanus;* it is described by Vitruvius and by Pliny, and was employed, mixed with an equal quantity of lime, for building under water. The *pulvis Puteolanus* was precisely the same substance as is known in the present day under the name of Puzzolana. The modern name of the town Puteoli is Puzzuoli.

Trass, or tarras.—After entering Germany, and having taken possession of the Rhine, the Romans soon recognized, in the layers of trass, near Bonn, the well-known *pulvis Puteolanus,* and opened the quarries, whence this important material is distributed, far and wide, even to the present day. Both Puzzolana and trass are conglomerates of fragments of volcanic rocks, transposed by the agency of water from their original sites; they often contain fragments of basalt, pumice-stone, trachyte, clay-slate, &c., indicating at once the connection of the one with Vesuvius, and of the other with the volcanoes of Eifel. The trass in Brohlthal is derived from the constituents of the trachyte rocks in the neighborhood; it forms very thick beds, often filling entire valleys, and is in the form of a friable, easily pulverized stone, the color of which is generally light, passing from a yellowish to a greenish hue. It is ground in a number of stamping-mills in the neighborhood, and exported in the form of a fine powder. Like most other volcanic productions, as basalt, klingstein, &c., trass is resolved into two distinct silicates by chemical agency. The one is readily soluble in muriatic acid, the other resists solution.

Puzzolana.—Berthier found the Italian Puzzolana composed of 44·5 per cent. silica, 15·0 alumina, 8·8 lime, 4·7 magnesia, 12·0 oxide of iron and titanium, 1·4 potash, 4·1 soda, and 9·2 water.

Clay as cement.—All those substances which render fat, slaked lime hydraulic, are called *cements.* Puzzolana, trass, and all similar cements have the advantage of requiring no preparation by burning, but are capable of acting in the natural state—of course in fine powder, that they may be properly mixed. All varieties of clay, to be used for cements, must be disintegrated by burning, with or without a certain proportion of lime, according to their different characters. They then afford very powerful cements, which property, however, is very much influenced by the temperature to which they have been exposed, and the manner in which they have been burnt. Treussart made some bricks from a clay which is used in Strasburg for the manufacture of alum, and contains 50 silica, 32·7 alumina, 1·6 magnesia, with mere traces of oxide of iron; a part of these he burnt in the alum-furnace, and the others in a lime-kiln. When the burnt clays were made into mortar with half their weight of slaked lime, a great difference was observed in the two kinds; that which had been burnt in the alum-furnace hardened in two or three days, and would withstand a weight of 400 pounds without being crushed, while that from the lime-kiln did not harden for thirty days, and, placed in the same circumstances, broke under a weight of fifty or sixty pounds. A similar comparison, instituted with two mortars, also composed of one part slaked lime and two parts cement, the one of which consisted of simple clay, the other of clay that had been calcined with 2 per cent. of lime, led to the same result in favor of the latter mortar, which hardened in 17 days, while the former required 30 days.

The excellent hydraulic mortar of Tournay, known under the name of "*cendrée,*" is prepared from the refuse which is left on burning the lias limestone. This waste, which remains after removing the lumps of lime, consists of small fragments of lime and of the ash, (the coal there used yielding a large amount of ash,) in about the proportions of 1 : 3. The mixture is slaked in a small quantity of water, and before being used is well beaten and worked about.

Dr. Elsner has published the following analyses of certain iron slags which are found to afford excellent hydraulic mortar when mixed with burnt lime:

	I.	II.
Silica	40·12	40·44
Alumina	15·37	15·38
Lime	36·02	33·10
Protoxide of manganese	5·80	4·10
Protoxide of iron	1·25	1·63
Potash	2·25	2·07
Sulphur	0·70	0·76

These slags in the state of fine powder, when treated with a small quantity of muriatic acid, are rapidly converted into a uniform gelatinous mass.

It is easy to ascertain whether a slag is suited for the production of hydraulic cement, by pouring over it, in the state of fine powder, a small quantity of hydrochloric acid; if it forms a gelatinous mass after a short time, it will then yield, with lime, a proper mixture for hydraulic mortar.

Roman cement.—It is a remarkable fact in the history of hydraulic mortars, which originates, as we have seen, with the Puzzolana and trass employed by the Romans, that the more the knowledge of their uses has been spread, the more substances have been discovered which either act as hydraulic mortars themselves, or can be mixed as cements in the preparation of artificial mortar; so that what appeared originally a privilege accorded to a few favored spots only, can now be obtained almost everywhere. A strong inducement to study the nature and modes of occurrence of hydraulic lime was created by the patent granted to Parker and Wyatt, in London, in the year 1796, for what they termed "Roman cement." The material employed in the manufacture of this cement are the nodules, of an ovoidal or globular form, which are found in the London clay, and known by the name of *Septaria.* They are calcined in perpetual lime-kilns with coal, in which a very moderate and well-regulated heat is carefully preserved. After calcination, the stones are ground under heavy edgestones to a very fine powder, which is sifted, and then packed in casks for sale. These nodules are found in many localities in this country.

Roman cement is one of the most powerful hydraulic mortars, and is exceedingly valuable, not only on account of the rapidity with which it hardens, and this is effected in a very few minutes, but because when hardened in considerable masses it is not liable to crack.

All artificial or natural hydraulic limestones are soluble (before as well as after calcination) in muriatic acid with the separation of silica, except when sand or some similar substance has been added to them.

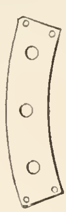
The hydraulic limestones, when they do not contain a sufficient quantity of lime to be capable of slaking with water, must be very finely pulverized; it is only by this high state of division that a proper action can ensue. A thorough penetration of the silicious portion by the lime is never entirely effected, but a certain proportion remains inclosed and removed from the sphere of action. See MORTAR.

LINK MOTION.—Variable expansion gear, now generally used on locomotives for the movement of the steam valves, first invented by Mr. Williams of Newcastle. Williams' incipient link was a slotted straight bar, which connected the straps of the fore and back eccentrics, formed with ears to secure the linking pins. In the slot of the link, a slide-block hung on the end of a radius link from the valve spindle, was adjustable towards one end or the other, to receive the motion of the one or the other eccentric for fore or back gear; while the link would partake jointly of the two motions of the eccentrics, its horizontal motion would be smallest at the centre of its length, and increase towards the extremities: thus by shifting the block towards the centre, the travel of the valve would be reduced, and variable expansion thereby obtained.

The objections to the special arrangement here proposed are obvious; the idea has however been developed by Mr. Howe, into the more practicable arrangement first applied to the engines of Robert Stephenson & Co. in 1843, and from this time the link has been adopted generally by all other English manufacturers.

2600.

2599.

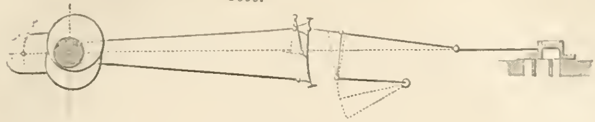


2598.

Link motions are all of two classes, in which, first the link is suspended directly from a fixed point as a stationary link, fig. 2601; secondly, the link is movable vertically, (fig. 2602,) carrying with it of course, the eccentric rods which are directly connected to it. In the first class, therefore, the variable expansion is accomplished by shifting the sliding blocks in the link: in the other class, the link is shifted upon the block. The link itself is employed under three general forms, distinguished as much by structural characteristics as by peculiarity of action. The box link, the open link joined to the eccentric-rods at the extremities, and the open link joined behind. The box-link, fig. 2598, is formed in two halves or sides bolted together at the extremities, enclosing a rectangular recess for the reception of the block as shown in section. The eccentric-rods are attached to the extreme stud pins, forged on the outside of the link, and thus a clear way is obtained for the blocks from one end of the link to the other; they may be shifted even to a position concentric with the eccentric rod ends. The two forms of open link are adopted with a view to simplify the parts, the one (fig. 2600,) with the extreme connections, is the form first used by Stephenson; by its form it does not permit of the block being placed concentric with the eccentric rod ends, the range being so limited, it is plain that the block never can receive and transmit the full throw of the eccentric to the valve, a feature in which the box-link has the advantage. With this link the throw of the eccentrics and therefore their diameters, must be greater than those required by the box-link for a given maximum travel of valve. The third form of link, (fig. 2599,) connected behind, permits of the same freedom for the block that is yielded by the box-link; the block may be shifted to a position level with the point of attachment at which it may transmit the whole throw of the eccentric. The overhung nature of this knuckle-jointed sort of link, and its peculiarly irregular movements in consequence, render it a more ticklish variety than the others; as, however, it combines the advantage of the box-link in respect of the transmission of the whole motion, with the simplicity of the other link, it is now most commonly employed, at least in locomotives, where vertical clearance is limited.

The first qualifications of expansion gear are to insure for every variation of expansive action, a free admission and free release for the steam; to render the periods of admission equal for the front and back strokes, and to promote the expansive action of the steam sufficiently to extract the most if not the whole of its works for propulsion, excepting a per centage required for the purposes of the blast.

2600.



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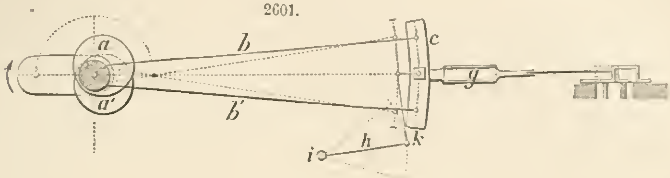


Lead. In the stationary link-motions, a constant lead throughout the forward and backward gear is obtained by circling the link to the radius of the valve-rod link, and the same lead may be for the front and back strokes. In the shifting link motion, the lead essentially varies with the expansion, the greater the degree of expansion—that is, the less the admission the greater also is the lead; the lead is thus least in full gear, and attains its maximum in the mid gear; it may however always be made the same for the front and back strokes, and thus equality is obtained by circling the link to the radius of the eccentric rod. Thus the conditions of constant lead and varying admission which are incompatible with the nature of the shifting link, motion are obtainable by the stationary link with a single valve. The longer the eccentric-rod, and the shorter the link, the less is the variation of lead in the shifting-link motion. The shifting-link motion may with advantage be set with the desired lead in half gear, which is the most ordinary working position of the mechanism; the evil of varying lead is thus divided and reduced.

Linear Advance. With the stationary link the linear advance of the eccentrics is in all cases less than that of the valve, and is a quality affected by the length of the eccentric-rods; these rods by their varying obliquity increase the advance while transmitting it to the link, and the shorter the rods the greater is the difference so caused. With the shifting-link, the linear advance of the valve is in all cases equal to that of the eccentrics in full gear, independent altogether of the length of the rods—expressly meaning by full gear, that the fore rod end is brought into the centre line of the valve rod; in other positions, however, the linear advance of the valve varies precisely with the lead, as the lead, in fact, partly constitutes the advance.

The Motion of the Link. The motion of the link is composed of the distinct motions of the eccentrics, and every part of the link is subject to this compound influence. The motion of each eccentric prevails in that half of the link to which it is coupled, and at the centre the motion of the link is equally composed of the two. The final result of this combined action is approximately the same as that available by the action of a single eccentric of variable throw. Thus the object which was proposed to be obtained by the spiral and wedge reversing motions of Fenton and Dodd's variable expansion, with (if possible) constant lead, is realized in the simplest manner by the combined operation of two eccentrics, and with an efficiency and precision which probably the original promoters of the link motion did not anticipate. Horizontal motion communicated to the link by the joint action of the eccentrics is a minimum at the centre of its length, where it is equal to twice the linear advance, and it increases towards the extremities various periods of the block in the link, or of the link on the block, on the general principle that admission varies with the travel of the valve. The distribution derived from the link is affected by the length of the connecting-rod relative to that of the crank; the shorter the rod, the greater is the front admission, and the less is the admission for the back stroke; therefore the term "link-motion" in so far as it involves the relation of the valve's motion to that of the piston, virtually includes the proportions of the piston motion. The quality of the motion derived from the link is modified by the positions of the working centres, and most especially of the centres of suspension and connection; the centre of suspension is the most influential of all in regulating the admission, and its transition horizontally is much more efficacious than a vertical change of place to the same extent. The periods of admission in half gear are much more sensitive to variation by mode of suspension and connection than those in full and mid gear. It is expedient to set the motion right for this position as regards the quality of the admissions, because these differences for other positions are then inconsiderable. There are certain neutral positions of the centre of the suspension, on which the link in vibrating yields equal admissions, and these may be found for any specific arrangement by the method of three trails. These neutral positions may be located either in the centre line of the link, vertically or horizontally in the neighborhood of the middle of the link. As the vertical movement of the body of the link with the consequent slip between the link and the block is the least possible when the suspended centre lies in the centre line of the link, increasing as the centre is removed laterally, the centre line of the link is, in this respect, the most favorable locality for the suspension, though not always practicable for equal admissions. It has been found that the stationary and shifting links have not the same neutral centres of suspension; that in general the stationary link should be hung by a centre in the neighborhood of the middle of its length, and the shifting link towards one of the extremities. The periods of expansion and release increase as those of admission are diminished, and when the points of suppression are equally adjusted, those of release do not considerably differ. It has been found in short, that in valves the admissions and the expansions may be made absolutely identical, as in the Great Western link, fig. 2601. An admission of 75 per cent. or three-fourths of the stroke is attended with a mean expansion of 16 per cent. of expansion, exhausting at 80 per cent. The utmost period of expansion obtained by a stationary link in mid gear is 38 per cent. for 12 per cent. of admission, in which case the steam is cut off at less than one-eighth of the stroke, and expanded into a volume of 50 per cent., or one half stroke 4 times the initial volume exclusive of clearance, after which it exhausts during the remaining half stroke. With the stationary link the shortest admission is 11 per cent., or one-ninth of the stroke, expanding into 50 per cent., or 4½ times the initial volume, before the release takes place. With the shifting-link, the smallest attainable admission is about 17 per cent., or one-sixth of the stroke; this is about one-half more than what is obtained by the stationary link, the difference being due to the excess of lead yielded by the shifting. As the release takes place at half stroke, the shifting-link cannot expand the steam above three times its initial volume, exclusive of clearance. The average period of admission in full gear does not exceed 75 per cent., or three-fourths of the stroke, according to the examples before us. More than this should not be required, nor indeed could it be beneficially employed at regular speed; the admission may, however, be increased by forcing the mechanism of the valve beyond full gear; that is, by causing the block to work in the extreme overhung parts of the link, which must be extended for the purpose beyond the centres of connection; by this expedient the throw of the valve is increased, and it is practicable with the box and back hug links, and may in many cases be usefully employed when a ready start with a heavy train is required.

The open link connected by its extremities in its own centre line, is identical in its motions with the box-link: in the use of that link it is imperative that the throw of the eccentric should be greater than that designed for the valve, as in full gear the block is of necessity placed nearer to the centre of the link than the rod centres.

LITHOGRAPHY. The art of transferring from stone writings or drawings made thereon, which is of quite modern invention. Unlike other kinds of printing, this is strictly chemical, and is in consequence called, in Germany, *chemical printing*. A drawing is made on the stone, either with ink containing oleaginous matter, or with chalk containing similar substances, but in a more concentrated and indurated state. The drawing is then washed over with water, which sinks into those portions of the stone that are untouched with the grease of the drawing. A cylindrical roller, charged with printing-ink, is then passed all over the stone, and while the drawing receives the ink, the rest of the stone is preserved from it by the water, on account of the greasy nature of the ink. This art is said to have been invented by mere accident, by Alois Senefelder, of Munich.

The stones, and the manner in which they are prepared to receive the drawings.—The stone most used in England is found at Corstan, near Bath; it is one of the white lias beds, but not of so fine a grain, nor so close in texture as the German stone, and therefore inferior; but it is good for transfers, and does tolerably well for ink drawings or writings. All calcareous stones may be used in lithography, because they imbibe grease and moisture; but a stone entirely calcareous does not answer well: there should be a mixture of alumina and silex. One of the most certain indications of lithographic properties is the conchoidal fracture; all stones of this kind will be found good, if they are also hard, have the fineness of grain, and the homogeneousness of texture that are necessary. It is, however, said that none have yet been found equal to those obtained from the quarries of Solenhofen, near Pappenheim, in Bavaria, and that the lithographers of eminence in Paris use no other. In order to sustain the pressure used in taking impressions, a stone, 12 inches square, ought not to be less than 1¼ inch thick, and this thickness should increase with the area of the stone. The stones are first sawn to a proper size, and are then ground smooth and level by rubbing two of them face to face, with water and sand. They must be very carefully examined with a straight-edge, to ascertain that they are perfectly level in every direction. This applies only to the side which is afterwards to receive the drawing, as the natural division of the stone is sufficiently true for the back. When the stones have thus been ground perfectly level, they are well washed, to free them from any of the coarser grains of sand which may have been used in smoothing them. They are then placed on a board over a trough, and they are again rubbed face to face with sand and water, but with a sand of much finer texture than that previously used. The greatest care must be taken to have the sand sufficiently fine; and for this purpose it must be sifted through a small close sieve, as a single grain of sand of a coarser texture than the rest will scratch the stone, and these scratches will afterwards appear in the impression taken from the stone. When the stones have been rendered sufficiently fine, and their grain sufficiently smooth, they must then be carefully washed and afterwards wiped dry with a clean soft cloth. This is the plan adopted to prepare the stones for chalk drawings, but to prepare them for ink drawings or writings the following method is the best: After the process just described has been completed, the stones are well washed to get rid of the sand, and they are then rubbed together, face to face, with powdered pumice-stone and water. After they are made perfectly smooth, they are again washed and wiped dry, and are then separately polished with a large piece of pumice-stone.

To clean the stones after they have been fully used, sand is strewed over the surface, which is sprinkled with water and rubbed with another stone, until the writing or drawing upon it has completely disappeared. It must then be washed in aquafortis, diluted with twenty times its bulk of water, and the stone is then prepared for a new drawing or writing, by being rubbed with fine sand or pumice-stone as before. The longer drawings remain on stones the deeper the ink or the chalk penetrates into their substance, and consequently the more of the stone must be ground away to remove them; this is also more necessary with ink drawings or writings than with chalk, owing to the greater fluidity and consequent penetrability of the former.

The substances used by the artist upon the stone are either lithographic ink or lithographic chalk.

The ink for making transfers should be somewhat less burned, and therefore softer than that used for writing or drawing directly upon the stone.

Lithographic chalk should have all the qualities of a good drawing crayon. It should be even in texture, and carry a good point. The following proportions are recommended: 1½ oz. of common soap, 2 oz. tallow, 2½ oz. virgin wax, 1 oz. shell-lac. The rest of the process is the same as in making the ink. Less black should be mixed with the chalk than with the ink, its only use being to color the drawing, that the artist may see the lines he traces. When the whole is well mixed it should be poured into a mould and very strongly pressed, to expel any air that may collect in bubbles, which would render it spongy.

Mode of drawing.—Previous to drawing or writing, the stone must be well wiped with a clean dry cloth. The ink is rubbed with water, like Indian ink, and is almost wholly used on the polished stone. The chalk is used only upon the grained stone; the polished surface of the other would not hold it. In drawing with ink, a gradation of tints is obtained either by varying the thickness of the lines, or their distances from one another, as in engraving. The ink lines on polished stones, being solid and unbroken throughout, receive the printing all over; and if the lines be drawn as fine and as uniform as they are usually on copper, the print from them will be in no respect inferior; but it requires a greater degree of skill to execute as well upon stone as is usually done upon copper or steel.

In using chalk, the grained stone should be very carefully dusted, and the utmost attention be paid to prevent any lodgment of the smallest particle of grease upon the surface; personal cleanliness is therefore absolutely necessary to the perfection of his work, especially in chalk drawings. The chalk is used upon the stone precisely in the same manner as crayon upon paper; but it is of essential advantage in lithography to finish the required strength of tint *at once*, instead of going over the work a second time, the stone being impaired in its ability to receive the second lining clearly, by the absorption of the first. Some practice is requisite to use the chalk cleverly, as there has been no chalk hitherto made that will keep so good a point as is desirable. There is likewise some difficulty experienced in obtaining the finer tints sound in the impression; and in order to obtain the lighter tints properly, it will be necessary to put the chalk in a rest, as the metal-port crayon is too heavy to draw upon the stone. A good lithographer is in the habit, before he commences his subject, of pointing 20 or 30 pieces of chalk, stuck in quill-holders, and placing them beside the stone in a little box, taking them up successively as the points become worn off, so as to avoid, if possible, the cutting off chalk during the work, which endangers the soiling of the stone. When a very sharp and delicate line is required, he sharpens the point of the chalk upon paper, by pushing it forward in an inclined position, and twirling it round at the same time between the fore-finger and thumb. As the chalk softens by the warmth of the hand, it is quite necessary to have several pieces, to be able to change them. Some artists cut their chalk into the wedge form, as being stronger. Those portions that break off in drawing should be carefully taken off the stone by a camel-hair brush.

Preparation of the stone for printing.—The drawing being finished on the stone, it is sent to the lithographic printer, on whose knowledge of his art depends the success of the impressions. The first process is to *etch* the drawing, as it is called. This is done by placing the stone obliquely on one edge, over a trough, and pouring over it very dilute nitric acid. It is poured on the upper part of the stone, and runs down all over the surface. The stone is then turned and placed on the opposite edge, and the etching water being collected from the trough, is again poured over it in the same manner. The degree of strength, which is usually about one per cent. of acid, should be such as to produce a very slight effervescence; and it is desirable to pass the etching water two or three times over the darkest parts of the drawing, as they require more etching than the lighter tints. Experience alone can, however, guide the lithographer in this department of the art, as different stones and different compositions of chalk will be differently acted upon by the acid, and chalk drawings require a weaker acid than the ink. The stone is next to be carefully washed by pouring clean rain-water over it, and afterwards with gum-water; and, when not too wet, the roller charged with printing-ink is rolled over it in both directions, sideways, and from top to bottom, till the drawing takes the ink. It is then well covered over with a solution of gum-arabic in water, of about the consistency of oil. This is allowed to dry, and preserves the drawing from any alteration, as the lines cannot spread, in consequence of the pores of the stone being filled with the gum. After the etching it is desirable to leave the stone for a day, and not more than a week, before it is printed from. The effect of the etching is first to take away the alkali mixed with the chalk or ink, which would make the drawing liable to be affected by the water, and, secondly, to make the stone refuse more decidedly to take any grease. The gum assists in this latter purpose, and is quite essential to the perfect preparation of the surface of the stone.

Printing.—When the intention is to print from the stone, it is placed upon the platen or bed of the press, and a proper sized scraper is adjusted to the surface of the stone. Rain-water is then sprinkled over the gum on the stone, which being dissolved gradually, and a wet sponge passed lightly over all, the printer works the ink, which is on the color-table placed beside him, with the roller in all directions, until it is equally and thinly spread on the roller. The roller is then passed over the whole stone, care being taken that the whole drawing receives a due portion of ink; and this must be done by giving the roller an equal motion and pressure, which will of course require to be increased if the drawing does not receive the ink readily. When the drawing is first used it will not receive the ink so readily as it will afterwards; and it is frequently necessary to wet the stone, and roll it several times, before it will take the ink easily. After this takes place care must be taken not to wet the stone too much; the dampness should not be more than is necessary to prevent the ink adhering to the stone where there is no drawing. After the drawing is thus rolled on, the sheet of paper is placed on the stone, and the impression taken. Upon taking the paper off the stone, the latter appears to be quite dry, owing to the paper having absorbed the moisture on the surface; it must therefore be wetted with a sponge, and again rolled with ink, the roller having been well worked on the color-table before being applied. During the printing some gum must always remain on the stone, although it will not be visible, other wise the ink will be received on the stone as well as on the drawing, by which the latter would be spoiled; so that if by too much wetting, or by rubbing too hard with the sponge the gum is entirely removed, some fresh gum-water must be laid on. If the stone has in the first instance been laid by with too small a quantity of gum, and the ink stains the stone on being first applied to it, gum-water must be used to damp the stone, instead of pure water. Sometimes, however, this may arise from the printing-ink being too thin, as will afterwards appear. If some spots on the stone take the printing-ink, notwithstanding the above precautions, some strong acid must be applied to them with a brush, and, after this is washed off, a little gum-water is dropped in the place. A steel point is here frequently necessary to take off the spots of ink. The edges of the stone are very apt to get soiled, and generally require to be washed with an old sponge after rolling in; they must also frequently have an application of acid and gum, and sometimes must be rubbed with pumice-stone. If an ink is too thin, and formed of a varnish not sufficiently burned, it will soil the stone, notwithstanding the proper precautions are taken of wetting the stone, and preparing it properly with acid and gum; and if, on the other hand, the ink is too thick, it will tear the lighter tints of the chalk from the stone, and thus destroy the drawing. The consideration of these circumstances leads at once to the

Principles of the printing.—The accidents just mentioned arise at the extreme points of the scale at which the printing-inks can be used, for it is evident that the only inks that can be used are those which are between these points; that is, thicker than that which soils the stone, and, at the same time, thinner than that which takes up the drawing. Lithographers are sometimes unable to print in very hot weather, the reason of which may be deduced from the foregoing. Any increase of temperature will diminish the consistency of the printing-ink; the stone will therefore soil with an ink which could be safely used at a lower temperature—hence a stiffer ink must be used. Now, if the temperature should increase so much that the stone will soil with any ink at all less thick than that which will take up the drawing, it is evident that the printing must cease till a cooler temperature can be obtained; for as the drawing-chalk is affected equally with the printing-ink, the same ink will tear up the drawing at the different degrees of temperature. This, though it sometimes occurs, is a rare case; but it shows that it is desirable to draw with a chalk or ink of less fatness in summer than in winter, and also that if the printing-room is in winter artificially heated, pains should be taken to regulate the heat as equally as possible.

Other difficulties in printing, not referable to the foregoing general principle.—If the pressure of the scraper be too weak, the ink will not be given off to the paper in the impression, although the drawing has been properly charged with it. Defects will also appear from the scraper being notched, or not correctly adjusted, or from any unevenness in the leather or paper. After printing a considerable number of impressions, it sometimes happens that the drawing takes the ink in dark spots in different parts. This arises from the printing-ink becoming too strongly united with the chalk or ink of the drawing, and if the printing be continued, the drawing will be spoiled. The reason of this is easily ascertained. The printing-ink readily unites with the drawing, and being of a thinner consistency, it will, by repeated applications, accumulate on the lines of the drawing, soften them, and make them spread. In this case it is necessary to stop the printing, and let the stone rest for a day or two, for the drawing to recover its proper degree of hardness. If the drawing should run smutty from any of the causes before enumerated, the following

Mixture for cleaning the drawing while printing must be used: Take equal parts of water, spirits of turpentine, and oil of olives, and shake them well together in a glass vial until the mixture froths; wet the stone and throw this froth upon it, and rub it gently with a soft sponge. The printing-ink will be dissolved, and the whole drawing will also disappear, though, on a close examination, it can be distinguished in faint white lines. On rolling it again with printing-ink the drawing will gradually reappear, as clear as at first.

Bleached paper unfit for lithographic printing.—Accidents sometimes occur in the printing from the qualities of the paper. If the paper has been made from rags which have been bleached with oxymuriatic acid, the drawing will be incurably spoiled after thirty impressions. Chinese paper has sometimes a strong taste of alum; this is so fatal as sometimes to spoil the drawing after the first impression. When the stone is to be laid by after printing, in order that it may be used again at a future period, the drawing should be rolled in with a

Preserving ink—as the printing-inks would, when dry, become so hard that the drawings would not take fresh printing-ink freely. The following is the composition of the printing-ink: Two parts of thick varnish of linseed oil, four parts of tallow, one part of Venetian turpentine, and one part of wax. These must be melted together, then four parts of lamp-black, very carefully and gradually mixed with it; and it must be preserved for use in a close tin box.

Autographic ink, or that which is suitable for transferring on to the stone the writings or drawings which have been executed on paper prepared for that purpose, should possess the following properties: The ink ought to be mellow, and somewhat thicker than that used immediately on stone; so that when it is dry on the paper, it may still be sufficiently viscous to cause adherence to the stone by simple pressure. The following is the composition: Dry soap, and white wax free from tallow, each 100 drachms, mutton suet, 30 drachms, shell-lac and mastic, each 50 drachms, lamp-black, 30 to 35 drachms; these materials are to be melted together.

Autographic paper.—The operation by which a writing or drawing is transferred from paper to stone, not only affords the means of abridging labor, but also of producing the writings or drawings in the same directions in which they have been traced; whereas, when they are executed immediately on stone, they must be performed in a direction opposite to that which they are eventually to have. Thus it is necessary to draw those objects on the left, which, in the impression, are to be on the right hand. To acquire the art of reversing subjects when writing or drawing, is both difficult and tedious; while, by the aid of transparent, and of autographic paper, impressions may be readily obtained in the same direction as that in which the writing or the drawing has been made. In order to make a transfer on to stone of a writing, or drawing in lithographic ink, or in crayons, or an impression from a copper plate, it is necessary, 1st, that the drawing or transcript should be on a thin and flexible substance, such as common paper; 2d, that it should be capable of being easily detached from this substance, and transferred entirely on to the stone, by means of pressure. But as the ink with which a drawing is traced penetrates the paper to a certain depth, and adheres to it with considerable tenacity, it would be difficult to detach them perfectly from each other, if, between the paper and the drawing, some substance was not interposed, which, by the portion of water which it is capable of imbibing, should so far lessen their adhesion to each other, that they may be completely separated in every point. It is to effect this that the paper is prepared, by covering it with a size, which may be written on with facility, and on which the finest lines may be traced without blotting the paper. Various means may be found of communicating this property to paper. The following preparation has always been found to succeed, and which, when the operation is performed with the necessary precautions, admits of the finest and most delicate lines being perfectly transferred, without leaving the faintest trace on the paper. For this purpose, it is necessary to take a strong, unsized paper, and to spread over it a size prepared of the following materials: starch, 120, gum-arabic, 40, and alum, 21 drachms. A moderately thick paste is made with the starch, by means of heat; into this paste is thrown the gum-arabic and the alum, which have been previously dissolved in water, and in separate vessels. The whole is mixed well together, and it is applied warm to the sheets of paper, by means of a brush, or a large flat hair-pencil. The paper may be colored by adding to the size a decoction of French berries, in the proportion of ten drachms. After having dried this autographic paper, it is put into a press, to flatten the sheets, and they are made smooth by placing them, two at a time, on a stone, and passing them under the scraper of the lithographic press. If, on trying this paper, it is found to have a tendency to blot, this inconvenience may be remedied by rubbing it with finely powdered sandarac. Annexed is another recipe, which will be found equally useful, and which has the advantage of being applicable to thin paper, which has been sized. It requires only that the paper be of a firm texture: namely, gum-tragacanth, 4 drachms; glue, 4; Spanish-white, 8; and starch, 4 drachms.

The tragacanth is put into a large quantity of water to dissolve, thirty-six hours before it is mixed with the other materials; the glue is to be melted over the fire in the usual manner. A paste is made with the starch; and after having, whilst warm, mixed these several ingredients, the Spanish-white is to be added to them, and a layer of the sizing is to be spread over the paper, as already described, taking care to agitate the mixture with the brush to the bottom of the vessel, that the Spanish-white may be equally distributed throughout the liquid. We will hereafter point out the manner in which it is necessary to proceed, in order to transfer writings and drawings. There are two autographic processes which facilitate and abridge this kind of work when it is desired to copy a fac-simile, or a drawing in lines. The first of these methods is to trace, with autographic ink, any subject whatever, on a transparent paper, which is free from grease and from resin, like that which, in commerce, is known by the name of *papier végétal*, and to transfer it to stone; this paper to be covered with a transparent size: this operation is difficult to execute, and requires much address, in consequence of the great tendency which this paper has to cockle or wrinkle when it is wetted. Great facilities will be found from using tissue paper, impregnated with a fine white varnish, and afterwards sized over. In the second process, transparent leaves, formed of gelatin, or fish glue, are employed, and the design is traced on them with the dry point, so as to make an incision; these traces are to be filled up with autographic ink, and then transferred. We will describe, in their proper places, these processes, as well as that of transferring a lithographic or a copper-plate engraving.

Autographic processes.—To transfer a drawing or writing to stone, it is made with ink on paper, both prepared in the way we have described. A crayon drawing may, on an emergency, be executed autographically; but this mode of procedure is too imperfect to admit of procuring, by its means, neat and perfect proofs; besides, it is as expeditious to draw immediately on the stone.

In order to write, or to draw on autographic paper, a little of the ink of which we have given the composition is diluted with water, taking care to use only rain-water, or such as will readily dissolve soap. The solution is facilitated by slightly warming the water in the cup; and the ink is dissolved by rubbing the end of a stick of it in the manner practised with Indian ink. There should be no more dissolved at a time than will be used in a day, for it does not redissolve so well, neither is the ink so good, particularly for delicate designs, after it has been left to dry for several days. This ink should have the consistence of rather thick cream, so that it may form very black lines upon the paper: if these lines are brown, good impressions will not be obtained. A sheet of white paper is placed under the hand while writing, in order that it may not grease the autographic paper.

The stone used for autography should be polished with pumice-stone, and the impressions will be neat in proportion as the stone is well polished. Autographic work may be executed either cold or warm; that is, taking the stone at its ordinary temperature, or making it warm by placing it near to the fire, or exposing it to the heat of the sun: if the first means of warming be used, care must be taken that the fire be not too hot, or it will crack the stone; the temperature given to it should be about that of an earthen vessel filled with lukewarm water. The work may be done, though less perfectly, without warming the stone. When the stone is thus prepared, it is fixed in the press, and the paper on which the writing is made is applied to it. The stone may be rubbed with a linen cloth, slightly moistened with spirits of turpentine; and in every case it is necessary that it be made perfectly clean. The turpentine is left to evaporate; and from five to eight minutes before the paper is applied, it is wetted with a sponge and water on the reverse side to that on which the writing is done, so that the moisture may penetrate throughout every part. The water, however, must not appear on the paper when it is about to be laid on the stone; but any superabundance which may remain on it must be removed by a pressed sponge. When the paper is brought to the proper state, it is taken by both hands at one of its extremities, and placed lightly and gradually upon the stone, so that there may be no plaits formed in it, and that it may be equally applied over its whole surface. Care must be taken so to fix the scraper that it may bear steadily on the autographic paper; for if it removes it at all it will change the place of pressure, and the lines will be doubled. There should be at hand five or six sheets of very even mackle paper, so that they may be changed with each impression. The paper on which the writing or drawing is made being placed on the stone, it is covered with a sheet of mackle paper, and subjected to a slight action of the press; then to a second, a third, or even to more, until it is believed that the writing is perfectly transferred. At each stroke of the press the mackle paper, which has imbibed moisture, is withdrawn, and a dry sheet substituted in its place. All these operations require to be performed with expedition and dexterity, particularly when the stone is warm. The next thing is to detach the autographic paper, which will be found adhering closely to the stone. To effect this, it is well wetted with a sponge, so that every part of it may be perfectly penetrated by the water; it may then be removed with facility, entirely detached from the writing, which will remain adhering strongly to the stone. If this operation, which requires much practice, be well performed, there will not be found the slightest trace of ink remaining on the paper. Should there be any lines not well marked on the stone, they may be retouched with a pen; or, which is better, with a hair-pencil and ink; but when this is done, care must be taken that the stone is quite dry. A part of the sizing of the paper may be found dissolved and adhering to the stone; this may be removed by washing or slightly rubbing it with a wet sponge. The stone is then prepared with aquafortis, and the impression taken.

Autography is not confined to the transferring of writings or drawings done with autographic ink; by its means a transfer may be obtained from a sheet of ordinary printed paper, and with such exactness, that it would be impossible, excepting to well-practised eyes, to perceive the least difference between that printed in the usual way, and that which was the result of the autographic process. This mode is very useful when it is desired to unite Oriental characters, which might not be possessed with words, phrases, or lines composed in ordinary typography. In this way have been executed, in the office of the Count M. C. de Lasteyrie, at Paris, (from whose papers on this subject, contained in the *Journal des Connaissances Usuelles*, and translated by the learned editor of the *Franklin Journal*, our account of this art is largely indebted,) many pieces, in which the French or the Latin language was intermixed with words or phrases in Chinese or Arabic. In the same way have also been executed typographic maps, in which all the details were lithographic, while the names of places were at first produced by typography, and afterwards by autography. This operation is begun by composing and arranging, in a typographic form, the words, the phrases, or the lines, as they ought to stand. The autographic paper is printed on by this form, and the words in the Oriental languages are afterwards written in the spaces which have been left for them; the whole is transferred to a stone, which is prepared for the purpose, and from which the impression is taken in the usual manner. The same mode is pursued in making geographical maps. After having printed the names on autographic paper, the other parts of the map, but without the names, are drawn immediately on the stone; and after having printed the names on white paper, the map drawn upon the stone is printed on this same paper.

Maps, or line engravings on copper, where the work is not very close, may be multiplied in a similar way. For this purpose the plate of copper is covered over with the autographic ink, diluted to a convenient consistence. Instead of the autographic ink, a composition is sometimes used, made of one ounce of wax, one ounce of suet, and three ounces of the ink with which the ordinary impressions in lithography are taken. The whole is warmed and mixed well together, and there is a little olive-oil added to the composition, if it is not liquid enough to spread itself over the plate; the plate ought to be warmed as usual. After having taken the impression in the rolling-press on a sheet of autographic paper, the transfer may be immediately made on to the stone, after having rubbed it with a sponge, dipped in turpentine. It is necessary to give three, four, or even more strokes of the press, increasing the pressure at every successive stroke; the other processes, which we have already described, are likewise to be followed. It is well to wait twenty-four hours before *preparing* the stone, in order that it may be better penetrated by the transferring ink; it is then gummed and washed, and is ready for use. This process, which has not yet come much into use amongst lithographers, merits the attention of artists; for it affords the means of reproducing and multiplying geographical charts, and some kinds of engravings indefinitely, so that they might be furnished at a quarter of their present actual value; in fact, all those which are done in lines, or those in which the shadows are boldly executed, are capable of reproducing good impressions by means of autography. The operation becomes extremely difficult when it is necessary to transfer fine line engravings; the lines of these are so delicate, and so near to each other, that they either do not take well on the stone, or are apt to be crushed and confounded together by the effect of the pressure. Much practice and address are necessary to obtain tolerable impressions; and this part of the art requires improvement. In the office of M. de Lasteyrie, they had succeeded in transferring to stone a small highly finished engraving, which had been printed on common half-sized paper. After having dry-polished a stone very perfectly, it was warmed, rubbed with spirits of turpentine, and then the engraving was applied to it. This had, however, been previously dipped into water, then covered on the reverse side with turpentine, passed again through the water, so as to remove the superfluous turpentine, and then wiped with unsized paper. In this state the engraving, still damp with the turpentine, was applied to the stone and submitted to pressure, when it afforded very good impressions; the *preparation* not being applied until it had remained on the stone for twenty-four hours. The difficulties increase, of course, in proportion to the size of the engravings which it is desired to transfer to the stone. Attempts have been made to transfer old engravings; they have, however, succeeded but imperfectly. It would be rendering an essential service to the art to discover a mode of reproducing old engravings by means of autography; the undertaking presents difficulties, but from the attempts made, success does not seem improbable.

Printing from two or more stones with different colored inks.—This is managed by preparing a composition of two parts of wax, one of soap, and a little vermilion. Melt them in a saucepan, and cast them into sticks; this must be rubbed up with a little water to the thickness of cream, and applied to the surface of a polished stone. An impression is taken in the common way from a drawing, and applied to a stone prepared in this manner, and passed through the press, taking care to mark, by means of this impression, two points in the margin corresponding on each of the stones. The artist, having thus on the second stone an impression from the first drawing to guide him, scrapes away the parts which he wishes to remain white on the finished impression. The stone must now be etched with acid stronger than the common etching water, having one part of acid and twenty of water; the whole is then washed off with turpentine: this plan is generally used in printing a middle tint from the second stone; the black impression being given from the first stone, a flat transparent brownish tint is given from the second, and the white lights are where the paper is left untouched. The dots are necessary to regulate the placing of the paper on the corresponding parts of the two stones.

LOCKS. *From the Proceedings of the Institution of Mechanical Engineers.* It was conceded about twelve years since in the United States, by all locksmiths, that a lock having a series of tumblers or slides, such as was used at that time in Europe, and more particularly those of Barron and Chubb, was secure against all known means of picking, or of forming a false key by any knowledge that could be obtained through the key-hole. The only point that seemed desirable was to make it secure against the maker, or any party who might have had possession of the key, and from it taken an impression.

The first step, therefore, was to construct the lock so that the party using it could change its form at pleasure. Mr. Andrews constructed a lock similar to that made by Mr. Chubb, having a series of tumblers and a detector; but before placing the lock on the door, the purchaser could arrange the tumblers in any way, so that the combination suited his convenience; the key being made with a series of movable bits, was arranged in a corresponding combination with the tumblers. In order to make a change in the lock without taking it from the door, each tumbler was so constructed that *in locking the lock* the tumbler could be raised, or drawn out with the bolt. A series of rings was furnished with the key, corresponding with the thickness of the movable bits of the key; and any one, or as many more of the bits could be removed from the key, and rings substituted. These bits being removed, and the rings taking their place, the corresponding tumblers would not be raised by the turning of the key, and consequently would be drawn out with the bolt, (*becoming, in fact, a portion of the bolt itself.*) Therefore, when a bit was removed and a ring substituted, so much of the security of the lock was lost as depended on the tumbler that was not raised; consequently, a lock having twelve tumblers, being locked with a key with alternate bits and rings, would evidently become a six-tumbler lock; but should a tumbler that was drawn out with the bolt be raised in the attempt to pick or unlock it, or should any one of the *acting tumblers* be raised too high, the detector would be thrown, and prevent the withdrawing or unlocking of the bolt. This lock was in great repute in the United States, and was placed on the doors of nearly all the principal banking establishments of the country; a large reward was offered by its maker to any one who could pick it; and from its great repute it consequently called out many rivals.

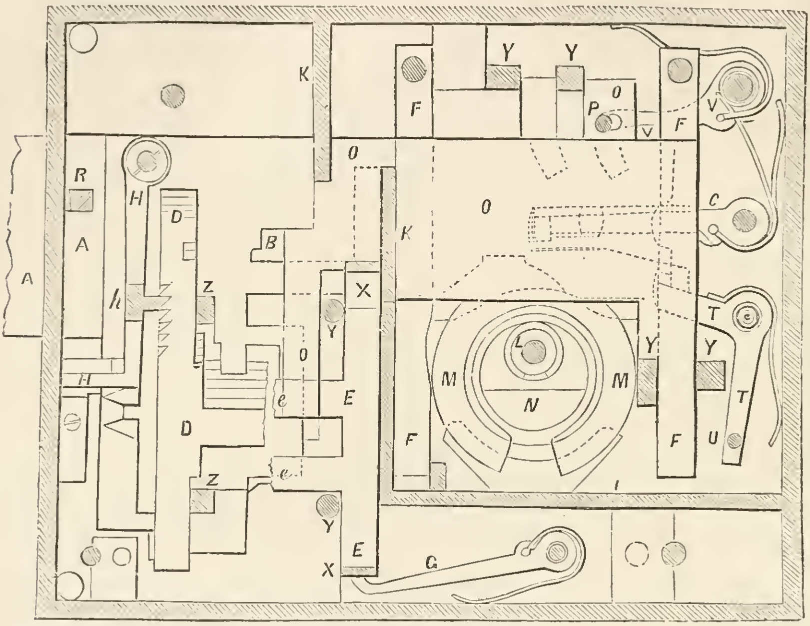
Mr. Newell constructed what he termed his Permutating Lock, which was composed of a series of first and secondary tumblers, the secondary series being operated upon by the first series. Through the secondary series there was passed a screw termed a clamp-screw, having a clamp overlapping the tumblers on the inside of the lock; each tumbler in the series having an elongated slot to allow the screw to pass through. On the back side of the lock was a small round key-hole, in which the head of the screw rested, forming, as it were, a receptacle for a small secondary key; so that when the large key gave the necessary form to the tumblers, the party took the small key and operated on the clamp screw, clamping and holding together the secondary series, retaining them in the relative heights or distances imparted to them by the large key; the door was then closed, and the bolt projected, and the first series of tumblers fell again to their original position. The objection to this mode of constructing a lock was, that it required the insertion of the small secondary key; and should the party neglect to release the clamp-screw every time he unlocked the lock, the first series of tumblers would be held up by the secondary series. Consequently, an exact impression of the lengths of the several bits of the key could be obtained through the key-hole while the lock was unlocked. This lock and Mr. Andrews' were both picked by Mr. Newell, who demonstrated that this lock as well as all others based on the tumbler principle was insecure.

The first step taken to make a secure lock, was to add a series of complicated wards to the locks; but it will be readily seen, that what can be reached with a key, could be reached by some other instrument; and, although it required an instrument of a different form, yet the operation was just as certain and fatal to the security of the lock.

The next step taken, and one which was considered effectual, for a time, was the notching of the abutting parts of the first and secondary series of tumblers, or of the stump face and the ends of the tumblers. So that if a pressure was put upon the bolt, the tumblers could not be successively raised by the picking instrument, being held fast by these "false notches." This lock baffled the skill of all the country for a time, and was considered perfectly safe, until an ingenious engineer of the name of Pettis picked this lock.

The Parantoptic Lock was then invented by Mr. Newell, retaining all that was deemed good in the locks previously made, and, at the same time, guarding against all the defects proved by actual experiment.

The annexed figure shows it locked, with the cover and the detector-plate removed, and the auxiliary tumbler in its place; A A is the bolt; B B are the first series of movable slides or tumblers; C, the tumbler springs; D D the secondary series of tumblers; and E E the third or intermediate series, which form the connections between the first and secondary series of tumblers; F F are the separating plates between the first series of tumblers; G, the springs, for lifting the intermediate slides or tumblers to make them follow the first series when they are lifted by the key. On each of the secondary tumblers D D, is a series of notches, corresponding in distance with the difference in the lengths of the movable bits of the key; and as the key is turned in the lock to lock it, each bit raises its tumbler, so that some one of these notches presents itself in front of the tooth *h*, on the dog or lever H H. As the bolt A is projected, it carries with it the secondary tumblers D D, and presses the tooth *h* into the notches in the tumblers, withdrawing the tongues *d*, from between the jaws *e e*, of the intermediate tumblers E E, and allowing the first and intermediate tumblers to fall to their original position: whilst the secondary tumblers D D, are held in the position given to them by the key, by means of the tooth *h* being pressed into the several notches, as shown. Should an attempt be made to unlock the bolt with any but the true key, the tongues *d* will abut against the jaws *e e*, preventing the bolt from being withdrawn; and should an attempt be made to ascertain which tumbler binds and requires to be moved, the secondary tumbler D D, that takes the pressure, being behind the iron wall I K, which is fixed completely across the lock, prevents the possibility of its being reached through the key-hole, and the first tumblers B B are quite detached at the time, thereby making it impossible to ascertain the position of the parts in the inner chamber behind the wall I K. The portion I I of this wall is fixed to the back plate of the lock, and the portion K K to the cover.



L is the drill pin on which the keys fits; and M M is a revolving ring or curtain, which turns round with the key, and prevents the possibility of inspecting the interior of the lock through the key-hole; and should this ring be turned to bring the opening upward, the detector plate is immediately carried over the key-hole S, by the motion of the pin P upon the auxiliary tumbler O O, which is lifted by the revolution of the ring M, thereby effectually closing the opening of the key-hole. As an additional protection, the bolt is held from being unlocked by the stud R bearing against the plate Q; also the lever T T holds the bolt when locked until it is released by the tail of the detector-plate Q pressing the pin U. V is a dog, holding the bolt on the upper side when locked, until it is lifted by the tumblers acting on the pin W. X X are the separating plates between the intermediate tumblers E E; Y and Z are the studs for preserving the parallel motion of the different tumblers.

There are several features in the construction of this lock which are deserving of particular attention. The most novel and extraordinary is, that the lock changes itself to the key; in whatever form the movable bits on the key are changed, the lock answers to that form, without moving any part of it from the door.

The party purchasing the lock can change it to suit his convenience. If a 6-tumbler lock, to 720; if 7 tumblers, 5,040; if 8, 40,320; if 9, 362,880; if 10, 3,628,800; and if 12, 479,001,600. Therefore it will be perceived that, by changing the numerical position of the bits in the key, the lock can be altered, or in fact alters itself to any number of new locks, equal to the permutation of the number of bits on the key. Two extra bits are supplied with each key, which add very greatly to the number of changes. As the key turns round, each bit raises its tumbler to a point corresponding with its length, imparting to the first and secondary series the exact form of the key. The secondary series of tumblers being carried out with the bolt, and the tooth on the lever or dog being pressed into the several notches on the front face of the secondary series, holds them in the position given them by the key, while all the other portions of the lock fall again to their original position.

Should a pressure be put on the bolt to ascertain the obstruction, it will be readily seen that it will be brought to bear on the third or intermediate tumblers. To prevent the possibility of reaching these, there is a wall of metal fixed across the lock, which confines the operator wholly to the key-chamber. By detaching the portion of the tumbler that takes the pressure given to the bolt, from the parts that can be reached through the key-hole, leaving that portion always at liberty, the possibility of ascertaining what is wrong is cut off; so that instead, as in the former lock, having only a first and secondary series, Mr. Newell here introduced a third or intermediate series; thereby throwing the whole security of the lock into a chamber beyond the wall of metal, which is wholly inaccessible, and forming as it were another lock without a key-hole. These are the principal features of security in Mr. Newell's Parautoptic Lock.

There is another source of insecurity that has still to be provided against; when the first tumblers can be seen through the key-hole, if the under side of them is smoked by inserting any flame, the key will leave a distinct mark upon each tumbler the next time it is used, showing where it began to touch each tumbler in lifting it. This can be seen by inserting a small hinged mirror into the lock through the key-hole, and the exact length of each bit of the key measured, from the centre-pin to the point where it touched the particular tumbler, from which a correct copy of the key can be made. (An electric light from a small portable battery, has been employed for this purpose, to illumine the interior of the lock.)

The possibility of seeing the tumblers is entirely prevented, by surrounding the inside of the key-hole with a ring or revolving curtain; and when this curtain is turned, to bring the opening opposite the tumblers, the key-hole is shut on the outside by the detector tumbler, which tumbler would also detect all attempts at mutilating the interior parts of the lock.

Should the lock be charged with gunpowder through the key-hole, for the purpose of blowing it from the door, the plug in the back of the key-chamber yields to the force, leaving the lock uninjured, whilst the curtain protects the interior of the lock from injury, thereby effectually preventing all known means of opening or forcing the lock.

LOCKS OF CANALS. A contrivance by which boats may pass from a lower to a higher level, or the reverse, by the buoyancy of the water.

The least length that can be allowed between the locks should be such that 12 inches of depth, over and above what a loaded boat will draw, will only lower the water 6 inches without the navigation being interrupted; and if it be required to draw the contents of each lock from the interval above, the distance for the locks must be so regulated that the quantity of water expended by one should not lower that of the upper interval more than 6 inches at most: thus the distance should be greater in proportion to the contents of the chamber of the locks and the width of the canal; that is to say, when the chambers are large and the canal is narrow, the distance between the locks should be greater. Chambers 110 feet in length between the gates, by 17 feet in width, contain 1870 superficial feet; therefore 11,843 cubic feet when the fall is 6 feet 4 inches, 15,859 cubic feet when it is 8 feet 6 inches, and 19,635 cubic feet when 10 feet 6 inches. If the canal be 48 feet in width, at 3 feet below the ordinary level of the water, the length of the interval should be 446 feet, in order that the expenditure of locks of 6 feet 4 inches of fall should not lower the water more than 6 inches; this length should be 607 feet when the locks are 8 feet 6 inches of fall, and 755 feet when they are 10 feet 6 inches: the distance then between the lower gate of one lock, and the upper gate of the other, should be always about 624 feet for ordinary canals. If two locks of 8 feet 6 inches fall were only distant 160 feet, the water drawn from the interval, for the purpose of mounting the boat, would lower it nearly 26 inches, and there would not remain sufficient to keep it afloat; consequently, it would be necessary to draw a lockful from the upper interval, and then a second, to cause it to rise, whilst only one would be required if the locks were at a sufficient distance.

This example will show the inconvenience of having locks too near each other, which is still further increased when they are contiguous. It frequently happens that several boats arrive together in the same interval, particularly where the bargemen stop or sleep, and that no water may be lost, the interval where they stop should be sufficiently long to admit more than one. If circumstances will not permit this, a greater width must be given, that the lockful which the rising boats draw from the interval should not cause the water to lower so considerably as to prevent their floating, or the descending boats force in such a quantity as to make it run over the gates. If the interval has only the ordinary width of 48 feet, it should be 6398 feet in length, so that ten rising boats could stop, if none were descending at the same time, otherwise a part of the water must be drawn from the other intervals to keep them afloat: if there were as many ascending as descending boats, this need not be so great, but this observation proves that in forming a canal it is necessary to have basins at those situations where boats are required to stop any length of time.

Quantity of water expended by boats in traversing a canal.—It was the opinion of MM. Gabriel and Abeille, that the passage of a boat through the whole length of a canal always cost twice the quantity of water necessary to fill a lock. Belidor thought the same, and it is still the common opinion. M. Thommason has nevertheless maintained that this idea is erroneous, and that when one boat passes several locks one after another, the second boat only expends two locksful in its whole passage; but when they pass alternately, one up and the other down, that it costs as many locksful as there are locks in the ascension of each boat. He founds this assertion on two statements, one of M. Caligny, the other of M. Regemorte, asserting that the expenditure of the water is the same, whether contiguous or separated; but this distinction not having been sufficiently examined, a second error has been committed; but it is undoubted that when locks are contiguous, they often expend more than two lock-ful; and it has not been remarked that when the locks are more than 640 feet apart, they often expend only a single lockful for the whole journey. When locks are distant from each other, and the boats pass alternately, one up and the other down, the boat which passes after the first frequently finds in mounting all the locks empty, and to fill them it must draw a lockful from each interval and one from the starting point; in descending, as it finds the locks full, it does not draw any from the starting point, consequently it will only expend a single lockful in its whole voyage.

When the locks are distant from each other, and the boats follow, the second boat will find all the locks full going up, and to ascend it must first empty all, and then fill them with water drawn from the intervals, and the highest from the starting point; in descending, all the locks will be empty, and the first lock will be filled with water from the starting point, which will serve to fill all the others, so that this boat will expend two lock-ful in its journey.

When the locks are so near each other that the water of one taken into the interval between the two diminishes the depth of this interval sufficiently to impede the navigation, or when the locks are contiguous and the boats pass alternately, the second boat in ascending finds all the locks empty, and as it cannot draw water from the intermediate intervals from the contiguity of the locks, all are filled with water from the starting point. Thus in ascending each boat expends as many locksful as there are contiguous chambers; in descending, all the locks being full, no water need be drawn from the starting point, consequently in a whole journey as many locksful may be expended as there are contiguous locks in ascending. When the locks are contiguous, and the boats pass each other in succession, the second in ascending will find all the locks full, and to enable it to enter the intervals, it must empty them successively to fill them with the water from the intervals, except the last, which it fills with water from the starting point; in descending, another lockful is taken from the starting point, so that in this case two locksful are taken from the latter.

Although the four above cases contain the whole theory of the working of locks, it may be remarked that if two boats meet at the starting point, and two others before or after the starting point, the four will expend five locksful; if two boats meet at the starting point, and the two following meet there also, the four will only expend four locksful; if the two last boats that have passed meet before or after the starting point, and the two succeeding meet also before or after the starting point, they then will only expend four locksful, had the first come in an opposite direction to that which had passed previously, and five if it had come in the same direction; and it has been generally observed, that a boat always takes a lockful from the starting point to ascend, but that it often does not take any to descend on the other side: consequently, when there are no contiguous locks, the boats will only expend a lockful for their whole journey, when they pass the starting point alternately, one going up, the other down: in like manner, where there are contiguous locks, the boats will expend in their journey as many locksful as there are contiguous locks in ascending; when one boat follows another, it will expend two locksful, whether the locks are contiguous or isolated. It must be remarked that the passage of those boats only can be considered relatively to the locks which join the starting point. When the locks are not contiguous, and their fall is equal, which happens in the lower intervals, it has no influence on the expenditure of water, especially when the boats do not stop any length of time; in giving 640 feet length to each interval, it is evident, when two boats follow each other, they will never be together in the same interval, since, while the second passes the lock, the first will have time to pass the interval and enter the following lock; thus two boats cannot meet in the smaller intervals, except when one ascends and the other descends, and in this case, as one takes a lockful from the interval, while a second pours one into it, consequently the water does not diminish or increase in it. It must be observed that we can never have above a lockful, more or less, in an interval, unless several boats remain in them together, which should be avoided when they are small; further, when the contiguous locks are distant from the starting point, it often happens that the lockful is not immediately taken; but when there is no second quantity of water before the contiguous locks, it is always the starting point which furnishes that of the canal above them.

Form to be given to the chambers of locks.—The most convenient is the parallelogram, a little wider than the boats that require to pass, and sufficiently long to admit of the gates being moved with facility. The chambers of the canal of Languedoc are of an oval form, to give greater strength in resisting the banks contiguous to them; but as this causes an increase of expense in construction as well as in the quantity of water necessary to fill it, it will be useful to inquire if, in avoiding one inconvenience, a greater is not produced. The oval chambers of the canal of Languedoc contain an area of 3636 feet, while if the side walls were parallel, they would only be 2248 superficial feet. Thus the expenditure of water in the oval chamber exceeds more than a third that of the parallelogram, the proportion being about 5 to 3. The inconvenience is considerably increased by want of water, which frequently occurs Another result of the oval form is, that the passage of the lock is also longer than in the rectangular; in the same proportion the expense of the timber platform is also increased. It is, however, certain that a curved wall is stronger against a pressure of earth than a straight one, and if the cost of masonry requisite to give the same strength to a straight wall is greater, the expense is compensated for by the diminution of the cost of the timber platform, which is two-fifths stronger. It is very essential to prevent the filtration of water through the side walls, and the best method to effect this is to place on their thickness a lining of beton, or of brick laid in cement, which will be impervious to water; but as this will destroy the bond, a greater thickness of wall is requisite; thus there are many circumstances where it might be necessary to give to curved walls as great a thickness as to straight. The thickness of straight walls which support earth should be a third of their height, while those which resist the thrust of water should be one-half; if the walls of the chambers of locks have a thickness relative only to the thrust of the earth, they may give way when the earth is put in motion, which often occurs from a slight filtration behind the wall. Gauthey has a rule for finding the thickness to be given to the wall of a basin intended to support water throughout its whole height, and in the chambers of locks it must be remembered that the thrust of the water against the vertical surface is equal to the product of these surfaces by half the height of the water. Call h the height of the wall, $x =$ its thickness, supposing its length to be 1 metre, the acting power will be $1000 \times \frac{1}{2} h^2$; supposing the cube metre of water to weigh 1000 kilogrammes, and the centre of impression of this thrust being at a third of the height of the wall, the arm of the lever of the acting power will be equal to $\frac{1}{3} h$.

The resisting power will be the wall itself $= h\,x \times 2000$, supposing that the cube metre of masonry generally weighs 2000 kilogrammes. The arm of the lever will be half the thickness of the wall $= \frac{1}{2} x$, consequently the momentum of the acting power will be $1000 \times \frac{1}{2} h^2 \times \frac{1}{3} h$, and that of the resisting power $2000 \times \frac{1}{2} h\,x^2$; and as in the state of equilibrium these two powers should be equal, we shall have $167\,h^3 = 1000\,h\,x^2$, from whence we have $x = \sqrt{0{\cdot}167\,h^3} = 0{\cdot}41\,h$; but as something should always be allowed above the equilibrium, by adding $\frac{1}{5}$, we shall have $x = \frac{1}{2} h$ nearly. Hence it is evident that the thickness of a wall intended to support water should be at least equal to half the height of the water which acts against it.

The length and width of chambers of locks must necessarily be regulated in conformity with the boats used on the canal; these are generally longer and narrower than those on rivers, where the shallows which occasionally occur require flatter bottoms to be given them. With regard to the length of the chambers, it should be such as to enable the gates at the lowest ends to open and shut easily; if the rudder of the boat cannot be unshipped, or occupies any portion of the length of the chamber, then the chambers must be made sufficiently long to prevent them from interfering with the opening of the gate, on which account the most proper rudders for navigable canals are those like broad oars, which can be taken out while passing through the locks. The height of the water in the intervals is regulated by the mean height of the waters of the river which communicate with the canals. It is, however, customary to allow the latter a sufficient height of water to receive boats of the same tonnage as those which navigate the river; another advantage in giving an extra depth of water to canals is the greater ease with which the boats can be drawn, the weeds at the bottom causing less inconvenience, and the evaporation being of course less than in a shallower body of water; in summer also, when the boats can only carry half a load, two loads may be put into one boat, and the transport rendered less expensive.

The quantity of water expended by locks is found to be in direct proportion to the height of the fall, and the time employed in going through them, and the expense of construction nearly in the same proportion; this is greater as the locks are least elevated, because they are more in number, but the increase is not in proportion to the number.

Gates of locks are composed of two posts placed vertically, and united by horizontal rails; the former, being supported throughout their height, are not subject to much wear, although they are of larger scantling than the other timbers of the gate, which is necessary, as they sustain the entire framework. The horizontal rails resist the weight, and as that weight is greater where the rails are placed below the level of the water, it would seem natural that their dimensions should vary in proportion to the weight. To determine these dimensions it must be recollected that the thrust of water against vertical surfaces is equal to the weight of a prism of water having its surfaces as a base, and its height half that of the water. It must next be considered that the rails of the gate are at least 26 inches apart, and 38 inches from centre to centre, so that, on account of the casing of plank in the first instance, 12 inches of height support 26 inches of water, and in the second 38 inches. The weight supported by each rail will be found by multiplying their length, the interval from one to the other, the height of the water above the centre of the rail, and the whole by 62 pounds, the weight of a cube foot of water; the product of these measures will be the number of pounds which the rails ought to support throughout their whole length.

Timbers from 4 to 5 inches square would be sufficient for small gates, and for larger from 8 feet 6 inches to 10 feet 6 inches of fall; with a width of 17 feet between the hanging-posts, the rails would be sufficiently strong if from 7 to 8 inches square, putting six rails in the height. They are generally from 9 to 10 inches at least, which is double the strength required; it is true that the gates are more durable, but the weight is greater, which is sometimes injurious to the collar and the masonry to which it is attached, requiring more reparations than lighter gates.

The frames or styles of gates should be at least 5 inches in thickness more than the rails, and the joint covered by a fillet, as well as the edge of the planks, which are affixed perpendicularly to the rails, and mortised into the styles, increasing the strength of the rails and the framework by their greater thickness. Braces are also introduced between the rails, which aid materially in strengthening them, and by their inclined position transfer the stress to the hanging-post.

Great gates should always have a line of braces placed diagonally, and making an angle with the lower rail; all the braces above should have the same effect, and consequently the same inclination; those below resting on the lower rail tend to depress it, and, even when properly framed and pinned into the rails, their inclination towards the hanging-post renders them insufficient to sustain the lower rail; but they may be made useful by giving them an inclination in a contrary direction, and uniting them by pins to the rails.

Instead of inclining the braces below the diagonals on the side of the strutting-post, a bar of iron is sometimes placed diagonally from the collar to the lower end of the strutting-post, which is an excellent contrivance; or the planks may be placed diagonally, inclining them from the side of the hanging-post, and crossing them solidly, especially that of the diagonal above the hanging-post, and at the extremity of the lower cross-piece; or instead of a plank, a piece may be let in in an opposite direction to the cross-pieces, which must not be mortised into, or very little, that it may not be in any way weakened; this piece united carefully to the lower cross-piece would tie it to the post, and give more solidity to the framework; the diagonal position of the planks gives them more strength to resist the pressure. There is a little loss of material, but, on the other hand, plank of different kinds may be used after cutting out the knotty or defective portions.

Gates are opened by means of large timbers fixed above the posts, forming a counterpoise to the gate, and preventing it from grinding the collars and racking the framework; for this purpose the tail of the balance-beam must be very large. Trees are sometimes used with their butt ends not cut off, to which it is easy to add any additional weight. The hanging-posts often allow much water to be lost, in consequence of being obliged to give them sufficient play, and this could scarcely be prevented if the pivot had not a little motion, and the collar fitted exactly; but the weight of water occasions the gate to unite by pressing it considerably against the hanging-post; still as this is cut circularly, it only leans against a small portion of its surface, and the water easily passes, notwithstanding the great pressure. To remedy these defects, the posts should be partly cut in a circular form, and partly bevelled, the latter leaning along its whole length upon the rebate made to receive it, which having a corresponding bevel interrupts any filtration; the circular part should not touch the masonry, but have sufficient play without affecting the ease of the motion.

The gates of locks of navigable canals are made in a right line, but in great sea-locks they are curved: Belidor has demonstrated that these latter are not more solid than the former, but this must only be understood when the curved timbers are made out of straight pieces; for it is undoubted that, if naturally curved, they are much stronger, and will resist more pressure than straight pieces, especially when resting on their two extremities. The collars embrace the whole heel-post, which being generally 12½ inches in diameter, produces considerable friction, especially when the balance-beam does not act as a counterpoise; a large bolt may be placed in the axis of the post, and a smaller collar be substituted to confine it; but this method can only be applied to chamfered posts; round posts must have a motion in their collar to lean against the hanging-posts, which could not be effected by an axis; the collars must be attached to iron anchors strongly bedded into massive masonry. The pivots often get deranged, the posts, as generally made, causing considerable play; if these were bevelled, the pivots might be fixed and bedded in large stones cramped to those adjoining, or united with anchors to the surrounding masonry. Formerly the pivots were made of copper, but cast-iron is equally efficient; they should be the same size as the ends of the posts, and terminated at the lower end in a spherical form. The other iron work of the gates consists of squares laid on at right angles, which must be very strong; it is also well to lay on the rails of each sluice a band or two of iron to bolt them securely together.

Lock-gates measuring 8 feet from the centre of one heel-post to that of the other, are in some canals on a segment of a circle, the chord of which is about the sixth of the span, or a little more: these proportions not only allow of the gates being smaller, lighter, and stronger, but also increase the pressure of the heel-post against the hollow quoins, which renders them quite water-tight. Where canals are narrow, the paddles of both the upper and lower gates are usually kept open by an iron pin inserted between the teeth of a rack and pinion which raises them: when the paddle is required to be shut, the pin is withdrawn, and the paddle falls by its own weight.

Hollow quoins, or upright circular grooves, are formed in the side walls, at the ends of the timber sills, serving as the hinge for the gates; the upright post that turns within them is called the heel of the gate, and the other the head. The former are retained in their position by a gudgeon or pivot turning in a cup let into the foundation stones for the purpose; sometimes the pivot is fixed, and the cup revolves upon it. The upper part of the post is retained by an iron ring or strap let into the side wall, and made very secure; the hollow quoins should be worked with great attention; they are usually of stone or brick, though cast-iron has been found well suited for the purpose.

Lock-gates of large dimensions are now usually opened and shut by machinery, and the boom or spar attached to the head-post entirely dispensed with: on many canals a rack-bar of wrought-iron is connected with the gates, which are furnished with rollers to run in a groove fitted into the sill, and by working a wheel and pinion, they can be opened and shut at pleasure. We ought not to omit mention of several gates formed like boats, upon the principle of the camel, which rise and fall in deep recesses prepared to receive them as water is pumped out or admitted into them: such boat-gates are sometimes constructed with three parallel keels, which fit into as many grooves in the side walls of the lock; they are maintained in their position by admitting the water, and raised by pumping out their contents, after which they are floated away; for the stop-gates of docks such a contrivance is well adapted, but where the navigation is regular, as on a canal, they are not found to answer, from the time requisite to open and replace them. See Floating Gates of Dry Dock.

The angle to be given to double lock-gates has long occupied the attention of engineers, but the strongest position may be taken when the angle at the base is 35° 16′ nearly, and the sally of the gate is $\frac{7}{20}$, or a trifle more than one-third of the breadth of the lock.

Valves.—Some lock-gates have their paddles, or valves, made to open and shut by the movement of a lever, the lower end of which being loaded, keeps it always over the aperture in the lower part of the gate: when it is required to be moved, the upper part or handle of the lever is pulled back, and the water forcing its passage through, keeps it open until its weight overcomes the power, and it is balanced back into its original position.

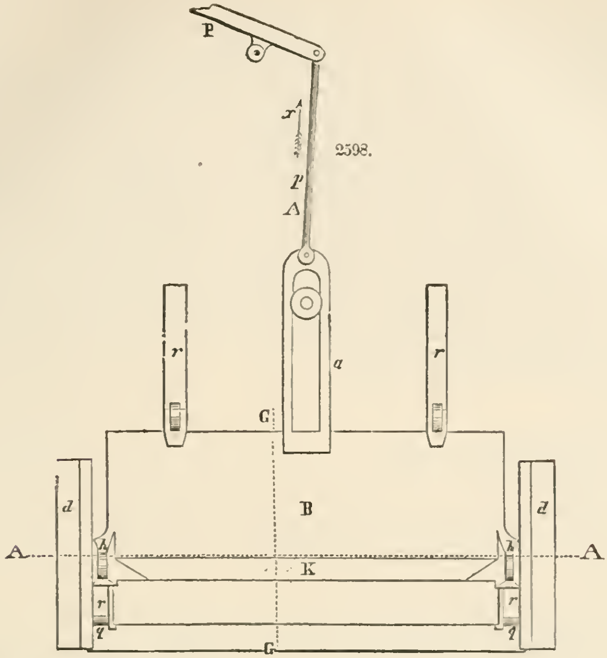
The crank and pinion working in a toothed-rack are now generally applied to raise the paddle.

Screws are sometimes used for this purpose, formed of wood, sliding up and down in a rebated frame, fixed in the stone mouth of the conduit or paddle-hole; the lateral pressure of the water occasions it to adhere closely to the frame, so that it is not only necessary to make it run with the grain of the wood, but also to have considerable power to move it: this is occasionally effected by means of a long iron lever, with an eye at one end that spans the square end of the screw, and allows a sufficient force to be applied to raise the paddle.

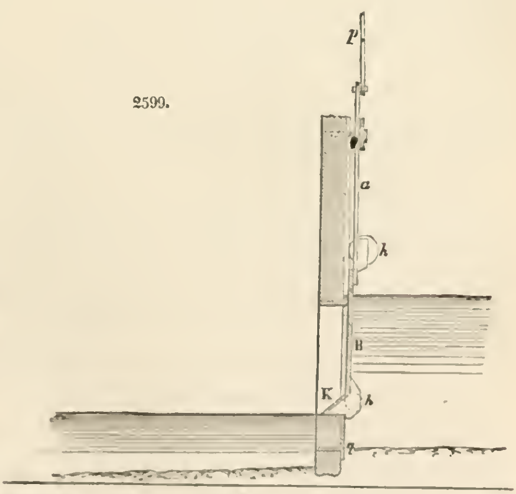
There are several applications of the screw, one of which, as used at the gates of Dunkirk, is very simple, and was for a long time adopted throughout Europe. To overcome the hydrostatic pressure and friction at the mouth of the paddle-hole was a horizontal circular opening, within which was inserted an open cylinder of wood or iron ground to fit it, which could be raised by a lever; the waste water of the canal could then escape over the upper lip of the cylinder and afterwards pass out by the paddle-holes.

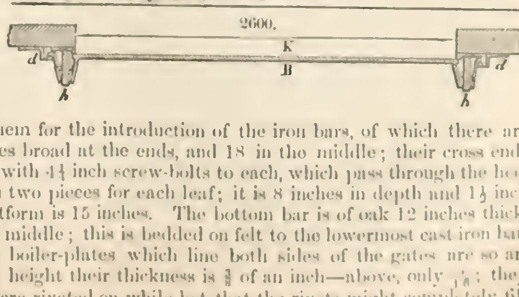
The following figures represent the latest improvements for the valves or sluices of a lock-gate. Fig. 2598 is an elevation. Fig. 2599 a vertical section through G G. Fig. 2600 a horizontal section through A A.

The object of this improvement is, that while the gate is kept close and tight by the pressure of the water forcing it against its seat, the effort of lifting the gate shall at the same time relieve the seat from the pressure of the water; and this is effected by means of friction-rollers *h h*, which immediately, upon the commencement of the lifting of the gate, act as short inclines, thus taking the pressure from the seat, and throwing it upon the friction-rollers or wheels, easing the lifting of the gate. When the gate is closed, the wheels have run off the inclines, and the gate bears against its seat with the pressure due the head of water



Iron lock-gates.—The frames of those at the Wet Dock at Montrose are of cast-iron, and entirely covered on both sides with wrought-iron boiler-plate: where they are placed the entrance is 55 feet wide in the clear, and the centre of the heel-post is 1 foot within the face of the wall, the distance between their centres being 57 feet: the height of the gates is 22 feet 6 inches; they point 10 feet, and their ribs have a curvature on the hollow side of 18 inches. The heel-posts are 21 inches in diameter, and in form a little more than a semicircle; after casting they were turned in a lathe: the thickness of the metal is 1¼ inch; they each fit into a cast-iron socket, and work on an iron gudgeon 10 inches in diameter, cast on a sole-plate 4 feet 6 inches long, 21 inches wide, and 2 inches thick; this is dovetailed and riveted firmly into the stone, and afterwards so keyed as to press the heel-posts into the quoins, which are of Kingoodie stone, polished as nearly to the circle as possible, and the stone and iron are in such close contact, that the water is effectually prevented from passing throughout any portion of their height.





The mitre-posts are 18½ inches in breadth, 1½ inch thick: holes are cast in them for the introduction of the iron bars, of which there are eleven to each leaf, 2 inches thick, 16 inches broad at the ends, and 18 in the middle; their cross ends are 18 inches in height and 2 in thickness, with 4¼ inch screw-bolts to each, which pass through the heel and mitre posts. The clap sill was cast in two pieces for each leaf; it is 8 inches in depth and 1½ inch thick; the height of the sill above the platform is 15 inches. The bottom bar is of oak 12 inches thick, 17 inches broad at the ends, and 19 in the middle; this is bedded on felt to the lowermost cast iron bar, and securely fixed by 1¼ inch bolts. The boiler-plates which line both sides of the gates are so arranged that they break joint; for 6 feet in height their thickness is ⅜ of an inch—above, only $\frac{5}{16}$; they overlap each other about 2½ inches, and were riveted on while hot, that the rivets might completely fill up the holes. The collars of the heel-posts are of wrought iron, 4 inches by 2 inches, keyed through the anchors, which are of cast-iron, 3½ inches square; they are dovetailed into the quoins, and run with lead The roller segments or railways are 10 inches in breadth by 1¼ inch, 4 inches in thickness; they are sunk into the stone, and securely bolted, and bedded with felt and white lead.

The rollers are of cast-iron and conical, 18 inches in diameter, and 5 inches in thickness, with turned steel axles; the roller-boxes are of cast-iron 1¼ inch thick, moulded to the bevel of the gates, and fastened by screw-bolts through the flanks of the horizontal bars: cast-iron covers confine the roller-blocks, which slide up and down withinside the boxes by the action of the top screws; the roller-bars are of wrought-iron, 3 inches in diameter, keyed into the blocks at the bottom, each being steadied by three plummer-blocks; each bar near the top has a coupling, with a square threaded screw, and a brass nut at the top, working in a cast-iron bracket, which bears the whole weight of the outer end of the gate, and is fastened by three screw-bolts through the flanges of the horizontal bars. Each leaf has a sluice, 3 feet by 2, the frames of which are 7 inches broad and 1¼ inch thick; the sluice-valves are also 1¼ inch thick; all the screwed bolts have zinc nuts, to prevent the iron from rusting: the sluice-rods are 2 inches in diameter, and have a square threaded screw, and a brass nut at the top; these are worked by a wheel and pinion, and bevelled geer, with a crank-handle, nearly level with the hand-rail.

The gangway is 42 inches in width, and is supported on cast-iron brackets for each leaf; cast-iron ballusters and a wrought rail is attached to the convex side of the gates, with movable iron stanchions and chains on the other; in each heel-post is a pump with a brass chamber and boxes, 2½ inches in diameter, with a lead pipe down to the bottom.

The gates are worked by four double-purchase capstans, and geering with seven 8-inch chains. Their weight is as follows:

	Tons.	Cwt.
Cast-iron work in the gates	64	14
Wrought-iron	22	15½
Brass	0	5
Zinc	0	1½
Cast-iron in segments and other fittings	19	0
	107	0

At Woolwich the clear opening of the dock-gates is 65 feet, and the weight of each of the two iron gates is 150 tons. See Gates of Dry Dock, Brooklyn Navy Yard.

LOCOMOTIVE ENGINE.—1. A locomotive engine is a steam-engine with two cylinders, formed on the high-pressure principle, without a condenser. The motion of the pistons is caused by the introduction of steam into, and its alternate escape from, the cylinders, which is transmitted by means of connecting-rods to an axle, furnished with two cranks.

In boilers of locomotive engines the fire is inclosed in a box having a double casing, with a body of water between. The air enters between the grate-bars. The smoke, flame, and gas, produced by the combustion of the fuel pass through, in their way to the chimney, a great number of tubes, which are situated in the cylindric part of the boiler, and extend from the fire-box to the smoke-box, and are surrounded by water. These tubes, being of very small diameter, would not pass off the flame and gas with sufficient rapidity if they were not urged by a powerful draught; this is also rendered necessary to overcome the friction, and the resistance offered by the cold air within them.

2. *Of the draught.*—The draught is employed to produce a fresh supply of air in the fire-grate, and thereby supply the oxygen necessary for the combustion of the fuel; it is accomplished by allowing the waste steam to escape at a tolerably high pressure, after it has fulfilled its office in the cylinders. This steam is conveyed from the cylinders to the chimney by a pipe, the upper end of which is contracted for the purpose of confining it, and checking its too rapid escape. It passes off at regular intervals, according to the velocity of the engine, and the force of each puff depends upon the pressure of the steam. The velocity of the steam in the blast-pipe is equal to that due to the initial pressure of the steam, whatever may be the size of the mouth of egress; but the pressure is at once reduced if the size of the orifice of the blast-pipe be considerable. The great speed with which the steam escapes in the chimney imparts to the air around it a corresponding velocity; and this air can only be replaced by a current passing from the grate through the fire and tubes.

We should observe that the contraction of the blast-pipe at its upper extremity, being for the purpose of checking the escape of the steam, and prolonging the time of its engagement, a continued pressure of waste steam is consequently the result, which should be regulated by proper rules or laws, as it ought not to exceed more than is necessary. This pressure is therefore an obstacle to the progress of the engine, in consequence of the draught invariably having the effect of absorbing a part of the power of the engine. Its influence, however, is not felt when moving at a slow velocity, on account of the intervals being longer, which gives more time for the steam to escape; but when the speed is great, the piston-strokes are so rapid that the pressure of steam in the blast-pipe is almost continuous. This pressure, consequently, forms a resistance to the motion of the piston.

3. *Of the boiler.*—The boiler is the most important part of the engine. There is a fire-box connected with it, the bottom of which supports the grate-bars, and the four sides are formed double, in such a manner as to allow of a space of 2½ to 4 inches between them, which is occupied by water; the fire-box is therefore surrounded by water. It is very important to preserve a sufficient width of water space, otherwise the velocity of the steam at this part of the boiler would prevent the water being replaced with sufficient rapidity, the great heat to which the fire-box is exposed producing steam of very great force the walls, also, from not being sufficiently cooled by the water, would acquire a high degree of temperature, which would likewise promote the formation of incrustations—the space would consequently become filled up, and the casing soon destroyed from the action of the fire. This serious inconvenience has occurred in boilers where the water-space has been made 2 or 2½ inches. The top of the

fire-box is strengthened by pieces of iron, that the force of the steam may not rupture it; and the whole of the flat portions of the boiler, being unable to resist the pressure of the steam within, are also strongly secured together by bolts to prevent their giving way; but this is unnecessary with the cylindric portion of the boiler, which resists the pressure without the tendency to rupture. This part is traversed by 100 to 150 or more copper tubes, through which the flame and the gas produced from the fuel escape The extremities of these tubes are secured to the plates at each end of the boiler.

Considering the complication of this casing, one can readily conceive the great play of expansion and contraction produced by the rise and fall of the temperature, and how much the action of such powerful forces tends to wear it out, and to occasion shocks which the several surfaces exposed to the pressure of the steam are unequal to withstand, their form being unfavorable to it; thus, the flat parts become the soonest deranged. Another circumstance which increases these defects arises from the two extreme parts of the boiler being secured together, partly by the frame and partly by the rails or cross-pieces. The latter are attached to the lining of the fire-box at one end, and to the smoke-box at the other, and are kept cool by the air, and therefore are not subjected to those alternate changes which the body of the boiler undergoes. As long as they remain fixed in their original position, they offer resistance to the play of the other parts; but when at length they become unfastened, they afford a passage of escape to the water of the boiler. We must conclude, from all these forces acting against each other, that locomotive engines possess some degree of elasticity in their several joinings and fastenings, although difficult to be perceived, and which, so far from impeding their progress, actually renders it, after a time, more easy than before.

The surface of the grate varies. The economy attending great fires arises from the heat being proportionately much more regular than with small ones. It is possible that the rise of temperature, produced by the burning of a large body of fuel, exerts an unfavorable influence on the flat sides of the fire-box, the dimensions of which are so considerable. It is probable that an increase in the depth of the grate, combined with the employment of a fuel so little inclined to cake as coke, would be found more advantageous than enlarging its surface, since the passage of the air through a great thickness of coke would raise a large quantity of it to the temperature necessary for its combustion, instead of passing through the fire unconsumed, as it does when filled with too large pieces or laid too thin. This remark applies equally well to the employment of anthracite coal.

We have only to remark, in addition to our description of the boilers of locomotive engines, that the casing should, at the same time, possess great strength and pliability: thus, where a very powerful draught is created from a rapid succession of *puffs* of high-pressure steam, the heat of the fire gives a high temperature to the several surfaces of the fire-box and tubes, and steam of extraordinary power is generated; but if the door of the fire-box be opened, a large quantity of cold air is admitted, or if the pumps be held open too long, the air introduces itself into the boiler, and instantly checks the generation of steam; the pressure is consequently diminished, and at length becomes unequal to a rapid transit of the engine.

In locomotive, as in stationary engines, the whole of the parts in contact with fuel, flame, and hot air, should be covered with water. The most serious consequences occur if the uncovered portions are allowed to become red-hot, and a quantity of water sufficient to cover them is suddenly let into the boiler; the production of steam is so rapid, that it becomes too considerable to be wholly carried off by the valves, and an explosion consequently follows.

Another very essential point for the preservation of boilers is to prevent the formation of deposits. These arise from the calcareous matter disengaged from the water when it is converted into steam, and which is not wholly carried away with it; but an earthy matter is left, which is constantly increasing in bulk. These incrustations become fixed principally on those parts where the greater portion of the steam is generated; and, as they acquire thickness, it results that less steam is produced, from their being bad conductors of heat: the metal upon which they are fixed is heated to a much higher degree than the other parts, as it is not cooled by immediate contact with the water. This rise in the temperature of the metal increases the action of dilatation, and renders it less able to resist the pressure; it also has the effect of burning it; the boiler, therefore, requires to be often cleaned.

This incrustation is the most powerful destroyer of locomotive engines, and it is of the greatest importance to find some means of getting rid of it.

When the escape of steam from the cylinder is sufficiently strong to cause a powerful draught, then the power of generating steam attains its maximum; at which instant the bulk of the water in the boiler rises artificially to the height of two or three inches. This is caused by the rapid passage of the particles of steam through the water, which has the effect of increasing its volume. As soon as the throttle is shut, the emission of steam is suspended and the water takes its natural level; also when cold water is injected into the boiler, which, in proportion as it is introduced, condenses those particles of steam with which it comes in contact in the mass of heated water, and thus restores the density it had lost. It results that the level of the water remains constantly at the same mark as long as it continues to be fed, and that the introduction of water is only perceivable by the reduction of the pressure.

Another fact equally important is the disposition of all locomotive engines, more or less, to carry away a quantity of water into the cylinders with the steam, called *priming*. This inconvenience arises from various causes. Among them may be reckoned particles filling the boiler so full that the water rises up beneath the dome over the steam entrance, and is conveyed into the steam entrance pipe with the same velocity as the steam, and introducing greasy matters, which, becoming mixed with the water, give it a property analogous to that of milk when submitted to an ebullition, and the quantity of water engaged by the steam in this case is very considerable.

It may also result from the small diameter of the dome, its want of height, or the space reserved for steam above the surface of the water being too small, or the dome being placed over the fire-box, which is too often the case; that is to say, it is placed at that part where the evaporation is greatest, and the particles of water are in the strongest agitation.

Of the draught.—One of the means employed in regulating the draught consists in placing a disk valve at the extremity of the blast-pipe, which was the invention of Stephenson. This valve is open in the middle, by which it does not offer any obstacle to the passage of the steam; but it can be made to close the passage whence the flame or gas produced by the fuel issues, when required. This damper is managed by the engine-driver by means of a lever-rod.

This valve is also useful for another purpose. Thus, when the men extinguish the fire of the engine after it has finished work, the grate being done with and removed, the air enters at this part with great freedom, the heat of the engine maintaining a very strong draught. Now the effect of this passage of cold air is detrimental to the boiler, for the reasons before stated; therefore, if Stephenson's damper be fitted in the chimney, and care be taken to shut it close on these occasions, the current of air would be checked, and an excellent effect would result from it.

Of explosions.—We have few remarks to make on the subject of explosions connected with locomotive engines. Accidents of this kind are wholly attributable to the wilfulness of the engine-driver, or a want of care on his part. His first duty is to notice that the safety-valve does not emit steam exceeding a given pressure.

It is probably from these explosions being so rare, that the cause of them has been a question up to the present time; we can give none other than that they are owing to the imprudence of the engine-drivers, from their endeavors to raise the power too high, and thus impeding the escape at the safety-valves. Perhaps this imprudence may be combined with a bad system of closing and bolting the iron plates, and defectiveness in the large interior iron bolts of the front plate. We do not, however, mean to affirm this, but only mention it to our readers, inasmuch as we know that the *joinings* and arrangement of the plates of some boilers are much less skilfully contrived to resist internal pressure than others.

One observation will be sufficient to prove to mechanics the uselessness, generally speaking, of increasing the pressure, and of tightening the safety-valves. When they thus increase the pressure of the steam in the boiler, the engine simply acquires the power of propelling a heavier train, but it has not any sensible effect upon the speed. They should, therefore, remember that they do not derive any advantage from committing this very great offence. As the steam in the cylinders acts at a less pressure than that in the boiler, of what use is it to increase the latter, when, by opening the regulator a little more, sufficient additional strength is obtained in the cylinders? The most essential thing for the speed is the generation of a large quantity of steam at once, and of the requisite force—sufficient for the discharge of a great number of strokes, and not steam generated under a greater pressure than there is any occasion for.

Distribution.—The steam entrance, or the aperture by which the steam is introduced into the pipes of distribution, is situated in the interior of the boiler, and opens at the upper part of the dome surmounting it. The object of the dome is to carry the steam as high as possible, that the water held in suspension may have time to drain from it. The pipe by which the steam is introduced (steam-pipe) is carried along to the extremity of the boiler, and passed through into the smoke-box, where it is divided into two, to supply each of the cylinders. This pipe may be contracted in the interior, by means of an apparatus termed a regulator, which is inserted for the purpose of regulating the transmission of steam to the cylinders; this apparatus will also entirely close the passage of the steam-pipe, if required. The steam entrance is placed either at the head of the boiler, above the fire-box, or, otherwise, towards the extremity near the chimney. In the first case, where the pipe traverses the entire length of the boiler, it is attached to the plates at each extremity; and, in order that it may readily yield to the action of expansion, it is furnished with a stuffing-box.

The joints of that portion of the steam-pipe within the boiler should be made with the greatest care, that the water may not gain admittance into the pipe. It is generally formed with a section equal or superior to that of the steam-ports in the passage to the cylinders, and the same as the apertures opened and shut by the regulator.

Throttle-valves are constructed of various forms; but that generally employed consists of two separate disks, one being made movable; and they are cut in such a manner that the open parts of one will either correspond with or cross those of the other, so that the steam passage may be left either open or closed.

The movable disk is secured to the fixed disk by the pressure of the steam, also by a screw and a spring. The spring is rendered necessary from the steam within the steam-pipe being sometimes of greater pressure than that in the boiler.

Other forms of throttle have also been employed—and the principle of safety-valves has been applied in some cases, and in others the principle of cocks—again, that of slides; those which present the least surface-friction, and in which the apparatus is brought into action upon the least degree of force, are the best, for it is important to counteract the effort required to overcome the pressure of the steam by suitable contrivances, as by equilibrating it by a pressure nearly equal; the friction resulting from the unequal expansion of the several pieces fixed and inclosed within each other should also be reduced as much as possible. Throttles formed with cylindric surfaces exposed to the action of friction, possess this inconvenience in the highest degree. There also appears to be some ground for rejecting regulators which require helixes in the interior of the boiler, upon which the pressure of the steam would act.

Of the cylinders, slide-boxes, and slides.—The steam passes along the breeches-piece leading to the cylinders through the slide-boxes, from whence it is distributed alternately upon each side of the piston.

The mode of introducing the steam may be readily comprehended: the bottom of each slide-box is pierced by three holes called *ports;* the two extreme *ports* convey the steam into the interior of the cylinders at their extremities. A sort of cover, called a slide, is placed over them, which is subjected to an alternating motion when at work, and thus leaves each port alternately uncovered; and as the slide-boxes are kept constantly filled with steam, the latter passes through these ports into the cylinders at the moment of each being uncovered. It will therefore be perceived that the system of introducing steam is very simple. The ejection of the steam from the cylinders remains to be explained every time that steam enters upon one side of the piston, that which has effected the preceding half-stroke escapes at the third port, which is pierced in the bottom of the slide-box, and is not in communication either with the cylinder or the slide-box, where the steam is lodged, but is separated from these and is constantly covered with the movable slide, which covers and uncovers alternately the two other ports; it is furnished with a pipe at the extremity which leads into the chimney. Now, the movable cover or slide being hollow, it results from its alternate motion that when it uncovers one of the steam-ports and admits steam into the cylinder, it puts the other steam-port in communication with the waste steam-port situated between them, by means of the cavity beneath it; and the steam admitted into the cylinder, at the preceding *half-stroke* of the piston, by the port then uncovered, enters the interior of the slide, forces itself through the waste steam-port, and thence escapes; therefore the slide-box constantly answers as a passage to conduct the steam into the cylinders, and the cavity within the slide serves only for a passage to convey the steam away from them. The true steam-ports admit steam when they are uncovered, and they alternately convey steam to the waste steam-port when they are covered by the slide; thus the slide never leaves more than one of the steam-ports uncovered at a time for the passage of the steam, and it covers the other two at the same time, to allow of the waste steam escaping. The force of the steam lodged in the slide-box is therefore employed upon the piston. The waste steam, being put in communication with the atmosphere under the slide, instantly loses its force. The piston is then quickly carried along to the other end by the force of the steam, and the resistance it encounters on the other side is quickly overcome. Now it is the difference between these two forces which causes the engine to perform its several functions; if these forces were equal, the piston would remain in equilibrio, and without motion. In order that this difference shall be as great as possible, the force of the steam entering the cylinders should not be less than that which exists in the boiler, or the pressure of the steam that passes out of the cylinders greater than the pressure of the atmosphere into which it escapes; but this desideratum is difficult to be attained. The pistons of locomotive engines being impelled with great velocity, the steam is necessarily carried into the ports of introduction with a velocity which is in inverse proportion to the section of the uncovered part (of the port) with the area of the cylinders. This velocity is further affected by the irregularity attending the conversion of a rectilinear motion into a circular one. The latter is accomplished by means of a crank-arm, which follows every movement regularly, and transmits the motion to a rectilinear horizontal rod, the velocity of which is represented by 0·293 for the quarter of the revolution which approaches nearest to the vertical, and by 0·707 for the quarter nearest the horizontal. Thus, the total speed of the piston is composed of a minimum and of a maximum; the minimum takes place when the crank-arm passes above and below the horizon—the maximum, when it performs the quarter of the circle of the passage from one side to the other of the vertical; in other words, the more the direction of the movement of a crank-arm approaches to a parallel with the rectilinear rod which it works, the greater is the speed transmitted to the rod; and the more it moves from a parallel, and approaches the rod by a perpendicular movement, the slower is the motion imparted to the rod.

When the engine works at its greatest speed, or at about 38 miles an hour, or 1093 yards per minute, the size of the wheels being 5 feet 3 inches, and their circumference 16 feet 6 inches, the number of strokes of each of the pistons is about 200 per minute, and of their movements 400, the length of each being about 1 foot 6 inches, which gives the piston a velocity of 192 yards per minute, or 10 feet per second, instead of about one yard, which is the velocity given to the pistons of stationary engines. The dimensions of the ports are generally 1-10th the area of the piston; the velocity of the steam in the ports would be about 100 feet per second, if they were always entirely open when the piston was moving, which is not the case, the aperture being only fully open during the middle of its course, and at a point where the piston has a speed once and a half as fast as its mean velocity; the velocity of the steam through the ports would therefore be about 165 feet. Taking the contractions, also, into account, reduces the openings to two-thirds; we thus find that the steam has a mean velocity of 200 to 250 feet per second at the ports. This velocity, although very considerable, does not, however, produce the injurious effect that was at first imagined. The velocity of the waste steam, in passing into the void, is upwards of 1970 feet per second, and its velocity upon escaping into the atmosphere is about 1400 feet, when the absolute pressure of the steam is about two atmospheres.

This velocity is more than 870 feet for an effective pressure of a quarter of an atmosphere, or an absolute pressure of 1 at : 25; indeed, the generating pressure of a velocity of escapement equal to 290 feet does not exceed 1 50th part of the atmosphere alone.

The resistance arising from the steam-ports is, then, perfectly unaffected at high velocities, but if the latter were even considerable, it would not have a troublesome effect; indeed, with a speed of 37 miles an hour, the boiler cannot furnish the cylinders with any other than steam of reduced pressure; therefore, of what consequence is it that this reduction should be partly caused by the ports, instead of being wholly effected by the regulator?

But although we have no loss of force arising from the steam-ports, this is not the case with the waste steam-ports. The force which the steam exerts in its escape always diminishes the useful pressure—and it is very considerable, since the velocity is of necessity very great, in order that the cylinders may be instantly cleared. It is, therefore, necessary that the velocity of 250 feet, although sufficient when continued throughout the stroke, should be considerably increased, in order that it may be enabled to free one side of the cylinder instantly.

In the next place, the steam, after passing out of each of the cylinders, again unites in a pipe, which is contracted at the upper extremity, and presents another impediment to its passage. This peculiarly formed pipe is employed for the purpose of creating a draught. But the resistance which it produces is naturally detrimental to the moving-power, which may be accounted for as follows: [illegible] that, with a speed of 39 miles, the cylinders are filled with steam of 3 at : 75, which is successively held and dispersed. In calculating the volume of this steam, with successive stops, we should find that it is nearly double that of the cylinder. Taking the total volume of steam supplied, having the section of the blast-pipe, (whose conical shape does not present much contraction,) we arrive at this result: that, supposing the escapement to be incessant, the steam would have a mean velocity of 820 feet, corresponding to a generating pressure of a quarter of an atmosphere. This result shows that this great velocity of escape absorbs a considerable portion of the power of the engine; and if we remember that at these same velocities, the motive steam must necessarily diminish the pressure, also that the air operates upon and at length overcomes it, we can easily conceive that there are certain limits to the velocity which cannot be exceeded with certain engines, even when running without a load. These limits, which were originally from about 39 to 44 miles an hour, have been increased, with engines made more recently, to nearly 53, or even upwards of 60 miles an hour.

Eccentrics.—The two pistons are each attached by fixed rods, to guide them in their rectilinear strokes, and by movable rods, called connecting-rods, to an axle furnished with two cranks, set square with each other; this axle is mounted upon two wheels, which are termed the driving-wheels, and receive a rotative movement direct from the pistons.

The readiest plan of distributing the steam, at the commencement of the action of the piston, consists in employing the rotative motion of the axle to conduct two eccentrics at the same time with the wheels, which, by their alternating motion, open and close the slides. The eccentrics are placed on the axles of the driving-wheels in such a manner as to disengage the slides from those ports whereby the steam is introduced into the cylinders, and to cover those reserved for its escape, at the commencement of the stroke of the piston; to accomplish which, each eccentric is mounted upon the axle of the wheels square with the crank of the cylinder, the slide of which it conducts. In order to understand perfectly what then transpires, it is necessary to bear in mind that, when a crank transmits motion to a horizontal rod, it impresses the rod with a rapid motion when it passes in a vertical, and with a slow one when it passes in a horizontal direction.

In accordance with this general law, when two crank-arms are mounted on the same axle, and transmit their motion to two rectilinear rods, the motion of each will be different, notwithstanding the cranks are both animated with the same velocity.

Now, the slow movement occurs precisely at the commencement and at the termination of each half-stroke of the piston, since the crank-arm crosses the horizontal at this particular period. Therefore, if the eccentric be mounted square with the crank, the instant that it crosses in a vertical direction, and transmits the greatest amount of velocity to the slide, the crank will be in a horizontal position, and the piston will be taking its slowest movement. The steam is introduced and let off uniformly every time the crank-arm is in a horizontal position—that is to say, every time the piston has finished one stroke and is commencing another—and it is performed with great precision, depending upon the uniform action of the slide. It may be further observed, in the case of one crank being placed on the same axle with another, when one is passing from one side to the other, in making a semi-revolution, the other is passing from the top to the bottom; or if each of these cranks transmits a rectilinear motion to a rod, the rod conducted by the first crank conveys a certain motion in one direction, and that conducted by the other conveys the same amount of motion, but distributed in the opposite direction. The results of this uniform principle in the construction of locomotive engines are as follow: At the instant one of the cranks is in a horizontal position, and the piston at the commencement of its stroke, during the first half (of this stroke) the slide moved by the eccentric, which is in a vertical position, conveys a motion which has the effect of uncovering one of the ports, and by the time the eccentric arrives at the horizon it becomes wholly uncovered. In the second half of the course of the crank, the slide returns to its original position, and the port becomes again covered. The slide is, therefore, always ready to uncover the opposite port at the commencement of the following stroke.

It further results, when the crank is horizontal, that the two steam-ports are shut, the eccentric being then in a vertical position.

Such is the principle of the distribution of steam. We shall not enter into the particulars of the several plans for effecting it at present, but their details, which do not differ essentially from each other, will be found in their proper place. The return motions, from the eccentrics to the slides, are constructed of slight rods, and are therefore readily shifted; yet, as the slides are drawn backwards and forwards under the pressure of the steam they are subjected to considerable friction, the rods are liable to be strained, and frequently become deranged by the eccentrics, also from the play of the points of the levers, and the several turning-joints being so very elastic. These circumstances of derangement have an important influence, by retarding the slide slightly, which has a powerful effect upon the regularity of the distribution; and since the course of the eccentric is similar to that of the slide, the detention of the action and the loss of speed occurring in the return movement from the above causes, show the necessity of the engine-man devoting the greatest attention to this point, and avoiding the evil as much as possible. The distribution of steam may be suspended whenever required, by means of hand-geer and reversing-handles, which detach the rods of the eccentrics from the levers which conduct the slides; the same levers are also employed to reverse the movement of the slides at the time of running, and in such a manner as to render it opposite to the direction the engine is running in.

This reversing the distribution of the steam is employed to stop the engine where other means are found insufficient, in which case the steam-ports on that side where the piston is returning become instantly uncovered, and the steam fills the whole cylinder, and thus opposes the progress of the piston; the latter returns the steam again to the boiler if it should not be arrested. At the same instant the waste steam-port is covered by the slide, and consequently put in communication with the air, which enters by the blast-pipe and fills the cylinders, being drawn in by the action of the piston. Thus, the advance of the engine against the steam has the effect of conveying the air into the boiler, and the safety-valves consequently emit steam mixed with air.

Of the feeding of the boiler.—Having described the means of generating steam, and of distributing it in the cylinders, we shall now consider those for renewing the water in the boiler in sufficient quantity, as it becomes absorbed by the work of the engine. There are two pumps employed in effecting this, which are on the lift-and-force principle; the pistons consist of plungers, similar to those employed in ordinary stationary engines. They transmit the water from the tender to the boiler. One of these pumps can deliver a volume of water in the course of about twenty minutes sufficient to supply the boiler for one hour's run. The quantity of water furnished by the pumps may be properly regulated, and the delivery of the same rendered continuous, but the latter is only accomplished in new engines, the boilers of the other engines are sure to be momentarily chilled, either in the operation of feeding with water, or in replenishing the fire with fuel; but the fires of new engines are not so liable to this.

Of the machinery and its disposal. We shall conclude our general observations on locomotive engines by referring to the disposal of the machinery connected with them. The power of the engine originates in the cylinders, the force produced within them proceeding through the smoke-box in which they are inclosed. This force or power acts in two ways, dependent upon the steam being on one side or the other of the pistons, and imparts to the rods an effort of traction or of pressure accordingly. The whole of this force is exerted upon the cranked axle, wherefore it becomes highly necessary that this axle should be attached to the cylinder-box by very strong framing; the boiler is for this purpose placed on a frame, with which it is connected by stays secured by strong bolts. There are many engines which, after a few months' work, manifest a sensible play, to an experienced eye, between the cylinder-box and the supports of connection between the boiler and the frame, from this reason. The carriages, or grease-boxes, which receive the gudgeons at the extremity of the axles, and thus support the entire weight of the engines, are situated beneath this frame, the gudgeons turning freely in them.

If these carriages were the only points of resistance to the cylinders, it is probable that not only the supports of the boiler on the frame would soon give way, but the axletree, being only secured at its extremities, would also be subjected to these vibrations, and the greater part of it so powerfully forced in each direction, horizontally, by the cranks, that they would be soon broken. It is to obviate this that the cylinder-box is attached to the cranked axle by four, or at least three iron rails. These rails are strongly fastened to the cylinder-box, and each carries a copper collar, in which the cranked axle is inclosed. This collar is capable of moving in a vertical direction, whereby it is enabled to accommodate itself to the play of the springs and countersprings, which frequently have the effect of separating the axletree from the boiler; but the collar is always secured horizontally, being that in which the cranked axle offers the greatest resistance, by means of suspended wedges, which operate similarly to keys, and tighten the carriages against the axletree. The cranked axle is secured in this manner at five or six places respectively, and further attached to the cylinder-box. The attention of the engine-driver should be directed to these rails of attachment, and he should constantly notice that they fulfil their office properly; and in furtherance of which he should tighten them, by heightening the wedges as the carriage of the axletree becomes worn.

The three principal rails or cross-pieces which we have noticed, are attached just at their extremities, next the axletree, to lugs fastened to the fire-box. It is of consequence that these joints should not be made too stiff, and that a little play be allowed for their extension in cooling, for the reasons before stated, viz., that these rails are not subjected to the same degree of elongation from the effects of expansion as the body of the boiler; and, upon this occurring, the boiler is forced upon the rails, and the joints connecting them with the fire-box consequently become deranged, and give passage to the water situated within the double casing surrounding the fire-box.

We have now to observe, that the necessity of reducing the weight of locomotive engines has led to the almost exclusive employment of iron in their construction, from which it results that the whole of the several pieces in friction against each other, from the effects of rotative or rectilinear movement and the sliding of one surface upon another, are proportionately weaker than those of ordinary stationary engines, the castings included, viz., the axeltrees, the beams, the connecting-rods, the guides, the eccentrics, &c., and formed of smaller proportions. Now, there is a very important fact connected with engines, viz., the circumstance that the friction does not depend solely on the pressure, but on the degree of fitness of the metal to support the pressure without alteration. Thus when the state of the carriages becomes altered, the friction acquires immense influence; the bodies become heated and reduced from the filing, arising from the grip they have of each other; they also sometimes become melted. The rubbing surfaces are therefore kept constantly oiled, to prevent any alteration taking place; and this is more especially necessary with locomotive engines, as these surfaces are generally reduced almost to the minimum limits commensurate with the amount of pressure which they have to support. The least negligence on this point is consequently attended with serious consequences; the first, from its increasing the resistance of the engine considerably, and often stopping its progress; secondly, from its increasing the wear of the carriages; and, thirdly, from its causing the rupture of the pieces in consequence of their becoming heated, and the strains to which they are subjected. If the carriages become heated in the smallest degree, they are subjected to great pressure, and the relative hardness of the metals in contact is instantly changed, and the adherence between their surfaces increased, so that they become full of holes and impaired, and oil will never restore the delicate finish which is thus destroyed.

A constant attention to the greasing, therefore, constitutes one of the surest means of preservation, and of insuring good work in the locomotive. Another circumstance no less necessary, is the maintenance of the whole of the several pieces in a condition as near their original form and mounting as possible. An engine is composed of so many pieces, and is subjected to such strong vibrations under the influence of shocks, and from the sudden and incessant strains that it is subjected to, that it yields in a certain degree at its joinings. The engine-driver should direct his attention to the prevention of this movement, and he should not allow of any more play in the carriages than is necessary; he should re place those pieces which become worn, and tighten those mountings as they become loosened. The several joinings are, moreover, disposed in such a manner as to counteract the difficulties connected with them, and exhibited with all the pieces thrown in friction with each other.

Respecting the frames of locomotive engines, we may remark, that the plan of arrangement has been a subject of much controversy, whether they should be placed on the outside or on the inside of the wheels. If a perfectly rigid shaft were urged in a rotative direction by a rectilinear force, it would revolve with a degree of firmness proportionate to the distance its carriages were placed apart. If a cranked axle be supported by carriages situated near its centre, and impelled by forces acting in contrary directions, as those transmitted to it from the cylinders, it would cease to be perpendicular to the movement of the pistons, upon the carriages becoming the least worn, and would form an angle proportionably large, accordingly as the carriages were placed near the centre. The flanges surrounding the wheels would therefore knock against the rails, and the engine undergo violent lateral movements from its direct course, which would be dangerous, on account of the great velocity. A like effect occurs when the cranks are placed at the extremities of the axle, instead of near the middle of it, as in the case of engines having the cylinders placed on the outside. The wear of the carriages, also, has the effect of increasing the force of the lateral movements considerably.

Of locomotives employed in conveying freight.—It is customary, in the conveyance of freight, to employ engines with their driving-wheels coupled to the fore ones, which is effected by connecting-rods; in which case the fore-wheels are of equal diameter with the driving-wheels. This coupling possesses no other advantage than that of increasing the power of adhesion, by allowing the fore-wheels to partake of the weight carried by the others.

Of the tender.—A sort of wagon is attached at the extremity of a locomotive engine when in motion, which is called a tender, and which is generally mounted on four wheels, and sometimes on six. It contains water and fuel sufficient to feed the boiler and grate during a run of about twenty-five miles as a maximum, and about fifteen miles as a minimum. In order to supply trips exceeding these limits, reservoirs of water and depots of fuel are arranged at convenient distances on the line, which enables them to extend their run to distances which are only limited by the strength of the engines.

The tender is joined to the engine which it accompanies by a bolt, which is adjusted to fit into a staple. This bolt should be capable of resisting the entire power of the engine. The reservoir of water communicates with the engine by the two pipes of the feed-pumps; the connection of the barrels of the pumps is made by means of a flexible pipe, denominated hosing, whose nature is such that it can readily yield to all lateral and vertical movements of both engine and tender; the movements are inevitable, for reasons before stated, from the little stability of the railway, the great velocity of the engines, &c. The bolt admits of every movement, except that of lengthening.

Tenders of good construction should present an appearance of lightness combined with solidity; the joints of the iron plates composing the reservoir of water should be well stopped; the cocks of the supply-pipes to the pumps also require to be made perfectly water-tight, which is a condition they do not always fulfil. The fuel in the tender is placed upon a level with that in the fire-grate. The wheels are wedged on the axletrees similar to those attached to the engine, and the weight of the tender is suspended on springs, to remedy the abrupt motion of the water. There is a hook at the back of the tender, which is attached to a powerful spring, to neutralize the effects of concussion, and for the purposes of traction, and it converts all shocks occasioned by the jerking of the engines, which are sometimes very abrupt, into pressures more or less strong accordingly.

Explanation of the principles which govern the power of locomotive engines.—The power of a locomotive engine is not to be estimated alone by the pressure of the steam in the boiler, and the diameter and length of stroke of the piston. In passing between the boiler and the cylinder, the elastic force of the steam is diminished, before it reaches the cylinder, by the smallness of the apertures of the steam-pipes, through which it has to pass. This difference is, likewise, more frequently produced by the evaporating power of the engine not being capable of keeping up a supply of steam to the cylinders, of an elasticity equal to that in the boiler; and, therefore, the pressure upon the piston is less than that against the steam-valve of the boiler; and this diminution of the elasticity of the steam, in the cylinders, as compared with that in the boiler, will, in many cases, be in the ratio of the increase of velocity of the engine. Thus, suppose an engine capable of evaporating a certain quantity of water per hour, or converting it into a certain bulk or quantity of steam, of the elasticity indicated by the valve on the boiler; if this production of steam is sufficient to supply as many cylinders full of steam, of the density of that in the boiler, as shall be equal to the number of strokes per minute of the piston, required to produce the given velocity; then, the elasticity of the steam in the cylinder will be the same as that in the boiler, except that which is required to force the steam through the steam passages with the requisite velocity; and, consequently, the pressure on the piston will be nearly the same as that in the boiler. But, if the velocity of the engine is such, that the number of cylinders full of steam required is greater than the evaporation of the boiler can supply, at the elasticity marked by the steam valve, then the elasticity in the cylinders is correspondingly diminished. Thus, suppose an engine capable of evaporating 50 cubic feet of water into steam per hour, and that the pressure on the steam valve is 50 pounds per square inch; this will supply a given number of cylinders full of steam of that elasticity. Suppose the resistance to the motion of the piston be equal to this pressure of the steam, or equal to the elasticity of 50 pounds per square inch of the surface of the piston; then the engine will travel at that rate, which the evaporating power of the engine will supply it with the requisite number of cylinders full of steam. But, suppose the resistance upon the piston increased by a change in the gradients of the railway, then the velocity of the engine will be diminished, until the evaporating power raises the elasticity of the steam in the boiler, so as to counterbalance the increased resistance of the piston, and the engine will consequently move more slowly. On the contrary, if the resistance be diminished by a change of the gradients of the railway, then steam of a less density will be required, and, consequently, a greater number of cylinders full will be furnished by the boiler, and the velocity of the engine will be increased.

We see, therefore, that the only correct expression of power of these engines, is the evaporating power of the boiler, and that the velocity with which the engine will move, will depend entirely upon the quantity of water it can convert into steam in a given time; or the number of cylinders full of steam, of a given elasticity, which the boiler can produce in a given time. Having found, therefore, by experiment, the quantity of water which an engine, of given dimensions, can evaporate per hour, we then find the power which that engine is capable of exerting upon the piston, and the velocity, or number of strokes per minute, which that evaporation will produce, with a given load. The volume of steam which a cubic foot of water will produce, depends upon the elasticity; this has been ascertained by various experimentalists, and the following Table will show the result. The third column is the result of Mr. Pambour's later investigations:

Relative volume of the steam generated under different pressures, calculated by the proposed formula.

Total pressure of the steam, in pounds per square inch.	Volume of the steam, calculated by the ordinary formulæ.	Volume calculated by the proposed formula for high-pressure non-conducting engines.	Total pressure of the steam, in pounds per square inch.	Volume of the steam, calculated by the ordinary formulæ.	Volume calculated by the proposed formula for high-pressure non-condensing engines.
15	1669	"	65	434	436
20	1280	1243	70	406	406
25	1042	1031	75	381	381
30	882	881	80	359	358
35	765	768	85	340	338
40	677	682	90	323	320
45	608	613	105	281	276
50	552	556	120	249	243
55	506	509	135	224	217
60	467	470	150	203	196

We propose now to give the formulæ for calculating the powers and proportions of locomotive engines, commencing with the values, as ascertained, of the various causes of retardation in the movement of a train on a railroad drawn by a locomotive engine; and, combining these values, exhibit a general formulæ for all cases of the movement of a locomotive, and under all circumstances.

1. *Resistance to motion caused by the atmosphere.*—The resistance against a body moving in an indefinite fluid, at rest, is less than the resistance experienced by the same body placed at rest in an indefinite fluid moving against it, which seems to denote that a fluid in motion separates itself less easily than a fluid at rest. The second is, that a thin plate meets with a greater resistance from the air than a prismatic body presenting in front the same surface, and that the resistance diminishes according as the prism is longer. This circumstance is occasioned thus: The air having glided over the edges of a thin body, rushes immediately behind it with great rapidity, and carrying in its motion the portion of fluid which we have mentioned above, produces a relative vacuum behind the opposed surface. But if the moving body be a lengthened prism, the air in passing along its sides loses a certain portion of its acquired velocity, and, consequently, on reaching the hind-face of the prism, extends itself behind it with a force more and more moderated; whence results that it produces there a partial vacuum, or non-pressure, less considerable than in the case of a simple surface. And as we have seen that the definitive resistance against a moving body is the difference between the pressure of the air in front and the partial vacuum created behind, it follows that longer bodies definitively suffer from the air a less resistance than bodies of inconsiderable thickness.

The experiments of M. Thibault have confirmed those of Borda, on the proportionality of the resistance of the air to the square of the velocity, within the limits of velocity that we have to consider. They have, moreover, demonstrated that if two square surfaces be placed so that one shall precisely screen the other, and at a distance apart equal to one of their sides, the resistance against the screened surface will be 7-10ths of the resistance suffered by the surface in front. It consequently results that, when two surfaces are separated by a considerable space relatively to their extent, the resistance of the air against the second is to be estimated nearly as if it were isolated in the air; but if, on the contrary, the two surfaces are very near each other, relatively to their extent, there is room to think that the screened surface may be almost entirely protected against the effect of the air, since a space equal to one side of the surface would be requisite for the air to exert against it a resistance equal to two-thirds of the resistance against an isolated surface.

Uniting the results, and limiting ourselves to the case of a body moving in the air at rest, we have, to determine the resistance of the air, the following formulæ, in which Σ represents the front surface of a body traversing the air in a direction perpendicular to that surface, V the velocity of the motion, ϵ a coefficient variable with the length of the body, and, lastly, Q the definitive resistance produced by the air against the body:

$Q = \cdot 0011896\, \epsilon\, \Sigma\, V^2$. Resistance of the air expressed in English pounds, the surface Σ being expressed in square feet, and the velocity V in English feet per second.

And in applying these formulæ it will be necessary, according to the case, to give to the letter ϵ the following values.

For a thin surface .... $\varepsilon = 1{\cdot}43$
For a cube .... $\varepsilon = 1{\cdot}17$
For a prism of a length equal to three times the side of its front surface .... $\varepsilon = 1{\cdot}10$

Of the resistance of the air against the wagons, isolated or united in trains.—From what we have just seen, it will be easy to estimate the resistance of the air against a prismatic body in motion, when its front surface and dimension in length are known. But as a wagon does not present a regular prismatic form, it becomes necessary first to consider how we may find what surface it really offers to the shock of the air.

The front surface of a wagon may be directly measured; it consists of two distinct parts, the surface of the load, and that of the wagon itself. The former of these surfaces necessarily varies according to the nature of the goods which form the load; and the surface of the wagon, properly so called, includes the spokes of the wheels, the axletrees, axle-boxes, springs, and hind-wheels of the wagon.

We obtain, as the result of sufficiently extended experiments for separate wagons, the value of ε in the preceding formulæ to be $= 1{\cdot}15$.

As to the trains of several wagons, we see that for the resistance of the wheels, an addition must be made to the transverse section of the train; but as the wagons composing the same train, though very near each other, are not however in contact, it is necessary further to seek upon what extent of surface these wagons, thus united, still suffer the resistance of the air during their motion.

From the result of a number of experiments undertaken to determine this resistance, it was found that in order to estimate the effects of the resistance of the air against the progression of a train, to take as resisting surface that of the wagon of greatest section, augmented by 10 square feet per intermediary wagon, and by 6 square feet for the first wagon, including of course in this number the engine itself and its tender.

On railways of about 5 feet width of way, the surface of the highest wagon may, at a medium, be reckoned at 70 to 74 square feet; we may then esteem, in general, the resisting surface of a train of wagons at 70 square feet, plus as many times 10 feet as there are carriages in the train, including the engine and its tender.

If the road has a wider way, or if the carriages offer a surface different from that we have just indicated, the carriage of greatest section must be measured, and that measure used instead of the number 70. If the wheels of the wagon are more than three feet in diameter, there will likewise be an addition to make to take account of the greater surface which they expose to the shock of the air during the motion. This addition would be about 3 square feet per wagon, for wheels of 5 feet in diameter instead of 3. Finally, if the interval between the wagons, instead of being as it is at a medium on ordinary railways, considering the different kinds of carriages and the inequalities of their loading, were augmented by any important quantity, there might also be some addition to make for the effect of the air against the loads of the successive wagons; but as our determination in this respect gave something less than one square foot per wagon, and as the interval between the wagons could not be augmented by any thing considerable without being liable to inconveniences in practice, we deem that one square foot per wagon may comprehend nearly all cases.

When the effective surface presented to the shock of the air shall be known by the preceding calculation, it must be substituted for the letter Σ in the formulæ given above, putting at the same time for ε its value suitably to the length of the prism formed by the train of wagons. According to the variation of ε observed by Dubuat for prisms of divers proportions, it will be found that in the case of a train of 5 wagons, we must make $\varepsilon = 1{\cdot}07$, and that the case of a train of 25 wagons would require $\varepsilon = 1{\cdot}04$. In order then not to have to return continually upon these considerations we will take as a medium $\varepsilon = 1{\cdot}05$, which is suitable to a train of 15 wagons, and expressing at the same time, in the formula given above, the velocity in miles per hour, we shall have, in fine, to express the resistance of the air against a train of wagons in motion, the following formula:

$Q = {\cdot}002687\, \Sigma\, v^2$. Resistance of the air, in pounds, the effective surface of the train or the quantity Σ being expressed in square feet, and the velocity of the motion in miles per hour.

Table of the resistance of the air against the trains.—To dispense with all calculation relative to the resistance of the air, we here subjoin a table showing its intensity for all velocities from 5 to 50 miles per hour, and for surfaces of from 10 to 100 square feet. Were it required to perform the calculation for a velocity not contained in the table, it would evidently suffice to seek the resistance corresponding to half that velocity and to multiply the resistance found by 4; or, on the contrary, to seek the resistance corresponding to the double of the given velocity, and to take a quarter of the result. So the resistance of the air against a surface of 100 square feet, at the velocity of 50 miles per hour, is equal to four times the resistance of the air against the same surface at the velocity of 25 miles per hour. As to surfaces greater than 100 square feet, they must be decomposed into surfaces less than 100 feet, and then the table will still give the results required; for the resistance against a surface of 120 square feet is evidently nothing more than the sum of the resistances against one surface of 100 square feet and one of 20 square feet.

By means of the table in question will be obtained, without calculation, the resistance of the air expressed in pounds, for any velocity of the moving body; but it is to be observed that the table supposes the atmosphere at perfect rest. If, then, there be a wind of some intensity favorable to the motion, or contrary to it, account must be taken thereof. In order to effect this, it will suffice to observe that if the wind is favorable, the body will move through the air only with a velocity equal to the difference between its own absolute velocity and that of the wind; and that if on the contrary the wind is opposed to the motion, the effective velocity of the body through the air will be equal to the sum of its own velocity augmented by that of the wind. In this case, then, the velocity of the wind must first be measured, by abandoning a light body to its action, and noting the time in which it traverses a space previously measured on the ground; or else an anemometer may be used for the purpose. Then the velocity of the wind must be subtracted from that of the train in motion or added to it, according to the case; and that difference or that sum is the velocity to be sought in the table, or substituted in the formula, to obtain the corresponding resistance against the whole train.

If the wind, instead of being precisely contrary or favorable to the motion, should exert its action in an oblique direction, it would tend to displace all the wagons laterally; and consequently, from the conical form of the wheels, all those on the further side from the wind would turn on a larger diameter than those on the side towards the wind. The resistance produced will therefore be the same as that which would take place on a curve on which the effect of the centrifugal force were not corrected, and that resistance would necessarily be very considerable.

Practical Table of the resistance of the air against the trains.

Velocity of motion in miles per hour.	Resistance of the air in pounds per square foot of surface.	Resistance of the air in pounds; the effective surface of the train, in square feet, being:								
		20	30	40	50	60	70	80	90	100
Miles.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
5	·07	1	2	3	3	4	5	5	6	7
6	·10	2	3	4	5	6	7	8	9	10
7	·13	3	4	5	7	8	9	11	12	13
8	·17	3	5	7	9	10	12	14	15	17
9	·22	4	7	9	11	13	15	17	20	22
10	·27	5	8	11	13	16	19	22	24	27
11	·33	7	10	13	16	20	23	26	29	33
12	·39	8	12	15	19	23	27	31	35	39
13	·45	9	14	18	23	27	32	36	41	45
14	·53	11	16	21	26	32	37	42	47	53
15	·60	12	18	24	30	36	42	48	54	60
16	·69	14	21	28	34	41	48	55	62	69
17	·78	16	23	31	39	47	54	62	70	78
18	·87	17	26	35	44	52	61	70	78	87
19	·97	19	29	39	49	58	68	78	87	97
20	1·07	22	32	43	54	65	75	86	97	107
21	1·19	24	36	47	59	71	83	95	107	119
22	1·30	26	39	52	65	78	91	104	117	130
23	1·42	28	43	57	71	85	100	114	128	142
24	1·55	31	47	62	78	93	109	124	140	155
25	1·68	34	50	67	84	101	118	134	151	168
26	1·82	36	55	73	91	109	127	146	164	182
27	1·96	39	59	78	98	118	137	157	176	196
28	2·11	42	63	84	106	127	148	169	190	211
29	2·26	45	68	90	113	136	158	181	203	226
30	2·42	48	73	97	121	145	169	194	218	242
31	2·58	52	77	103	129	155	181	206	232	258
32	2·75	55	83	110	138	165	193	220	248	275
33	2·93	59	88	117	147	176	205	234	264	293
34	3·11	62	93	124	156	187	218	249	280	311
35	3·29	66	99	132	165	197	230	263	296	329
36	3·48	70	104	139	174	209	244	278	313	348
37	3·68	74	110	147	184	221	258	294	331	368
38	3·88	78	116	155	194	233	272	310	349	388
39	4·09	82	123	164	205	245	287	327	368	409
40	4·30	86	129	172	215	258	301	344	387	430
41	4·52	90	136	181	226	271	316	362	407	452
42	4·74	95	142	190	237	284	332	379	427	474
43	4·97	99	149	199	249	298	348	398	447	497
44	5·20	104	156	208	260	312	364	416	468	520
45	5·44	109	163	218	272	326	381	435	489	544
46	5·69	114	171	228	285	341	398	455	512	569
47	5·94	119	178	238	297	356	416	475	535	594
48	6·19	124	186	248	310	371	433	495	557	619
49	6·45	129	194	258	323	387	452	516	581	645
50	6·72	134	202	269	336	403	470	538	605	672

Of the friction of the cars of a train.—From experiments, the mean friction of the cars taken independently of the resistance of the air, amounts to $\frac{1}{389}$ of their gross weight, or to 5·76 pounds per ton; but to simplify the calculations we will take it at 6 pounds per ton, which makes $\frac{1}{373}$ of the weight of the cars.

These are the results which ought to be used when, for the resistance of the air, the determination deduced from the most recent and most exact experiments on the subject is used, and when account is taken, as it ought to be, of the length of the prism formed by the train in motion, as well as of the effects of the air against the rotation of the wheels and the accessory parts of the wagons.

It appears from this result that for the mean velocity of trains it would be indifferent to compute the friction of the cars at 5·76 pounds per ton, taking account of the real resistance of the air and of its effects against the accessory parts noticed above, or to take the friction of the wagons at 7 pounds per ton, accounting merely for the resistance of the air against the wagon of greatest section. On the other hand, as during the work of the engines their velocity is so much the greater as the train they draw is less considerable, whence the resistance of the air increases as the friction of the train diminishes, it will be found that either of the two preceding calculations leads to very nearly the same result, for the total resistance opposed by the moving train, and that it is only in cases of extreme velocity that the two modes of calculation present a notable difference.

Without any important error, the second of the two modes of calculation may be used; but the first is introduced with a view to the exhibition of a *general formula.*

It should be premised that the valuation of the friction, which we obtained above, ought to be understood only of carriages similar to those which were submitted to experiment, and subject to like conditions, viz., with iron axles, turning on brass chairs, and provided with self-acting grease-boxes; with three-feet wheels and axle-bearings $1\frac{3}{4}$ inches; with the use of a well-kept railway, and finally with the usual proportions of about $\frac{5}{6}$ between the weight of the body of the loaded carriage and the total weight of the wagon. Were these conditions *materially* altered, a new determination of the friction would become necessary.

Of gravity on inclined planes.—We have seen how the resistance caused on a railway by the friction of the wagons may be valued. But it sometimes happens that this friction is the smallest part of the total resistance which the engine has to overcome, in order to effect the motion of the train. This case occurs when the way is not level, and the train is obliged to ascend an acclivity. The resistance then caused is, as every one knows, much greater than on a level line, and in consequence it becomes necessary to take account of it in the calculations.

When a body is placed on an inclined plane, the weight which urges it, and which always acts in a vertical line, is decomposed into two forces; one perpendicular to the plane, and which measures the pressure produced against the plane, by virtue of the weight of the moving body, and the other parallel to the plane, and which tends to make the body slide or roll along the declivity. The latter force, which we will call *the gravity* along the plane, would inevitably drag the body towards the foot of the declivity, were it not counteracted by a contrary force. When therefore a train of wagons has to ascend an inclined plane, the moving power must apply to it: firstly, a force able to overcome the friction of the wagons themselves; and again, another force able to overcome the gravity in the direction of the plane. If, on the contrary, the mover draw the train of wagons down the plane, then, in order to produce the motion, it will evidently have to apply only a force equal to the difference between the friction proper to the wagons and the gravity, since the latter force then acts in the same direction as the mover.

When a body of a given weight is set on a plane of a given inclination, we know that, in order to obtain the gravity of the body along the plane, its weight is to be multiplied by the fraction which expresses *practically* the inclination of the plane. Thus, for instance, on a plane inclined $\frac{1}{89}$, that is to say, on a plane which rises 1 foot on a length of 89 feet measured along the acclivity, the gravity of 1 ton, or 2240 lbs., is

$$\frac{2240}{89} = 25{\cdot}2 \text{ lbs.}$$

Moreover, when a train of wagons ascends an acclivity, the engine has not only to surmount the gravity of the wagons of the train, but likewise its own gravity and that of the tender which follows it; and these forces do not present themselves when the motion takes place on a horizontal line. It is then on the *total* weight of the train, that is, including engine and tender, that the resistance caused by gravity on acclivities is to be calculated.

If it be supposed, for instance, that a train of 40 tons, tender included, be drawn up a plane inclined $\frac{1}{89}$, by an engine weighing 10 tons, it is clear that the definitive resistance opposed to the motion by the train will be

40×6 lbs. $= 240$ lbs., friction of the carriages at 6 lbs. per ton	240 lbs.
$50 \times \frac{2240}{89} = 1258$ lbs., gravity of the 50 tons of the train (reduced to lbs.) on a plane inclined $\frac{1}{89}$, to be added	1258
Total resistance arising from friction and gravity	1498 lbs.

If, on the contrary, the same train had to descend a plane inclined $\frac{1}{1000}$, the resistance it would then offer would be

40×6 lbs. $= 240$ lbs., friction of the wagons	240 lbs.
$50 \times \frac{2240}{1000} = 112$ lbs., gravity of the train to be deducted	112
Definitive resistance arising from friction and gravity	128 lbs.

In general, let M be the weight of the train, in tons gross and including the tender; let m be the weight of the engine, expressed also in tons; k the friction of the wagons per ton, expressed in lbs., as has been explained; finally, let g be the gravity, in lbs., of 1 ton on the plane in question. It is clear in the first place, from what has been said above, that the quantity g will be equal to 2240, multiplied by the practical inclination of the plane; so that if $\frac{1}{e}$ express that inclination, or the ratio of the height of the plane to its length, we shall have, to determine g, the equation

$$g = \frac{2240}{e}.$$

This premised, the friction of the wagons will have for its value k M. Again, since g expresses the gravity of 1 ton, it is plain that g (M + m) will represent, in lbs., the gravity of the total mass, train and engine, placed on the inclined plane.

Thus, according as the motion takes place in ascending or in descending, the total resistance, in lbs., offered by the train on the inclined plane, will be

$$k\,M \pm g\,(M + m) = (k \pm g)\,M \pm g\,m,$$

an expression in which the sign + belongs to the ascending motion, and the sign — to the descending motion of the train.

It will always be easy then to obtain the number of lbs., which represents the resistance opposed by a train in motion on a plane of a given inclination.

Of the effects of the blast-pipe.—We have just examined several of the resistances which are opposed to the engine in its motion, viz., that of the wagons along the rails, and that of the air against the trains. But among other resistances which the piston has yet to overcome, is one arising from the disposition of the engine itself, and of which it will be proper to treat before proceeding further.

The steam, after having exerted its action in the cylinder, might escape into the atmosphere by a large opening. It would then be possible for it entirely to dissipate itself in the air, during the time the piston takes to change its direction. Consequently the steam would in nowise impede the retrograde motion of the piston, whatever might be the velocity of the piston. But the disposition adopted is contrary to this. The steam, on leaving the cylinder, has no other issue towards the atmosphere than an aperture exceedingly narrow; nor can it, by that aperture, escape totally within the time of one stroke, except by assuming a very considerable velocity in its motion. For this, the steam in the cylinder must necessarily be at a pressure sensibly greater than that of the atmosphere into which it flows; and as the pressure of the steam while flowing acts in all directions, and consequently against the piston, it results that the latter, instead of having simply to counteract the atmospheric pressure, finds an additional one to overcome, which is to be added to the divers resistances already measured.

This new cause of resistance might, as has been said, be in a great measure suppressed, by enlarging sufficiently the outlet of the steam. But to do this would be to lose one of the most active causes of the definitive effect of the engine; for the object of the disposition of which we treat is to excite the fire sufficiently, and to produce, in a boiler of small dimensions, the very great quantity of steam requisite for the rapid motion of the engine. To this end, the waste steam is conducted to the chimney, and thrown into it by intermittent jets, through a blast-pipe or contracted tube, placed in the centre of the chimney and directed upwards. The jet of steam, as it rushes with force from this aperture, rapidly expels the gases which occupied the chimney. It consequently leaves behind it a vacuum; and this is immediately filled by a mass of air rushing through the fire-grate into the space where the vacuum has been made. At every aspiration thus produced, the fuel contained in the fire-box grows white with incandescence. The effect then is similar to that of a bellows continually urging the fire; and the artificial current created in the fire-box by this means is of such efficacy for the vaporization, that were the blast-pipe suppressed, the engine would become almost useless, which proves that the current of air attributable to the ordinary draught of the chimney is in comparison but very trifling.

Omitting the experiments and calculations from which it is derived, we obtain as the value of the resistance against the piston caused by the action of the blast-pipe, the formula

$$\cdot 0113\, v \frac{S'}{o};$$

in which v is the velocity of the engine in miles per hour: S′ the *total* vaporization of the boiler in cubic feet of water per hour; o the area of the orifice of the blast-pipe expressed in square inches; and the result of the calculation will give the pressure in the blast-pipe expressed in pounds per square inch. The pressure per square foot will be 144 times as much.

With respect to the quantity represented here by S′, the experiment from which we deduced the formula shows, that the vaporization signified is the *total* vaporization effected in the boiler, that is to say, the vaporization counted before deduction of the water carried away in a liquid state with the steam.

Making in the preceding formula

$$\cdot 0113 \frac{S'}{o} = p',$$

the pressure in the blast-pipe may be represented by the expression $p'\,v$, in which p' will be the ratio of the vaporization to the orifice of the blast-pipe, multiplied by a constant coefficient.

Now, for engines which vaporize as much as 60 cubic feet of water per hour, practice has established the use of a blast-pipe of 2·25 inches diameter, or 3·96 square inches of area, which gives for the value of the ratio $\frac{S'}{o}$,

$$\frac{60}{3 \cdot 96} = 15 \cdot 2.$$

In constructing engines of a greater vaporizing power, it would be natural to increase the area of the blast-pipe in proportion to the quantity of steam to which it is to give issue. There is room therefore to think that the proportion thus established between the production of steam and the area of the blast-pipe, will not be notably changed by the different engine-makers. Consequently the ratio $\frac{S'}{o}$ may be regarded approximatively as a constant quantity, given by the above proportion.

Then the preceding formula will be reduced simply to the expression ·175 v, which will be useful especially in valuing the pressure due to the blast-pipe in engines whose vaporization is unknown. In this formula, v is the velocity of the engine, in miles per hour, and the result is the pressure in the blast-pipe, expressed in pounds per square inch. As the pressure per square foot is 144 times as much, it follows that if we require the pressure expressed in that manner, we shall obtain its value by the formula $25{\cdot}2\, v$.

We shall then represent generally the pressure in the blast-pipe under the form $p' v$; and for the most ordinary cases, it will suffice to give to p', in this expression, one of the constant values above mentioned, according to the measures employed. But if the engine in question should differ too considerably from the proportions which we have just indicated with reference to the area of the blast-pipe, it would be necessary to substitute for that approximate value of p', its value function of S' and o.

In fine, to dispense with all calculation on this head, we here subjoin a table, in which will be found, on inspection, the pressures in the blast-pipe for given circumstances, and we continue that table beyond the actual effects of locomotive engines. It will there be recognized how, by augmenting the orifice of the blast-pipe, the resistance against the piston, arising from that cause, may be diminished at pleasure; and it may probably be found, in consequence, that in the regular work of locomotives, it might be useful to adopt a blast-pipe with a variable orifice, such as was employed temporarily in the experiments from which these values were deduced. Then, by contracting the orifice of efflux of the steam only just as much as is necessary, there will be no more resistance against the piston than what is indispensable for the proper action of the engine.

Practical Table of the pressures against the piston, due to the action of the blast-pipe.

Diameter of the blast-pipe.	Velocity of the engine, in miles per hour.	Effective pressure against the piston, in lbs. per square inch, the vaporization of the boiler, in cubic feet of water per hour, being:							
		30	40	50	60	70	80	90	100
	miles.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
2 inches.	5	0·5	0·7	0·9	1·1	1·3	"	"	"
	10	1·1	1·4	1·8	2·2	2·5	"	"	"
	15	1·6	2·2	2·7	3·2	3·8	"	"	"
	20	2·2	2·9	3·6	4·3	5·0	"	"	"
	25	2·7	3·6	4·5	5·4	6·3	"	"	"
	30	3·2	4·3	5·4	6·5	7·6	"	"	"
	35	3·8	5·0	6·3	7·6	8·8	"	"	"
	40	4·3	5·8	7·2	8·6	10·1	"	"	"
2¼ inches.	5	0·4	0·6	0·7	0·9	1·0	1·1	"	"
	10	0·9	1·1	1·4	1·7	2·0	2·3	"	"
	15	1·3	1·7	2·1	2·6	3·0	3·4	"	"
	20	1·7	2·3	2·8	3·4	4·0	4·5	"	"
	25	2·1	2·8	3·6	4·3	5·0	5·7	"	"
	30	2·6	3·4	4·3	5·1	6·0	6·8	"	"
	35	3·0	4·0	5·0	6·0	7·0	8·0	"	"
	40	3·4	4·5	5·7	6·8	8·0	9·1	"	"
2½ inches.	5	0·3	0·5	0·6	0·7	0·8	0·9	1·0	"
	10	0·7	0·9	1·2	1·4	1·6	1·8	2·1	"
	15	1·0	1·4	1·7	2·1	2·4	2·8	3·1	"
	20	1·4	1·8	2·3	2·8	3·2	3·7	4·1	"
	25	1·7	2·3	2·9	3·5	4·0	4·6	5·2	"
	30	2·1	2·8	3·5	4·1	4·8	5·5	6·2	"
	35	2·4	3·2	4·0	4·8	5·6	6·4	7·3	"
	40	2·8	3·7	4·6	5·5	6·4	7·4	8·3	"
	45	3·1	4·1	5·2	6·2	7·3	8·3	9·3	"
	50	3·5	4·6	5·8	6·9	8·1	9·2	10·4	"
2¾ inches.	5	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
	10	0·6	0·8	1·0	1·1	1·3	1·5	1·7	1·9
	15	0·9	1·1	1·4	1·7	2·0	2·3	2·6	2·9
	20	1·1	1·5	1·9	2·3	2·7	3·0	3·4	3·8
	25	1·4	1·9	2·4	2·9	3·3	3·8	4·3	4·8
	30	1·7	2·3	2·9	3·4	4·0	4·6	5·1	5·7
	35	2·0	2·7	3·3	4·0	4·7	5·3	6·0	6·7
	40	2·3	3·0	3·8	4·6	5·3	6·1	6·8	7·6
	45	2·6	3·4	4·3	5·1	6·0	6·8	7·7	8·6
	50	2·9	3·8	4·8	5·7	6·7	7·6	8·6	9·5

Diameter of the blast-pipe.	Velocity of the engine, in miles per hour.	Effective pressure against the piston, in lbs. per square inch, the vaporization of the boiler, in cubic feet of water per hour, being:							
		30	40	50	60	70	80	90	100
	miles.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
3 inches.	5	0·2	0·3	0·4	0·5	0·6	0·6	0·7	0·8
	10	0·5	0·6	0·8	1·0	1·1	1·3	1·4	1·6
	15	0·7	1·0	1·2	1·4	1·7	1·9	2·2	2·4
	20	1·0	1·3	1·6	1·9	2·2	2·6	2·9	3·2
	25	1·2	1·6	2·0	2·4	2·8	3·2	3·6	4·0
	30	1·4	1·9	2·4	2·9	3·4	3·8	4·3	4·8
	35	1·7	2·2	2·8	3·4	3·9	4·5	5·0	5·6
	40	1·9	2·6	3·2	3·8	4·5	5·1	5·8	6·4
	45	2·2	2·9	3·6	4·3	5·0	5·8	6·5	7·2
	50	2·4	3·2	4·0	4·8	5·6	6·4	7·2	8·0
	55	2·6	3·5	4·4	5·3	6·2	7·0	7·9	8·8
	60	2·9	3·8	4·8	5·8	6·7	7·7	8·6	9·6
3¼ inches.	5	0·2	0·3	0·3	0·4	0·5	0·5	0·6	0·7
	10	0·4	0·5	0·7	0·8	1·0	1·1	1·2	1·4
	15	0·6	0·8	1·0	1·2	1·4	1·6	1·8	2·0
	20	0·8	1·1	1·4	1·6	1·9	2·2	2·4	2·7
	25	1·0	1·4	1·7	2·1	2·4	2·7	3·1	3·4
	30	1·2	1·6	2·0	2·5	2·9	3·3	3·7	4·1
	35	1·4	1·9	2·4	2·9	3·3	3·8	4·3	4·8
	40	1·6	2·2	2·7	3·3	3·8	4·4	4·9	5·4
	45	1·8	2·4	3·1	3·7	4·3	4·9	5·5	6·1
	50	2·0	2·7	3·4	4·1	4·8	5·4	6·1	6·8
	55	2·2	3·0	3·7	4·5	5·2	6·0	6·7	7·5
	60	2·4	3·2	4·1	4·9	5·7	6·5	7·3	8·2
3½ inches.	5	0·2	0·2	0·3	0·4	0·4	0·5	0·5	0·6
	10	0·4	0·5	0·6	0·7	0·8	0·9	1·1	1·2
	15	0·5	0·7	0·9	1·1	1·2	1·4	1·6	1·8
	20	0·7	0·9	1·2	1·4	1·6	1·9	2·1	2·3
	25	0·9	1·2	1·5	1·8	2·1	2·4	2·7	2·9
	30	1·1	1·4	1·7	2·1	2·5	2·8	3·2	3·5
	35	1·2	1·6	2·0	2·5	2·9	3·3	3·7	4·1
	40	1·4	1·9	2·3	2·8	3·3	3·8	4·2	4·7
	45	1·6	2·1	2·6	3·2	3·7	4·2	4·8	5·3
	50	1·8	2·4	2·9	3·5	4·1	4·7	5·3	5·9
	55	1·9	2·6	3·2	3·9	4·5	5·2	5·8	6·5
	60	2·1	2·8	3·5	4·2	4·9	5·6	6·4	7·0
3¾ inches.	5	0·2	0·2	0·3	0·3	0·4	0·4	0·5	0·5
	10	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
	15	0·5	0·6	0·8	0·9	1·1	1·2	1·4	1·5
	20	0·6	0·8	1·0	1·2	1·4	1·6	1·8	2·0
	25	0·8	1·0	1·3	1·5	1·8	2·1	2·3	2·6
	30	0·9	1·2	1·5	1·8	2·1	2·5	2·8	3·1
	35	1·1	1·4	1·8	2·1	2·5	2·9	3·2	3·6
	40	1·2	1·6	2·0	2·5	2·9	3·3	3·7	4·1
	45	1·4	1·8	2·3	2·8	3·2	3·7	4·1	4·6
	50	1·5	2·1	2·6	3·1	3·6	4·1	4·6	5·1
	55	1·7	2·3	2·8	3·4	3·9	4·5	5·1	5·6
	60	1·8	2·5	3·1	3·7	4·3	4·9	5·5	6·1
4 inches.	5	0·1	0·2	0·2	0·3	0·3	0·4	0·4	0·5
	10	0·3	0·4	0·5	0·5	0·6	0·7	0·8	0·9
	15	0·4	0·5	0·7	0·8	0·9	1·1	1·2	1·4
	20	0·5	0·7	0·9	1·1	1·3	1·4	1·6	1·8
	25	0·7	0·9	1·1	1·4	1·6	1·8	2·0	2·3
	30	0·8	1·1	1·4	1·6	1·9	2·2	2·4	2·7
	35	0·9	1·3	1·6	1·9	2·2	2·5	2·8	3·2
	40	1·1	1·4	1·8	2·2	2·5	2·9	3·2	3·6
	45	1·2	1·6	2·0	2·4	2·8	3·2	3·6	4·1
	50	1·4	1·8	2·3	2·7	3·2	3·6	4·1	4·5
	55	1·5	2·0	2·5	3·0	3·5	4·0	4·5	5·0
	60	1·6	2·2	2·7	3·2	3·8	4·3	4·9	5·4

Of the several elements of the friction of locomotive engines.—After having examined the resistance offered by the loads to be moved, it will be proper also to make known the passive resistance or friction of the movers which we have to employ; for it is only the surplus of their power over and above what is necessary to propel themselves, that these movers can apply to the drawing of burdens.

While a locomotive engine is performing the traction of a train, it evidently requires:—1st, a certain force to make the train advance, or to overcome the resistance of all the loaded carriages; and 2dly, another force to propel itself by overcoming its own friction. It is this second force, that which causes the engine to move, which represents the *friction of the engine;* whereas the first is *the resistance of the load,* and the union of the two efforts constitutes the *total force applied by the mover.*

The friction of a locomotive engine is then the force it expends to maintain itself in motion on the rails. But that force must clearly vary according to the weight or resistance of the load which the engine draws. In effect, the greater that weight, the greater also will be the pressure it causes on the axes of rotation, and on the divers moving parts of the apparatus; and as the friction is always in proportion to the pressure, it follows that the friction which takes place at these points, must augment with the load. Hence the friction of the engine, which is nothing more than the force resulting from the union of these different frictions, must equally increase with the load.

Thus we find a difference between the friction of an engine *unloaded,* and that of the same engine *loaded.* The value of the first is found to be 15 *lbs. per ton of their weight,* and of the second, ·137 lbs. *additional* per pound of traction in the case of uncoupled driving-wheels, and ·215 lbs. per pound of traction in the case of engines with wheels coupled.

It will readily be conceived, however, that it must vary some with the construction and state of every engine.

With reference to the manner in which the additional friction of engines ought to be calculated, we have to bear in mind that it is to be reckoned on every pound of the *total* resistance exerted against the motion; that is to say, *the resistance caused by the friction of the wagons, that of gravity, and that of the atmosphere, must first be calculated, and on the sum of these the additional friction of the engine is to be taken at the rate already indicated.*

Of the total resistance on the piston, resulting from the divers partial resistances just enumerated.—We have just estimated successively the divers resistances which oppose the motion of the engine. It is necessary now to seek the definitive resistance which results from them united, per square inch or per unit of surface of the area of the piston.

The resistances which we have hitherto considered are—the resistance of the air, the friction of the wagons, the gravity, the friction of the engines, and the resistance arising from the blast-pipe. But we must here add, besides, the atmospheric pressure; for the engines under consideration being high-pressure engines, it follows that the opposite face of the piston necessarily supports, like every other body in communication with the atmosphere, a certain pressure due to the elasticity of the atmospheric air.

Thus, the definitive resistance exerted against the piston consists of six resistances, which are—the friction of the wagons, the resistance of the air, the gravity of the train, the friction of the engine, the atmospheric pressure, and the pressure caused by the blast-pipe. Of these six resistances, the last two act immediately and directly on the piston. They must therefore be moved at the velocity of the piston itself; but it is not so with the other four. In an engine, the pressures exerted on different points by the same force, are in the inverse ratio of the velocities of those points. Here the engine and its train must be moved at a velocity greater than that of the piston, in the proportion of the circumference of the wheel, to twice the length of the stroke. The intensity of the pressure exerted by the resistance of the load, the air, the engine, and the gravity, is then increased by its transmission to the piston, in the above ratio of the velocity of the wheel to that of the piston.

Consequently, if M express the number of tons gross which compose the total load, that is to say, including the weight of the tender-carriage of the engine, and k the number of pounds requisite to draw one ton on a railway,

$$k\,M$$

will be the resistance, in pounds, resulting from the friction of the wagons which carry the load. If at the same time we call g the gravity of 1 ton on the inclined plane to be traversed by the engine, and if m represent the weight of the engine, in tons,

$$g\,(M+m)$$

will be the resistance, in pounds, produced by the gravity of the total mass, train and engine; so that, according as the motion takes place in ascending or in descending, the definitive resistance arising from friction and gravity will be

$$k\,M \pm g\,(M+m) = (k \pm g)\,M \pm g\,m.$$

Similarly, if we express by $u\,v^2$ the resistance, in pounds, exerted by the air against the train, at the velocity v of the engine,

$$(k \pm g)\,M \pm g\,m + u\,v^2$$

will be the resistance opposed to the motion of the engine by the friction, the gravity, and the shock of the air.

If, again, F represent the friction of the unloaded engine, expressed also in pounds, and δ its additional friction, measured as a fraction of the resistance, as has been already indicated, we see that

$$F + \delta\,[\,(k \pm g)\,M \pm g\,m + u\,v^2]$$

will be the total friction of the engine at the moment when it draws the resistance

$$(k \pm g)\,M \pm g\,m + u\,v^2.$$

Consequently

$$(1+\delta)\,[(k\pm g)\,M\pm g\,m+u\,v^2]+F$$

will be the total resistance opposed to the progression, along the rails, by the engine and its train.

As this force produces on the piston a resistance augmented in the ratio of the circumference of the wheel to twice the stroke of the piston, if D express the diameter of the wheel, l the length of the stroke, and π the ratio of the circumference to the diameter,

$$(1+\delta)\,[(k\pm g)\,M\pm g\,m+u\,v^2]\,\frac{\pi D}{2\,l}+\frac{\pi\,D\,F}{2\,l}$$

will be the resistance on the piston, caused by that force, that is to say, caused by the resistance of the wagons, the gravity, the air, and the friction of the engine.

This resistance is that which is exerted on the totality of the area of the pistons. But representing by d the diameter of the cylinders, $\frac{1}{2}\pi\,d^2$ will be the area of the two pistons. Whence

$$\frac{(1+\delta)\,[(k\pm g)\,M\pm g\,m+u\,v^2]\,\frac{\pi D}{2\,l}+\frac{\pi\,D\,F}{2\,l}}{\frac{1}{2}\pi\,d^2},$$

or, simplifying,

$$(1+\delta)\,[(k\pm g)\,M\pm g\,m+u\,v^2]\,\frac{D}{d^2\,l}+\frac{D\,F}{d^2\,l},$$

will be the same force, divided according to the unit of surface of the piston.

Adding to this the atmospheric pressure p, and the pressure caused by the blast-pipe $p'\,v$, which are already measured per unit of surface, we shall have, in fine, for the *total* resistance R exerted on the piston,

$$R=(1+\delta)\,[(k\pm g)\,M\pm g\,m+u\,v^2]\,\frac{D}{d^2\,l}+\frac{D\,F}{d^2\,l}+p+p'\,v.$$

In this expression, the quantity g represents the gravity on the plane to be traversed by the train; if the plane be horizontal instead of inclined, we shall have $g=o$. The weights M and m of the train and the engine are expressed in tons gross; the quantity k, which is the friction of the wagons per ton, is equal to 6 lbs.; the value of δ is ·137 or $\frac{1}{7}$, for engines with uncoupled wheels; the velocity v of the engine is expressed in miles per hour; in fine, according as the dimensions D, l and d are expressed in inches or in feet, and the forces u, p and p', in pounds per square inch, or in pounds per square foot, the value R which will result from the calculation will be the resisting pressure on the piston, expressed likewise in pounds per square inch, or in pounds per square foot.

Applying this calculation to a train of 9 wagons and a tender, weighing 50 tons gross, and drawn at the velocity of 20 miles per hour, up a plane inclined $\frac{1}{500}$, by an engine with two cylinders of 11 inches diameter, stroke of the piston 16 inches, propelling wheels 5 feet, not coupled, weight 8 tons, friction 104 lbs., blast-pipe 2·25 inches in diameter; and referring, for the resistance of the air, to what has been said above, the proceeding will be as follows:

$50\times 6=300$ lbs. Friction of the wagons, in pounds, or value of $k\,m$.

$\frac{2240}{500}\times 58=260$ lbs. Gravity of the total mass, train and engine, or value of $g\,(M+m)$.

194 lbs. Resistance of the air against an effective surface of 180 square feet, at the velocity of 20 miles per hour or value of $u\,v^2$.

754 lbs. Resistance of the train, or $(k+g)\,M+g\,m+u\,v^2$.

$754\times 1{\cdot}137=857$ lbs. Resistance of the train, including the additional friction which it produces in the engine, or $(1+\delta)\,[(k+g)\,M+g\,m+u\,v^2.]$

$+\ 104$ lbs. Friction of the unloaded engine, or F.

961 lbs. Total resistance to the progressive motion of the engine, or value of the term

$$(1+\delta)\,[(k+g)\,M+g\,m+u\,v^2]+F.$$

On the other hand, we have

$3{\cdot}1416\times 60$ in. $=188{\cdot}5$ Circumference of the wheel, expressed in inches, or π D.

2×16 in. $=32$ Double the stroke of the piston expressed in inches, or $2\,l$

$\frac{188{\cdot}5}{32}=5{\cdot}9$ Ratio of the velocities of the wheel and the piston, or $\frac{\pi D}{2\,l}$.

Thus,

$961\times 5{\cdot}9=5670$ lbs. Resistance produced on the piston, or value of the term

$$(1+\delta)\,[(k+g)\,M+g\,m+u\,v^2]\,\frac{\pi D}{2\,l}+\frac{F\,\pi\,D}{2\,l}.$$

Again,

$\frac{3{\cdot}1416\times 11^2}{2}=190$ Area of the two pistons, in squure inches, or $\frac{1}{2}\pi\,d^2$.

Consequently, we obtain in fine

$\frac{5670}{190} = 29{\cdot}8$ lbs.	Above-mentioned resistance, portioned per square inch of the surface of the piston.
$+$ 3·5 lbs.	Effective pressure per square inch, arising from the blast-pipe, or $p' v$.
$+$ 14·7 lbs.	Atmospheric pressure per square inch, or p.
48·0 lbs.	Definitive resistance, per square inch of the surface of the piston of an engine with two cylinders of 11 inches in diameter, &c., when drawing a load of 50 tons under the given circumstances.

Were it desired to know that resistance per square foot, it would suffice to multiply the last result by 144, that is to say, the pressure required would be 6912 lbs. per square foot, which number would have been obtained directly, if instead of expressing the area of the piston in square inches, and the partial pressures in pounds per square inch, these measures had been referred to the square foot as unit of surface.

This example shows what is to be understood by the different quantities contained in the formula, and how each of them ought to be introduced into the calculation.

To know the evaporating power of which a given engine is capable, it suffices *to measure the number of square feet composing its total heating surface, without distinction between the fire-box and the tubes, and then to multiply that number by the vaporization which each square foot of surface is capable of producing.* It is then the latter quantity which we must now seek to determine; but, as we have seen that the vaporization produced per unit of surface varies with the velocity of the motion, it is necessary to specify at the same time the velocity at which we wish to measure the vaporization.

We find that in certain engines the vaporization per square foot of heating surface was ·198 cubic foot, at the velocity of 18·15 miles per hour. On the other hand, we know that the vaporization *varies in the direct ratio of the fourth roots of the velocities.* We may then deduce from thence, that at the velocity of 20 miles per hour, the vaporization of those engines will be

$$\cdot198\left(\frac{20}{18{\cdot}15}\right)^{\frac{1}{4}} = \cdot203 \text{ cubic foot of water per square foot of heating surface.}$$

Operating in the same manner for the two following series, we obtain, for the velocity of 20 miles per hour, the determinations of the following table:

Experiments on the vaporization of locomotive engines, per unit of total heating surface of their boiler.

Number of the series.	Average velocity of the engine in miles per hour.	Vaporization per hour and per sq. foot of total heating surface, at the preceding velocity.	Vaporization per hour and per sq. foot of total heating surface, at the velocity of 20 miles per hour.
	Miles.	Cubic foot.	Cubic foot.
2d,	18·15	·198	·203
3d,	20·13	·200	·200
4th,	8·99	·172	·210
5th,	15·26	·194	·208
			Mean......·205

Thus, from these experiments, it appears that at the velocity of 20 miles per hour, the vaporization of locomotives may be valued at ·205, or, in round numbers, at ·2 cubic foot of water per hour, per square foot of total heating surface of their boiler; and it appears also that the different engines and different velocities lead to numbers almost identical, which tends to confirm the valuation we have just obtained.

This determination is, as we have said, suitable to the velocity of 20 miles per hour; but it is easy to deduce from it that which would take place at any other velocity, by multiplying by the fourth root of the ratio between the given velocity and the velocity of 20 miles.

It must, however, be observed, with respect to these determinations, that they are strictly suitable only to boilers constructed in proportions not very different from those used in the experiments; that is to say, according to what has been explained above, that the heating surface of the fire-box ought not to be under a tenth of the total heating surface of the boiler, and the orifice of the blast-pipe not much larger than we had it in our experiments, according to the adopted practice. Were any notable change made in this respect, were the fuel of an inferior quality, or the engine materially different in construction from what we have described, there would be grounds for a new determination of the vaporization.

In fine, we will again add, that the numbers obtained above indicate rather the consumption of water of the boiler, than the real *vaporization* produced; for we shall presently see, that out of the total water thus expended by the engine, there is a portion which is drawn into the cylinders, mixed with the steam, but without being itself vaporized. Consequently, to obtain the real vaporization of the engine, it will be necessary to take account of this circumstance, as we shall do further on.

Of the loss of steam which takes place by the safety-valves, during the work of locomotive engines.— Among locomotive engines there are a great number which are subject to a continual loss of steam by the safety-valves. This effect arises from the engine being designedly constructed with an excess of power; that is to say, that according to the production of steam which takes place in its boiler, the engine could draw its regular load at a greater velocity than it is allowed to do. The result is, that to prevent the engine from acquiring too great a velocity, it becomes necessary partially to close the regulator, that is, to diminish the passage of the steam, till no more enters the cylinder than the quantity necessary to produce the desired velocity. Then the surplus accumulating in the boiler, at last raises the safety-valve and escapes into the atmosphere. When this loss takes place only on the regulator being somewhat closed, it is but a proof, as we have said, of a surplus of power which the engine holds in reserve. But if it takes place more or less under all circumstances, then it depends on the steam-ways being too narrow, and is consequently a defect in the engine; in either case, however, it is necessary to obtain a valuation of this loss.

There is yet another case in which engines are subject to a loss of steam by the valves; but this loss is owing to a different cause from the preceding, and exhibits itself much more abundantly; it is when the engine ascends a steep acclivity, with an apparently moderate load, or when it ascends a moderate inclination, with a very heavy load. At these moments the valves are always seen to emit an enormous quantity of steam. The reason is that, as soon as the engine reaches the inclined plane, its load instantly becomes extremely heavy, on account of the surplus of traction required by the gravity on the plane. It has been shown, in effect, that on a plane inclined $\frac{1}{100}$, every ton produces, by gravity alone, a resistance equal to that of 3·7 tons on a level. It happens therefore, at that moment, that the resistance of the train may become greater than the actual pressure of the safety-valve. Consequently the steam, instead of flowing by the cylinder, driving back the piston, raises the safety-valve, and escapes into the atmosphere. If then the passage which the steam thus opens for itself were sufficient for its total efflux, no more steam would pass through the cylinder, and the engine would inevitably stop.

Moreover, since, supposing even the steam in the cylinder at the same pressure as in the boiler, which is the most favorable supposition we can make, it still happens that the volume of steam expended by the cylinder is less than the volume of steam generated in the boiler, a part of the water must have been carried from the boiler to the cylinder, in its liquid state; and the comparison between the quantity of water consumed by the boiler and that which, in the state of vapor, corresponds to the velocity of the piston, shows that the quantity of water really converted into steam, is to the total quantity of water consumed, in the ratio of the numbers

$$\frac{11827}{15641} = \cdot 76.$$

Thus, in this experiment, we see that ·24 of the water expended by the boiler was carried into the cylinders without being reduced to steam, or that the *real* vaporization of the engine was ·76 *of the total water expended.*

The results which have just been presented above show that the quantity of water carried away with the steam, varies in different engines, and ought to be determined for each separately; but as in taking the means between the different experiments, that loss is found to amount to ·24 of the total vaporization of the boiler, this proportion may be adopted approximatively for engines that have not been directly submitted to experiment in this respect; that is to say, in order to have the *effective* vaporization of a locomotive, *the total vaporization of which its boiler is capable must be first measured; from the result must be subtracted, if necessary, the loss, either accidental or permanent, which may be observed at the safety-valves, and the remainder must be multiplied by the fraction* ·76. Thus will be obtained the volume of water which passes into the cylinder, in the real state of steam, and produces the motion of the piston.

We have reason then to think, from the different experiments cited above, that with coke for fuel, and with the other circumstances of the work and the construction of the engines, the most advantageous ratio to establish between the total heating surface and that of the fire-box would be nearly that of 10 to 1: since for a less proportion there would be increase in the expenditure of fuel, without increase of vaporization; and for a greater proportion, on the contrary, there would be reduction in the vaporization of the engine per unit of surface, which would incur the necessity of a larger boiler, and consequently of a greater weight, which it is important to avoid.

In fine, to arrive at a general conclusion from the experiments which have been made in order to the determination of this question, it appears that, according to the proportion of the fire-box to the total heating surface, the consumption of fuel in locomotive engines varies from 9·2 to 11·3 and 11·7 pounds per cubic foot of *total* water vaporized: so that it may, on an average, be valued at 10·7 pounds of coke per cubic foot of total vaporization, or its equivalent in other fuel.

Fuel.—To find the quantity of fuel necessary for the engine per ton per mile, the load the engine is to draw must previously be given: in multiplying the given load by the velocity the engine will assume with that load, the product will immediately make known, in tons conveyed one mile per hour, the useful effect of the engine. Dividing then the consumption of fuel of the engine per hour by the useful effect produced in the same time, the quotient will give definitively the quantity of fuel which will be consumed by the engine per ton per mile in drawing the given load.

The principal problems which occur with respect to locomotive engines have reference in the first place to two circumstances, namely: 1. When the engine is already constructed, and the question is to determine the effects that it will produce; 2. When the engine is as yet unbuilt, and the question is to determine the proportions it ought to have in order to produce desired effects. At present we consider only the questions relative to the first case.

When an engine is already constructed, and all its dimensions may be directly measured, the following problems may present themselves:

1. To determine the velocity the engine will assume with a fixed load,
2. To determine the load it will draw at a desired velocity;

3. To determine the useful effect it will produce at a desired velocity, or with a fixed load.

And this last problem may itself be expressed under ten different forms—namely, to find successively

The useful effect of the engine in tons drawn one mile;
The useful effect expressed in horse-power;
The quantity of fuel necessary per ton per mile;
The quantity of water necessary per ton per mile;
The useful effect produced per pound of fuel consumed;
The useful effect produced per cubic foot of water vaporized;
The consumption of fuel which produces one-horse power;
The consumption of water which produces one-horse power;
The horse-power produced per pound of fuel;
The horse-power produced per cubic foot of water vaporized.

Moreover, as two cases are necessarily to be distinguished in the work of the engines, namely, the case in which they work with a load or velocity *indefinite*, and that in which they work with the load or velocity which produces the *maximum of useful effect*, there will yet occur in this respect a new series of questions, namely:

1. To determine the velocity at which the engine will produce its maximum of useful effect;
2. To determine the load corresponding to the production of the maximum of useful effect;
3. To determine the maximum of useful effect that the engine can produce.

And this last problem may be expressed under the ten different forms which we have indicated above.

Of the velocity of the engine with a given load.—Suppose, in effect, that a load of 50 tons gross, tender included, be drawn up a plane inclined $\frac{1}{300}$, by an engine with 2 cylinders 11 inches in diameter, stroke of the piston 16 inches, wheels 5 feet, friction 103 pounds, total pressure of the steam in the boiler 65 pounds, or effective pressure 50 pounds per square inch, and, finally, vaporizing power 60 cubic feet of water per hour, or 1 cubic foot per minute.

The total resistance opposed by that load to the motion of the piston is 48 pounds per square inch, when the velocity is 20 miles per hour. If, then, we admit that the engine will come near enough to that velocity, for the valuation which we have made of the resistance of the air and the pressure caused by the blast-pipe, in the calculation, not to be very far from the truth, we must conclude that, during the uniform or permanent motion of the engine with that load, the pressure of the steam, during its action in the cylinder, will likewise be 48 pounds per square inch.

Now, the quantity of water consumed by the boiler amounts to 60 cubic feet of water per hour, and we have shown in treating of the vaporization that out of that mass of water 75-100ths only, on an average, are really converted into steam, and that the rest is merely carried away with the steam into the cylinders, but in a liquid state. The effective vaporization of the engine is, then, firstly,

$$\cdot75 \times 60 = 45 \text{ cubic feet per hour, or}$$
$$\cdot75 \text{ cubic foot per minute.}$$

This water is first transformed, in the boiler, into steam at the total pressure of 65 pounds per square inch; but on passing into the cylinders it acquires the pressure of 48 pounds per square inch, and we know that, in this change, the steam remains always at the maximum density for its temperature. Its volume may then be determined by the table, which we have already given, on the volume of the steam formed under different pressures. According to this table, the volume of the steam formed under the total pressure of 48 pounds per square inch, is 573 times that of the water which produced it. Hence the quantity of water effectively vaporized per minute in the boiler, will form, during its passage through the cylinders, a volume of steam expressed by

$$573 \times \cdot75 = 430 \text{ cubic feet.}$$

On the other hand, the area of each cylinder is 95 square inches, or in square feet that area is represented by ·66 square foot; and the stroke of the piston is 16 inches, or 1·33 foot. Whence the capacity of each cylinder traversed by the piston is

$$\cdot88 \text{ cubic foot.}$$

But besides the portion traversed by the piston there still exists, at each end of each cylinder, a vacant space called the *clearance of the cylinder*, which is necessarily filled with steam at each stroke. The capacity of this vacant space, represented by an equivalent portion of the cylinder, and steam-ways included, is usually 1-20th of the part of the cylinder traversed by the piston. The real capacity, therefore, which is filled with steam at each stroke of the piston, is

$$\cdot88 \times \tfrac{21}{20} = \cdot924 \text{ cubic foot.}$$

Consequently the number of strokes of the piston which the engine will give per minute, by reason of its effective vaporization, will necessarily be

$$\frac{430}{\cdot924} = 465.$$

Now, each time the wheel makes one revolution the engine gives two strokes of the piston in each of its two cylinders; and the diameter of the wheel is 5 feet, which makes 15·71 feet in circumference. Therefore, at every four strokes of the piston the engine advances 15·71 feet; that is to say, its velocity, in feet per minute, will be

$$\frac{465}{4} \times 15\cdot71 = 1822 \text{ feet.}$$

Finally, as one mile contains 5280 feet, and one hour contains 60 minutes, the definitive velocity of the engine, in miles per hour, will be

$$\frac{60}{5280} \times 1822 = 20{\cdot}71 \text{ miles.}$$

Thus we see that the above vaporization will necessarily produce a velocity of 20·7 miles per hour for the engine; that is to say, a locomotive engine with the given proportions may, if in good order, and with a well-stocked fire, draw a load of 50 tons gross, tender included, up a plane inclined $\frac{1}{300}$, at the velocity of 20·7 miles per hour.

With regard to the velocity which we have just obtained, we must add that if the engine suffers besides a loss of steam by the safety-valve, which takes place in a great number of locomotive engines, there will then be a corresponding loss on the effective vaporization; and consequently the definitive velocity of the engine will be reduced in a corresponding proportion. For instance, if the engine be liable to a loss of ·05 of its vaporization in full activity, its definitive velocity, in the case above mentioned, will become

$$\cdot 95 \times 20{\cdot}71 = 19{\cdot}67 \text{ miles per hour.}$$

The calculation will be performed in the same manner for every other load and for every other engine. Thus, in general,

M, Representing the number of tons of the load, tender included;
m, The weight of the engine, in tons;
g, The gravity, in pounds, of one ton on the plane the engine has to traverse; this gravity being null for the case of a horizontal plane;
k, The friction of the wagons per ton, expressed in pounds;
v, The velocity of the engine, in miles per hour;
$u\,v^2$, The resistance of the air against the train, at the velocity v, resistance expressed in pounds;
$p'\,v$, The pressure against the piston, arising from the action of the blast-pipe, expressed in pounds per square foot;
F, The friction of the engine, in pounds;
δ, Its additional friction, measured as a fraction of the resistance;
D, The diameter of the propelling wheels of the engine, in feet;
d, The diameter of the cylinder, in feet;
l, The length of the stroke of the piston, in feet;
c, The clearance of the cylinder, represented by an equivalent portion of the stroke of the piston, and consequently in feet;
P, The *total* or *absolute* pressure of the steam in the boiler, in pounds per square foot;
p, The atmospheric pressure, expressed in pounds per square foot; finally,
S, The *effective* vaporization of the engine, in cubic feet of water per hour, at the velocity known or unknown of the motion;

$$R = (1+\delta)\,[(k \pm g)M \pm g\,m + u\,v^2]\,\frac{D}{d^2\,l} + \frac{D\,F}{d^2\,l} + p + p'\,v,$$

will be the pressure of the steam per unit of surface in the cylinder.

On the other hand, if we express by μ the relative volume of the steam generated under the pressure R, a relative volume which will be found in the tables given, p. 230, since S is the volume of water vaporized per hour in the engine, it follows that

$$\mu\,S$$

will be the corresponding volume of the steam under the pressure R; that is to say, during its action in the cylinders.

But, expressing by π the ratio of the circumference to the diameter, the capacity of each cylinder which is traversed by the piston, has for its measure

$$\tfrac{1}{4}\,\pi\,d^2\,l;$$

and the clearance of the cylinder offers, besides, a capacity of

$$\tfrac{1}{4}\,\pi\,d^2\,c.$$

Therefore the totality of the space filled with steam at each stroke, in each cylinder, has for its expression

$$\tfrac{1}{4}\,\pi\,d^2\,(l+c).$$

Consequently the number of strokes of the piston corresponding to the volume of steam expended μ S, will be

$$\frac{\mu\,S}{\tfrac{1}{4}\,\pi\,d^2\,(l+c)}.$$

But, while each piston performs 2 strokes, that is, at every expenditure of 4 cylinders-full of steam, the engine advances 1 turn of the wheel, that is to say, a space represented by

$$\pi\,D.$$

Therefore the velocity of the engine, in feet per hour, will be expressed by the above number of strokes, divided by 4 and multiplied by π D; that is to say, the velocity will be

$$V = \frac{\mu\,S}{d^2} \cdot \frac{D}{l+c}.$$

And finally, as 1 mile contains 5280 feet, the velocity of the engine expressed in miles per hour, will be

$$v = \frac{1}{5280} \cdot \frac{\mu\,S}{d^2} \cdot \frac{D}{l+c} \cdot \quad \ldots\ldots \quad (1)$$

This expression will make known the velocity required, on substituting, for each of the letters, the value suitable to it in the engine considered.

As it has been shown that the relative volume of the steam under the pressure R, may be expressed by

$$\frac{1}{n+q\,\mathrm{R}},$$

it is plain that, instead of seeking the relative volume μ in the table which we have given, its value may be represented by the expression

$$\mu=\frac{1}{n+q\,\mathrm{R}}=\frac{1}{n+q\left\{(+\delta)\left[(k\pm g)\,\mathrm{M}\pm g\,m+u\,v^2\right]\frac{\mathrm{D}}{d^2\,l}+\frac{\mathrm{D\,F}}{d^2\,l}+p+p'\,v\right\}}$$

and consequently the preceding expression of the velocity of the engine may equally be written under the form

$$v=\frac{1}{5280}\cdot\frac{1}{q}\cdot\frac{l}{l+c}\cdot\frac{\mathrm{S}}{(1+\delta)\left[(k\pm g)\,\mathrm{M}\pm g\,m+u\,v^2\right]+\mathrm{F}+\frac{d^2\,l}{\mathrm{D}}\left(\frac{n}{q}+p+p'\,v\right)}\cdots\cdots(1\text{ bis})$$

Such then will be the general expression of the velocity of the engine, in miles per hour; an expression in which all is known from measures taken on the engine, even the vaporization S, which results from the extent of heating surface.

Making use of this formula to find the velocities corresponding to divers loads of the engine, or to divers values of M, attention must be paid never to suppose, for M, a load capable of producing on the piston a resistance greater than the pressure of the steam in the boiler, because it is evident that the resistance would then exceed the power, and the motion could not take place. Nor can M be supposed of a value less than the weight of the tender, which is the *minimum* load an engine can have to draw. Beyond these two limits the solutions given by the formula would evidently cease to suit the problem.

Practical formulæ for calculating the effects of locomotive engines, and examples of their application.—We have hitherto presented the formulæ proper for calculating the effects of the engines, under a form completely algebraical, that is to say, leaving in them all the quantities represented by letters, without excepting the constant quantities whose values have been already determined in former pages. But we now purpose to reduce these formulæ to their most simple practical form; in order to effect which, it will be proper to replace in them, as far as may be, the letters, by the numerical values which they represent.

The letters which have a constant value in all cases and for all the engines are—

k, Friction of the wagons, which we have found equal to 6 lbs. per ton;

p, Atmospheric pressure, the value of which is 2118 lbs. per square foot;

n, Constant quantity relative to the volume of the steam, its value being ·0001421, when the pressure is measured in pounds per square foot;

q, Factor relative to the volume of the steam, equal to ·00000023 when the pressure is expressed in pounds per square foot;

c, Clearance of the cylinder, which may be taken generally at $\frac{1}{20}$ of the useful stroke of the piston, which gives $\frac{l}{l+c}=\frac{20}{21}$.

These values being constant for all engines, may be introduced permanently into the equations. Substituting them therefore for the respective letters, and effecting the calculation as much as possible, we obtain the following formulæ, which are quite prepared for practical applications.

In order to avoid recurring to another page of the work, we will first repeat here the signification of all the letters which subsist in these formulæ.

M, Load of the engine, in tons gross, tender included;

m, Weight of the engine, in tons;

C, Weight of the tender, in tons;

g, Gravity, in pounds, of 1 ton placed on the inclined plane to be traversed by the engine. If the inclination of the plane be $\frac{1}{e}$, that gravity will have for its value, in pounds, $\frac{2240}{e}$; and if the plane be horizontal, the gravity will be equal to zero;

v, Velocity of the engine, expressed in miles per hour;

$u\,v^2$, Resistance of the air against the train, at the velocity v, a resistance expressed in pounds;

$p'\,v$, Pressure owing to the blast-pipe, expressed in pounds per square foot;

F, Friction of the engine, in pounds;

δ, Additional friction of the engine, measured as a fraction of the resistance, namely: ·14 for engines with uncoupled wheels, and ·22 for those with coupled wheels;

D, Diameter of the propelling wheels, in feet;

d, Diameter of the cylinder, in feet;

l, Stroke of the piston, in feet;

P, *Total* or absolute pressure of the steam in the boiler, in pounds per square foot;

S, Effective vaporization of the engine, in cubic feet of water per hour. It varies according to the engines, but may, on an average, be valued at ·75 of the total or gross vaporization, when there is no blowing of steam at the valves;

S′, Total vaporization of the boiler, at the velocity of the motion, in cubic feet of water per hour;

N, Consumption of coke in the fire-box, in pounds per hour.

PRACTICAL FORMULÆ FOR CALCULATING THE EFFECTS OF LOCOMOTIVE ENGINES.

General case.

$$v = \frac{784\,S}{(1+\delta)\left[(6 \pm g)\,M \pm g\,m + u\,v^2\right] + F + \frac{d^2\,l}{D}(2736 + p'\,v)} =$$

Velocity of the engine, in miles per hour.

$$M = \frac{1}{(1+\delta)(6 \pm g)}\left[784\,\frac{S}{v} - \frac{d^2\,l}{D}(2736 + p'\,v) - F\right] - \frac{1}{6 \pm g}(u\,v^2 \pm g\,m) =$$

Load of the engine, in tons gross, tender included.

u. E.................. $= M\,v =$

Useful effect, in tons gross, drawn 1 mile per hour, tender included.

u. E. in H P.................. $= \frac{M\,v}{62{\cdot}5} =$

Useful effect, in horse-power.

Q. co. pr. t. pr. M.................. $= \frac{N}{M\,v - C\,v} =$

Quantity of coke in pounds, per ton gross drawn 1 mile, tender *not* included.

Q. wa. pr. t. pr. m.................. $= \frac{S'}{M\,v - C\,v} =$

Quantity of water, in cubic feet, per ton gross drawn 1 mile, tender *not* included.

u. E. 1 lb. co.................. $= \frac{M\,v}{N} =$

Useful effect produced per pound of coke, in tons gross drawn 1 mile, tender included.

u. E. 1 ft. wa.................. $= \frac{M\,v}{S'} =$

Useful effect produced per cubic foot of total vaporization, in tons gross drawn 1 mile, tender included.

Q. co. fr. 1 H P.................. $= \frac{62{\cdot}5\,N}{M\,v} =$

Quantity of coke in pounds, which produces the effect of 1 horse.

Q. wa. fr. 1 H P.................. $= \frac{62{\cdot}5\,S}{M\,v} =$

Quantity of water, in cubic feet, which produces the effect of 1 horse.

u. E. 1 lb. co. in H P.................. $= \frac{M\,v}{62{\cdot}5\,N} =$

Useful effect, in horse-power, produced per pound of coke.

u. E. 1 ft. wa. in H P.................. $= \frac{M\,v}{62{\cdot}5\,S'} =$

Useful effect, in horse-power, produced per cubic foot of *total* vaporization.

Case of maximum useful effect.

$$v' = \frac{1{\cdot}804}{1{\cdot}421 + {\cdot}0023\,P} \cdot \frac{D}{l} \cdot \frac{S}{d^2} =$$

Velocity of maximum useful effect, in miles per hour.

$$M' = \frac{d^2\,l}{(1+\delta)(6 \pm g)\,D}(P - 2118 - p'\,v') - \frac{1}{6 \pm g}\left(\frac{F}{1+\delta} + u\,v'^2 \pm g\,m\right) =$$

Maximum load of the engine, in tons gross, tender included.

M. u. E....... .... $= M'\,v' =$

Maximum useful effect, in tons gross drawn 1 mile per hour, tender included.

That there may be no misunderstanding as to the manner of expressing the divers quantities contained in the formulæ, nor on the manner of performing the calculation, we will here give an example or two with some detail.

Suppose a locomotive of 65 cubic feet of total vaporization, at the velocity of 20 miles per hour; with cylinders 11 inches or ·917 foot in diameter, stroke of the piston 16 inches or 1·33 foot, wheels 5 feet in diameter, not coupled, friction 103 lbs., weight 8 tons, blast-pipe 2·33 inches in diameter, *total* or absolute pressure in the boiler 65 lbs. per square inch, and consumption of coke per hour 598 lbs. Suppose this engine employed on a level railway, of about 5 feet of width of way, and let it be required to know what velocity it will attain with a train of 10 wagons weighing 56 tons, tender included, which is the same as 50 tons without tender.

1st. As the motion takes place on a horizontal plane, we have $g=0$; and since the wheels of the engine are not coupled, we have $\delta = \cdot 14 = \frac{1}{7}$. Moreover, from the ratio which we have found between the total and the effective vaporization of the engine, the value of the latter, at 20 miles per hour, is

$$S = \cdot 75 \times 65 = 48\cdot 75 \text{ cubic feet of water per hour;}$$

and in fine, from the proportions of the engine, we have

$$\frac{d^2\,l}{D} = \overline{\cdot 917}^2 \times \frac{1\cdot 33}{5} = \cdot 2237.$$

This done, to find what velocity the engine will acquire in drawing the train of 56 tons, we will first suppose that it may be, approximatively, 23 miles per hour, and we shall then have, for the pressure in the blast-pipe, 4 lbs. per square inch, or $p'\,v = 576$ lbs. per square foot. As the effective surface presented to the shock of the air, valued according to the mode already explained, is $\Sigma = 70 + 10 \times 12 = 190$ square feet, the resistance of the air at the velocity of 23 miles per hour, will be $u\,v^2 = 270$.

Thus the value of v, taken without supposing that the vaporization changes with the velocity, will be

$$v = \frac{784 \times 48\cdot 75}{1\cdot 14\,(6 \times 56 + 270) + 103 + \cdot 2237\,(2736 + 576)} = 24\cdot 88.$$

This first essay of calculation gives then 24·88 miles per hour, for the velocity of the engine, and we conclude from it that the two terms $u\,v^2$ and $p'\,v$ which we have calculated on the supposition of $v=23$, have not been valued in a manner sufficiently exact, but that the true velocity is comprised between 24·88 and 23 miles.

Trial then might be made of $v=24$, and this value would be found to satisfy the problem, when the variation which the vaporization undergoes with the velocity of the motion is neglected. Thus approximatively we might hold to this result; but if it be desired to calculate with greater accuracy, it will be proper to introduce the increase of vaporization due to the velocity.

For this purpose, as the increase of vaporization will have the effect of increasing the result of the calculation, we will try a number greater than 24, as $v=25$, for instance. Supposing then this datum for the valuation of the variable quantities, we shall have

$$S = 51\cdot 55,$$
$$p'\,v = 630,$$
$$u\,v^2 = 319;$$

and resolving the equation with these values we find

$$v = 25\cdot 19.$$

Consequently, in fine, taking a mean between 25 and 25·19, we have, for the definitive velocity sought,

$$v = 25\cdot 10 \text{ miles per hour.}$$

Such then will be the velocity which the engine will assume, when drawing on a level a train of 56 tons, tender included.

2d. To continue this example of the application of the formulæ, let it be required to find what will be the velocity of the maximum useful effect of the engine.

In order to effect this, we will replace in the equation proper to that problem, the pressure P in the boiler by its value $P = 65 \times 144 = 9360$ lbs. per square foot; and supposing first that the vaporization of the engine will undergo no change notwithstanding the reduction of velocity, we obtain the result

$$v' = \frac{1\cdot 804 \times 48\cdot 75}{1\cdot 421 + \cdot 0023 \times 9360} \cdot \frac{1}{\cdot 2237} = 17\cdot 13.$$

This would then be the velocity sought, if the vaporization of the engine were invariable; but as the diminution of velocity will lower the vaporization, which is such as we have supposed it, only at the velocity of 20 miles per hour, we will try whether the velocity of 16 miles will suit the formula. Then the effective vaporization of the engine, reduced in the proportion of the fourth roots of the velocities, will become 46·10 cubic feet of water per hour, and the formula resolved according to this supposition, will give

$$v' = 16\cdot 20 \text{ miles per hour.}$$

This is therefore the velocity suitable to the production of the maximum useful effect required.

3d. In fine, to obtain the load corresponding to the maximum of useful effect, we recur to the proper equation, which is

$$M' = \frac{d^2\,l}{D} \cdot \frac{1}{6\,(1+\delta)}\,(P - 2118 - p'\,v') - \frac{F}{6\,(1+\delta)} - \frac{u\,v'^2}{6};$$

and first calculating in this all the terms, except the last, we have as a result 208·46.

It remains then to subtract from this number the value of $\frac{u\,v'^2}{6}$, to conclude from it definitively the required value of the load. As the value of the term $\frac{u\,v'^2}{6}$ depends on the number of carriages in the train, which will itself be known only by the definitive solution of the problem, we will again in this place follow the method of approximations. Supposing the load to be of about 160 tons, the train will consist of 31 carriages besides the tender; thus the effective surface offered to the shock of the air, will be

$$\Sigma = 70 + 33 \times 10 = 400 \text{ square feet.}$$

Consequently the resistance of the air, at the velocity found, of 16·20 miles per hour, will be $u v'^2 = 282$ lbs., which gives

$$\frac{u v'^2}{6} = 47{\cdot}00\,;$$

substituting then this valuation in the formula, we obtain the result

$$M' = 208{\cdot}46 - 47{\cdot}00 = 161{\cdot}46.$$

Consequently the load of 161·5 tons, forming a train of 31 carriages, besides the tender, will be the maximum load required.

4th. In fine, if it be desired to know the maximum velocity the engine is capable of attaining, when followed by its tender only, and without drawing any train, the proceeding will be as in the first case; but supposing the load to be of 6 tons only, and taking account of the increase of vaporization, according to the velocity, the result will be

$$v = 35{\cdot}03 \text{ miles per hour.}$$

In this last case, the useful effect of the engine, *tender not included*, will be null.

From these detailed examples is seen how the calculation is to be performed in all the cases; but it must be remarked, that with the use of logarithms, these different trials present no sort of difficulty, and that those who have once got the habit of these researches, guess immediately and at a glance, what numbers they ought to employ in the approximations, so that the apparent length of the calculation entirely disappears.

Collecting the results which we have just obtained, calculating moreover the useful effect of the engine, and expressing it under the different forms already indicated, we form the following Table:

Effects of a locomotive of 65 cubic feet of vaporization, with a load of 56 tons gross, on a level, tender included.

M .... = 56 tons gross, tender included, (10 carriages and the tender;)
v .... = 25·10 miles per hour;
u. E. .... = 1411 tons gross drawn 1 mile per hour, tender included;
u. E. in H P. .... = 23 horses;
Q. co. pr. t. pr. m. .... = ·47 lb. per ton gross per mile, tender *not* included;
Q. wa. pr. t. pr. m. ... = ·052 cubic foot per ton gross per mile, tender *not* included;
u. E. 1 lb. co. .... = 2·36 tons gross drawn 1 mile, tender included;
u. E. 1 ft. wa. .... = 21·70 tons gross drawn 1 mile, tender included;
Q. co. fr. 1 H P. ...... = 26·50 lbs.;
Q. wa. fr. 1 H P. .... = 2·880 cubic feet;
u. E. 1 lb. co. in H P. = ·038 horse;
u. E. 1 ft. wa. in H P. = ·347 horse.

Maxima effects of the same engine.

M′ .... = 161·5 tons gross, tender included, (31 carriages and tender;)
v' .... = 16·20 miles per hour;
u. E. .... = 2616 tons gross drawn 1 mile per hour, tender included;
u. E. in H P. .... = 42 horses;
Q. co. pr. t. pr. m. ... = ·24 lb. per ton gross per mile, tender *not* included;
Q. wa. pr. t. pr. m. ... = ·026 cubic foot per ton gross per mile, tender *not* included;
u. E. 1 lb. co. .... = 4·38 tons gross drawn 1 mile, tender included;
u. E. 1 ft. wa. .... = 40·25 tons gross drawn 1 mile, tender included;
Q. co. fr. 1 H P. ...... = 14·29 lbs.
Q. wa. fr. 1 H P. ...... = 1·553 cubic foot;
u. E. 1 lb. co. in H P. = ·070 horse;
u. E. 1 ft. wa. in H P. = ·644 horse.

To give a second example of this calculation, we will suppose the railway to have 7 feet of width of way, and seek what will be the velocity of the engines of medium force, in use on such a line, under the same circumstances as we have just examined relatively to a railway of about 5 feet of width of way.

We will suppose then a locomotive of 120 cubic feet of vaporization, at the velocity of 25 miles per hour, with the following proportions: cylinders, 14 inches or 1·17 foot in diameter; stroke of the piston, 16 inches or 1·33 foot; wheels, 8 feet in diameter, not coupled; weight, 18 tons; friction, 270 lbs.; blast-pipe, 3·14 inches in diameter; total or absolute pressure in the boiler, 80 lbs. per square inch; and consumption of coke in the same time, 1050 lbs. or 8·75 lbs. per cubic foot of water vaporized. Moreover, by reason of the width of the way, we will take the surface of the largest wagon of the train at 100 square feet, the average surface of a wagon at 56 square feet, and the weight of the tender at 10 tons.

Seeking then by the same calculation as before, what effects this engine is capable of producing, first in drawing a train of 60 tons gross, tender included, which makes 50 tons without the tender and afterwards in drawing its maximum load, we obtain the following results:

Effects of a locomotive of 120 *cubic feet of vaporization, with a load of* 60 *tons gross, tender included.*

M .... = 60 tons gross, tender included, (7 carriages and the tender;)
v .... = 34·75 miles per hour;
u. E. .... = 2085 tons gross drawn 1 mile per hour, tender included;
u. E. in H P. .... = 33 horses;
Q. co. pr. t. pr. m. ... = ·60 lb. per ton gross per mile, tender *not* included;
Q. wa. pr. t. pr. m. ... = ·069 cubic foot per ton gross per mile, tender *not* included;
u. E. 1 lb. co. .... = 1·99 ton gross drawn 1 mile, tender included;
u. E. 1 ft. wa. .... = 17·38 tons gross drawn 1 mile, tender included;
Q. co. fr. 1 H P. ...... = 31·48 lbs.;
Q. wa. fr. 1 H P. .... = 3·597 cubic feet;
u. E. 1 lb. co. in H P. = ·032 horse;
u. E. 1 ft. wa. in H P. = ·278 horse.

Maxima effects of the same engine.

M′ .... = 147 tons gross, tender included, (20 carriages and the tender;)
v' .... = 25·55 miles per hour;
u. E. .... = 3756 tons gross drawn 1 mile per hour, tender included;
u. E. in H P. .... = 60 horses;
Q. co. pr. t. pr. m. ... = ·30 lb. per ton gross per mile, tender *not* included;
Q. wa. pr. t. pr. m. ... = ·034 cubic foot per ton gross per mile, tender *not* included;
u. E. 1 lb. co. .... = 3·58 tons gross drawn 1 mile, tender included;
u. E. 1 ft. wa. .... = 31·30 tons gross drawn 1 mile, tender included;
Q. co. fr. 1 H P. ...... = 17·47 lbs.;
Q. wa. fr. 1 H P. .... = 1·997 cubic foot;
u. E. 1 lb. co. in H P. = ·057 horse;
u. E. 1 ft. wa. in H P. = ·501 horse.

The velocity of the same engine, drawing its tender alone, would be 43·28 miles per hour; which would be the maximum of velocity that this engine could attain.

It is visible, in these examples, that the above formulæ present no difficulty, and that it is merely necessary to preserve in them the homogeneity of the measures employed.

Practical formulæ, to determine the proportions of locomotive engines, according to given conditions.—We will here give, in their numerical form, all the formulæ which are essential for determining the proportions of the engines, according to given conditions. For the signification of the signs employed, we refer to page 243 of this volume.

PRACTICAL FORMULÆ TO DETERMINE THE PROPORTIONS OF LOCOMOTIVE ENGINES, NECESSARY TO PRODUCE GIVEN EFFECTS.

$$S = \frac{(1+\delta)v}{784}\left[(6 \pm g)M \pm gm + uv^2 + \frac{F}{1+\delta} + \frac{1}{1+\delta} \cdot \frac{d^2 l}{D}(2736 + p'v)\right] =$$

Total vaporization of the boiler, in cubic feet of water per hour.

$$d^2 = \frac{D}{l} \cdot \frac{1+\delta}{2736 + p'v}\left[\frac{784}{1+\delta} \cdot \frac{S}{v} - (6 \pm g)M \mp gm - uv^2 - \frac{F}{1+\delta}\right] =$$

Square of the diameter of the cylinder, in feet.

$$l = \frac{D}{d^2} \cdot \frac{1+\delta}{2736 + p'v}\left[\frac{784}{1+\delta} \cdot \frac{S}{v} - (6 \pm g)M \mp gm - uv^2 - \frac{F}{1+\delta}\right] =$$

Stroke of the piston, in feet.

$$D = \frac{d^2 l}{1+\delta} \cdot \frac{2736 + p'v}{\frac{784}{1+\delta} \cdot \frac{S}{v} - (6 \pm g)M \mp gm - uv^2 - \frac{F}{1+\delta}} =$$

Diameter of the wheel, in feet.

$$S = \frac{1}{784} \cdot \frac{d^2 l}{D} \cdot v\,(618 + P) =$$

Total vaporization of the boiler, in cubic feet of water per hour.

$$P = (1+\delta)\frac{D}{d^2 l}\left[(6 \pm g)M \pm gm + uv'^2 + \frac{F}{1+\delta}\right] + 2118 + p'v' =$$

Total or absolute pressure of the steam in the boiler, in pounds per square foot.

$$P = 784\frac{D}{d^2 l} \cdot \frac{S}{v'} - 618 =$$

Total or absolute pressure of the steam in the boiler, in pounds per square foot.

$$d^2 = 784\frac{D}{l} \cdot \frac{S}{v'} \cdot \frac{1}{618 + P} =$$

Square of the diameter of the cylinder, in feet.

$$l = 784 \frac{D}{d^2} \cdot \frac{S}{v'} \cdot \frac{1}{618 + P} =$$

Stroke of the piston, in feet

$$D = \frac{1}{784} \cdot d^2 l \cdot \frac{v'}{S} (618 + P) =$$

Diameter of the wheel, in feet.

$$d^2 = (1 + \delta) \frac{D}{l} \cdot \frac{(6 \pm g) M' \pm g m + u v'^2 + \frac{F}{1 + \delta}}{P - 2118 - p' v'} =$$

Square of the diameter of the cylinder, in feet.

$$l = (1 + \delta) \frac{D}{d^2} \cdot \frac{(6 \pm g) M' \pm g m + u v'^2 + \frac{F}{1 + \delta}}{P - 2118 - p' v'} =$$

Stroke of the piston, in feet.

$$D = \frac{d^2 l}{1 + \delta} \cdot \frac{P - 2118 - p' v'}{(6 \pm g) M' \pm g m + u v'^2 + \frac{F}{1 + \delta}} =$$

Diameter of the wheel, in feet.

Of adhesion.—It has been observed, in the description of the engine, that the effort of the steam being applied to the wheel, the engine is precisely in the case of a carriage which is made to advance by pushing at the spokes. Thus, as in this action the only fulcrum of the mover is the adhesion of the wheel to the rails, if that adhesion were insufficient, the force of the steam would indeed make the wheels turn; but these, sliding on the rails instead of adhering to them, would turn without advancing, and the engine would remain on the same spot.

The heavier the train to be drawn, the more force the engine must employ, and the more resistance it must consequently meet with at the point on which it strains to effect the motion. It might then be feared that with trains of considerable weight, the engines would be unable to advance; not that force would be wanting in the mover itself, but in the fulcrum of the mover.

Adhesion being indispensable to the creation of the progressive motion, two conditions are requisite for an engine to be capable of drawing a given load: 1st, the dimensions and proportions of the engine and its boiler must enable it to produce, by means of the steam, the necessary pressure on the piston, which constitutes the force applied by the engine; and 2d, the weight of the engine must be such as to cause a sufficient adhesion to the rails. These two conditions of force and weight should accord together; for, were there a great force of steam and a slight adhesion, the latter would limit the effect of the engine, and steam would be lost; and were there too much adhesive weight for the power of the engine, that weight would, during the motion, become a useless burden, since the limit of the load would then be marked by the pressure of the steam.

It is necessary therefore, after having determined the dimensions of the engines from the conditions which they are to fulfil, as has been done in the preceding pages, to seek what ought to be their weight so as to enable them to draw the greatest load intended to be imposed on them during their work. The enormous weight now given to locomotive engines, generally causes this condition to be fulfilled of itself. Six-wheel engines however require, in this respect, more attention than four-wheel engines, because it often happens, on an uneven railway, that a six-wheel engine is wholly supported on its four extreme wheels, whereas the middle ones, which are the propelling wheels, being accidentally situated immediately above a low part of the railway, scarcely touch the rail, and therefore have but a slight adhesion. In the best state of the rails the adhesion which is the limit of the traction of an engine, may be taken at $\frac{1}{6}$ of the weight on the driver, and it is never less than $\frac{1}{20}$ in the worst state of the rails, when they are greasy and dirty from the effect of wet weather.

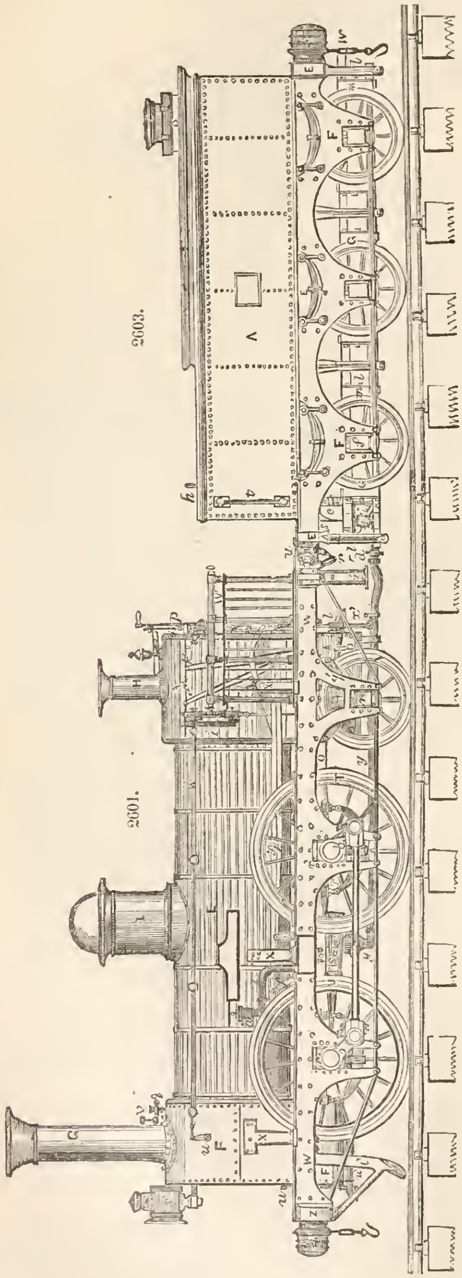
For the preceding calculations and formulæ we are indebted to M. Pambour, whose works on the steam-engine, both locomotive and stationary, should be in the hands of every engineer and machinist, and to which we refer for a more complete elucidation of the laws which govern the motion of this wonderful machine.

Locomotive engine and tender.—The example which we have chosen for detailed illustration is the form of locomotive engine and tender at present constructed by Messrs. Hawthorn, of Newcastle, England, a firm whose success and extensive employment in this branch of the trade is a sufficient guarantee for the excellence of their arrangements. In these figures are embodied all the most recent improvements which Messrs. Hawthorn have introduced into their engine, including their patent auxiliary expansion frame, and the mechanism by which it is moved.

The engine is made, according to the method generally adopted by Messrs. Hawthorn, with a cranked axle and outside bearings; it is furnished with six wheels, (designated a six wheeled engine;) the driving and fore wheels, which are five feet in diameter, are coupled together, and the hind-wheels, three feet diameter, are placed immediately below the fire-box. By this arrangement the greatest safety is insured, and particularly at high speeds; the same amount of stability being given to the engine as if the hind-wheels were placed *behind* the fire box, with this additional advantage, that the length of coupling between the wheels may, by the present disposition, be regulated to any convenient distance. An engine of this description will be found exceedingly useful for general purposes, being adapted both for merchandise and for mixed or passenger trains at ordinary speeds; while for express or special trains, where a high rate of speed is required, railway travelling would be rendered comparatively safe by employing engines specially made and adapted for such purposes.

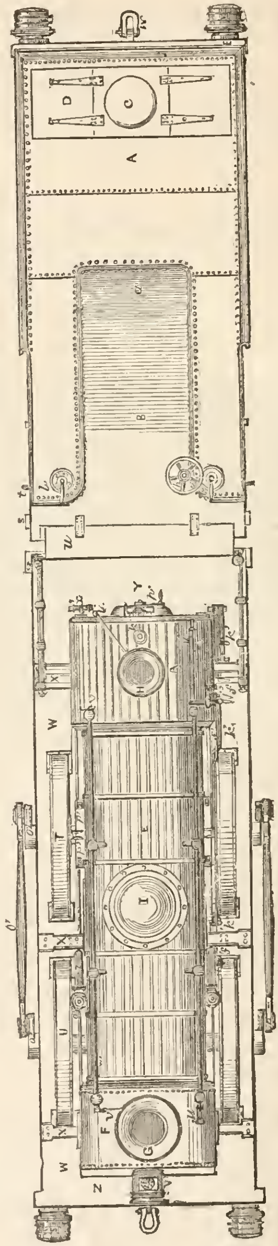
Enumeration of the figures.—Fig. 2601, a longitudinal elevation of the locomotive engine.

Fig. 2602, a general plan of the same.



2603.

2601.



2604.

2602.

Fig. 2603, a longitudinal elevation of the tender, showing the mode of its connection with the engine.

Fig. 2604, a general plan of the tender, in which are seen the cocks for regulating the supply of water to the boiler, and the hand-wheel for working the brake apparatus.

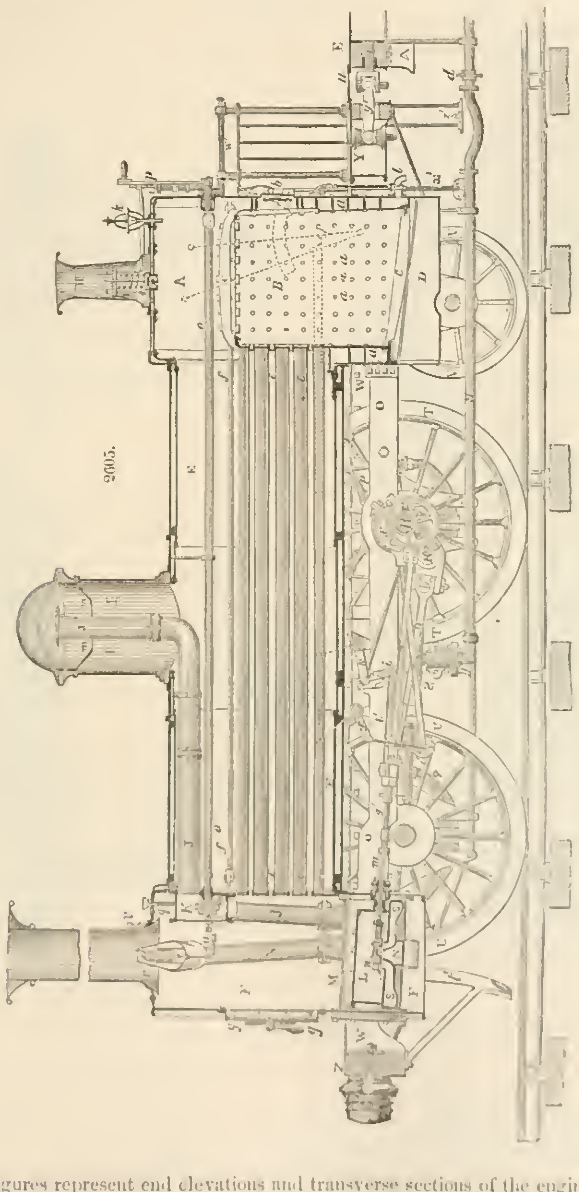
The following four figures are sectional views.

Fig. 2605, a longitudinal section of the engine, showing the internal arrangements of the boiler, and the working parts of the engine.

Fig. 2606, a sectional plan of the engine, with the cylindrical part of the boiler removed, for the purpose of exhibiting the general arrangement of the working parts, and the construction of the fire-box.

Fig. 2607, a longitudinal section of the tender.

Fig. 2608, a plan of the tender with the tank removed, showing the construction of the framing, drag-springs, brake-geer, &c.



2605.

The following figures represent end elevations and transverse sections of the engine

Fig. 2609, an elevation of the engine as seen at the fire box end.

Fig. 2610, a transverse section through the fire-box.

Fig. 2611, an elevation of the engine as seen at the smoke box end.

Fig. 2612, a transverse section through the smoke box. In this view the cylinder to the right is sectioned through the steam passage, while that to the right is supposed to be cut through the discharge port and blast-pipe.

The following figures represent detailed views, drawn to a larger scale, of such parts of the engine and tender as could not be fully shown in combination:

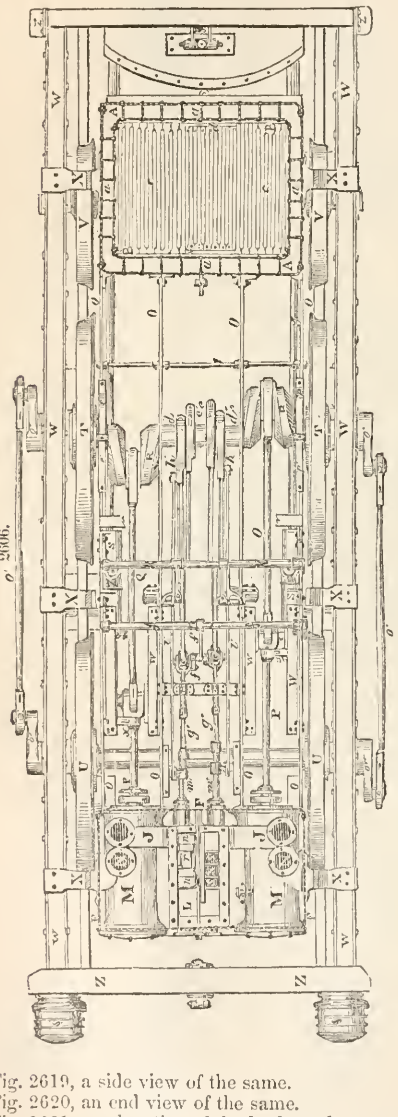
Fig. 2613, a transverse section of the steam regulator and chest; Fig. 2614, a longitudinal section of the same.

Fig. 2615, a plan of the piston, with the cover removed to show the packing.

Fig. 2616, a section of the piston through the lines 1 2 3.

Fig. 2617, a plan of the same, complete, with the cover and guards.

Fig. 2618, a plan of the piston-rod cross-head, with slide-blocks and projecting arm for working the feed-pump.



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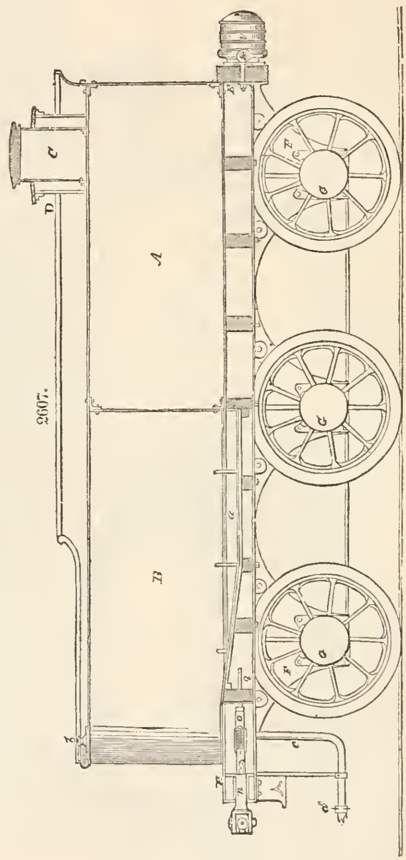


2607.

Fig. 2619, a side view of the same.

Fig. 2620, an end view of the same.

Fig. 2621, an elevation of the backward eccentric.

Fig. 2622, a plan of the same, showing the stud for working the expansion-geer.

Fig. 2623, a side view of the reversing or coupling link.

Fig. 2624, an edge view of the same, showing the stud by which the valve is shifted into forward or back geer.

Fig. 2625, an elevation of the front end of the eccentric-rod.

Fig. 2626, a plan of the same.

Fig. 2627, a longitudinal section of the feed-pump, with the plunger, valves, &c.

Fig. 2628, an end view of the same.

Fig. 2629, a plan of the double safety-valve, with the seat; Fig. 2630, a longitudinal section of the same.

Fig. 2631, an edge view of the driving-wheel, half in section, to show the mode of fixing the arms, tyre, &c. In this view is also given part of the cranked axle, to show the relative positions of the crank, wheel, bearing, &c.

2608.

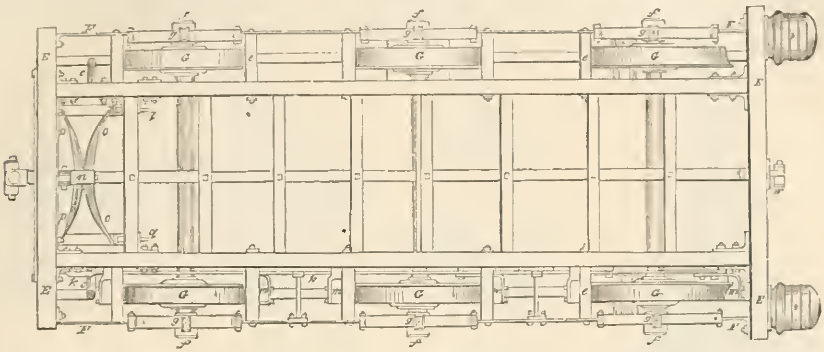
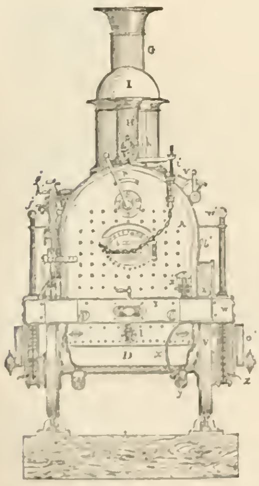


Fig. 2632, a transverse section of the driving-wheel axle-box, and of part of the outer spring Fig 2633, a longitudinal section of the same.

Fig. 2634, a section of the suspending link for adjusting the weight of the engine on the springs · Fig 2635, a side elevation of the same.

2609.



2610.

2611.

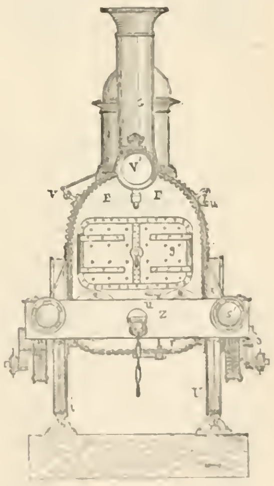
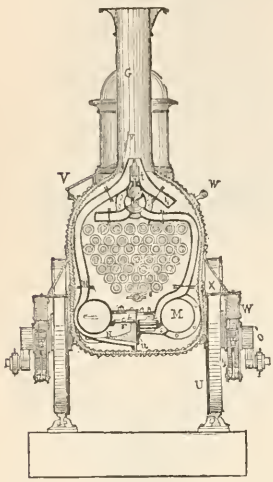


Fig. 2636, a general elevation of the tender brake-geer; Fig. 2637, a plan of the brake-lever and oothed sector; Fig. 2638, the screw and link-nut for the tender brake.

Description of the engine.—The fire-box.—The first part of the engine which claims our attention is the fire-box. The form of fire-box which Messrs. Hawthorn have adopted is clearly shown in the end elevation, Fig. 2609, and transverse section, Fig. 2610. It consists of two parts: the external fire box A, which in reality forms part of the boiler, being filled with water to about fifteen inches from the top; and the internal fire-box B, placed within the other, and which contains the fuel for generating steam. The internal fire-box is made of copper, and tapered slightly towards the top, for the purpose of allowing the globules of steam which are formed on its sides to ascend more freely. To resist the downward pressure of the steam, the roof is strengthened by the strong malleable iron stays C C bolted across, and having a bearing against its sides, while both external and internal fire-boxes are secured against the lateral strain by having numerous iron stay-bolts *a a a* screwed through both boxes, and riveted at each end. The fire-door *b* affords access to the internal fire-box for the admission of coke. It is of an oval form, and the latch is provided with a chain for the greater convenience of opening and shutting. The space between the two fire boxes at that part where the fire door is situated is filled by an oval shaped frame, securely riveted through both, and the fire-door itself is furnished with a plate of iron riveted to the inside at some little distance from it, to save it from warping by the intensity of the heat within. The fire-bars *c c* distinctly shown in the section Fig. 2605, and in the plan Fig. 2606, are ranged parallel to each other on a wrought-iron frame fixed to the under side of the fire-box, and a portion of them marked *d* in the plan, is so arranged as to admit of their falling at one end on the removal of the pin which supports them. In this case the burning fuel drops into the ash-box D fixed below to receive it and the combustion almost immediately ceases.

The boiler.—As before remarked, the external fire-box A forms part of the boiler, communicating freely with it, and being, like it, filled with water to the proper height when the engine is in operation The boiler, properly so called, is marked E in the figures, and in the specimen now under notice consists of a cylinder 11 feet 6 inches in length, and 3 feet 6⅝ inches in diameter outside. It is traversed throughout its length by 107 brass tubes *e e e*, 2⅛ inches outside diameter, of No. 13 and 14 wire gage.

2612.



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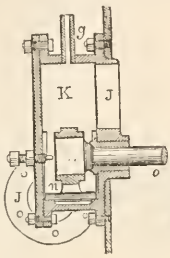

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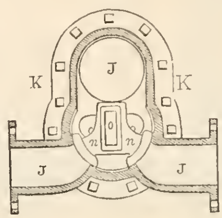

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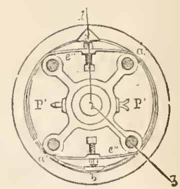

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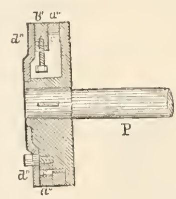
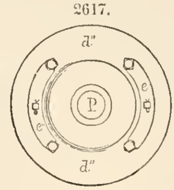
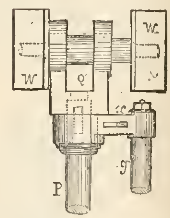


2617.

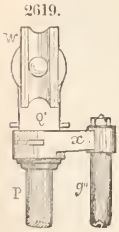


2618.



These tubes are inserted into the front plate of the internal fire-box, (called the *tube-plate*,) which is made of a sheet of copper considerably thicker than the other plates of which the fire-box is composed, so as to afford a better bearing for the fixing of the tubes. At the front extremity of the boiler, they pass through a similar plate of iron, which forms the partition between the boiler and the smoke-box Into these plates the tubes are secured at both ends by riveting, and subsequently by strong steel ferrules accurately turned, and driven firmly into the interior of the tubes, so as to render them perfectly tight and free from leakage. The cylindrical form of the boiler renders lateral staying unnecessary, and the tubes themselves, at that part where they are situated, secure it against the pressure in a longitudinal direction; but for further safety, three strong malleable-iron stay-bolts *f f f* traverse the whole length of the boiler, and are secured to it by round pins passing through brackets riveted to the front tube-plate, and to the back plate of the external fire-box. The whole boiler is covered externally with a coating of thick felt and with strips of wood, called the *lagging*, or *cleading*, to prevent the radiation of heat, as well as to give greater symmetry of appearance.

2619.



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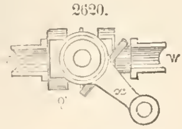

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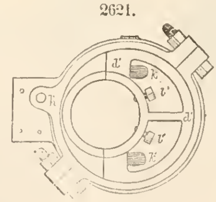

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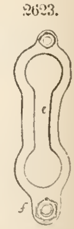
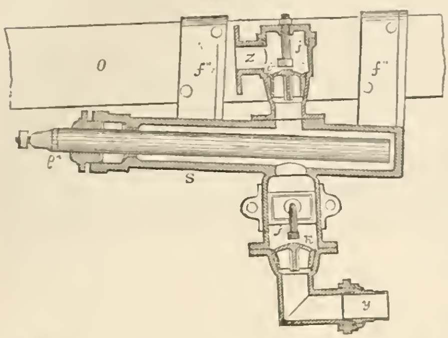
2623.

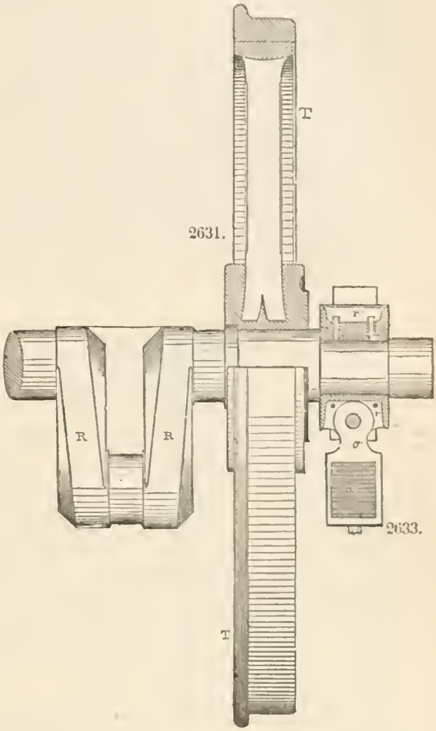


The smoke-box.—The tubes *e e e* all open into that part of the boiler called the smoke-box F, the purpose of which is to collect the gases evolved by the combustion of the fuel, and to transmit them through the chimney G into the air. In this compartment of the boiler are also placed the steam cylinders, and other very important parts of the engine, to be hereafter described. The front plate of the smoke-box is furnished with large folding-doors *g g*, fitted air-tight to it, and provided with a handle, by which both doors are simultaneously shut and opened. These doors, which are distinctly shown in the end elevation, Fig. 2611, and in the section, Fig. 2605, serve to afford access for the insertion and cleaning of the tubes, as well as for the examination and repair of the parts of the engine referred to above.

The safety-valves and boiler mountings.—Although the efficient working of the engine requires that the boiler be capable of generating steam of a high elastic force, it is yet essential to safety that the steam pressure be confined within certain limits. In order to insure this, the boiler is provided with two safety-valves, *h* and *i*, both placed in one chest, (Fig. 2629,) fixed on the summit of the external fire-box, and surrounded by a polished brass chimney H, of a form symmetrical with that of the large chimney G. One of these valves, marked *i*, which is of the kind called the *lever safety-valve*, can be regulated to any required degree of pressure by the engine-driver, being furnished with a *spring-balance*, by which the amount of pressure is distinctly indicated. The other safety-valve *h* is inaccessible, and is loaded by a spiral spring and screws, to such a pressure as may be considered safe, yet higher than the engine is expected, under ordinary circumstances, to require.

2627.





2631.

2633.

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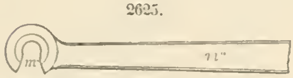
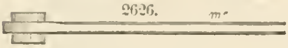


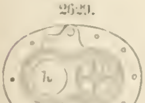
2626.



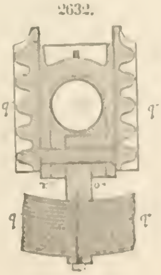
To indicate the height at which the water stands in the boiler, and to enable the driver to keep it always at its proper level, a set of gage-cocks and glass tube *j*, communicating with the water inside, are fixed at a convenient situation near the foot-plate. A graduated scale is fixed behind the glass tube, and the required level may thus be maintained with considerable accuracy.

As a precaution against accidents, and to give notice of the approach of the engine, a steam whistle *k* is attached to the top of the fire-box, and communicates with the steam within by a short pipe, provided with a stop cock. The internal construction of the whistle is such, that when the stop-cock is opened, the steam rushing out with great force encounters the sharp edges of a species of inverted cup, thereby emitting a shrill and very loud noise, which can be heard at the distance of several miles.

2629.



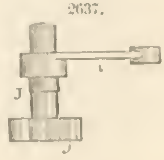
2632.



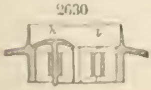
2635.

2634.

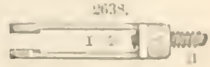
2637.



2630



2638.

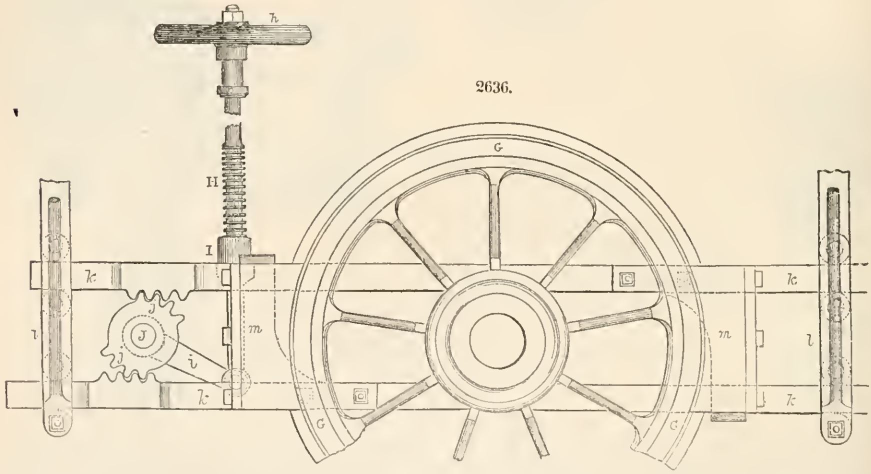


Behind, and at the lowest extremity of the fire-box, is situated the *blow-off cock l*, by which the boiler may be emptied of water when required; and, for the purpose of cleansing it of the accumulation of sediment which is constantly being formed in it when the engine is in operation, it is provided with *mud-holes* both at fire box and smoke-box ends. These mud holes, which are shown in Figs. 2609 and

2612, are secured when the engine is at work, by covers or *doors* bearing against the inside of the boiler and fixed each by a single bolt passing through a strong wrought-iron bridge bearing against the outside

The steam-pipes and regulator-valve.—The steam-chest or receiver I rises from the centre of the cylindrical part of the boiler, and is carried to a considerable height above it, in order that the mouth of the steam-pipe J, which opens into it, may be removed to as great a height as can conveniently be obtained, from the surface of the water in the boiler. The object of thus raising the open orifice of the steam-pipe is to prevent *priming*, that is, the ascent of water along with the steam, and its consequent flow through the steam-pipe into the cylinders, where its presence in any considerable quantity would produce the most serious inconveniences, besides the danger to which the boiler would be exposed by its rapid abstraction. As a further precaution against priming, Messrs. Hawthorn make use of a simple but very ingenious contrivance. This consists of a species of inverted cone *m*, Fig. 2605, made of sheet-iron, and riveted to the interior of the steam-chest, with an aperture in the centre just wide enough to allow the free ascent of the steam between it and the steam-pipe, which passes through it. The water in the boiler tends to prime chiefly where there is a surface of metal to which it may adhere; consequently, when, in rising up the sides of the steam-chest, it encounters the inverted cone *m*, its course is diverted downwards and towards the centre, where being unsupported it falls back into the boiler. Should any priming occur round the sides of the steam-pipe itself, the water is, in a somewhat analogous way, diverted by the bell-shaped mouth of the pipe, and returned into the boiler. The steam-receiver is surrounded by a polished brass dome, which, besides being highly ornamental to the engine, serves the very important purpose of diminishing the radiation of heat, by interposing a stratum of heated air between the steam-chest and the external atmosphere.

2636.



The steam-pipe J is made of copper, and that part of it which is inclosed within the boiler is 5¾ inches internal diameter. It enters an orifice accurately bored and fitted to receive it, in the cast-iron *regulator-valve chest* K, which is bolted steam-tight to the exterior of the front tube-plate of the boiler. The valve-chest K incloses a regulator-valve *n*, of a new and improved form, which, as well as the chest itself, is shown on an enlarged scale in Figs. 2613, 2614. It is formed of cast-iron, and has two projecting faces accurately and smoothly turned, and of such form and dimensions as, when placed in the position shown in Fig. 2613, completely to cover the orifices of the two branch steam-pipes J J, whose faces are bored truly cylindrical, and of the same diameter as that of the faces of the valve. The distance between the contiguous edges of the two branch-pipes is somewhat greater than the breadth of the valve face, so that when turned round in either direction, the orifices of both pipes may be fully opened. In the centre of rotation of the valve is an oblong hole, into which is fixed the correspondingly formed end of a long rod *o o*, traversing the whole length of the boiler, and passing steam-tight through a stuffing-box in the back plate of the fire-box. A long lever-handle *p*, is fixed to the outer extremity of this rod, and the engine-driver is thereby enabled, with the greatest ease and precision, to regulate the supply of steam to the cylinders. A small pipe *q*, screwed into the upper part of the regulator-valve chest, rises through the smoke-box, and is surmounted by a cup, and provided with a stop-cock, by which oil may be admitted into the interior of the valve-chest, for the lubrication of the working parts.

The two branch steam-pipes J J, as will be distinctly seen by reference to the transverse section, Fig. 2612, open a communication for the admission of steam from the regulator-valve chest K, into the valve casing or steam-chest L L. They are each 3¾ inches internal diameter, and they, as well as the discharge-pipes N N, are so disposed within the smoke-box as not to obstruct the cleaning or replacing of the tubes.

The cylinders and valves.—The slide-valves, with their expansion-slide frames, are placed between the cylinders M M, in one steam-chest L, formed by the construction of the cylinders when bolted together, as will be seen by inspection of Fig. 2606. By this arrangement access is afforded to both valves by the removal of only one cover, which seems to be an improvement over the other methods now in use.

The steam cylinders M M are 14 inches diameter, with a stroke of 21 inches. They are placed at a slight angle in the smoke-box, for the purpose of being accommodated to the position of the cranked axle. The form and dimensions of the pistons P′ P′, and the arrangement of the packing-rings $a''a''$, are clearly indicated in Figs. 2615, 2616, 2617. The packing consists of two cast-iron rings $a''a''$, turned slightly eccentric, the thick sides in each being set diametrically opposite. At these points they are cut, and wedges $b''b''$ fitted accurately into the openings. These wedges are pressed outwards by two springs $c''c''$, which are adjustable by set-screws. The whole is rendered compact and secure by the piston cover, d'', which is bolted to the body of the piston by four bolts, guarded by the pieces $e''e''$, as shown in Fig. 2617.

The steam-ports *s s*, which communicate between each extremity of the cylinders and the slide-valves *r r*, are formed in the body of the cylinders, as are also the discharge-ports N N, to the point where the blast-pipes are jointed to them. The discharge or blast pipes N N, ascend from each cylinder till they reach the bottom of the chimney, where they are formed into one pipe, in the orifice of which is placed a cone or tapered plug *t*, so disposed and connected by means of a system of rods and levers *u u*, as to be capable of being raised or depressed by the engine-driver. By this means the orifice of the blast-pipe may be enlarged or contracted at pleasure, thereby causing a greater or less draught to the fire. By this simple contrivance, the engine-driver is enabled to adapt the quantity of steam generated in the boiler to the exact amount required for the supply of the engine, and thereby to prevent the waste of fuel indicated by the steam blowing off at the safety-valve. For the further regulation of the draught when the engine is at rest, it is provided with a damper *v*, at the lower end of the chimney, worked, like the blast regulator, by a system of rods and levers, also marked *v v*, and terminating near the foot-plate.

The framing and connections of the engine.—Having described the internal arrangements of the engine, we now proceed to explain the parts by which motion is communicated to the wheels. These are most fully and clearly delineated, in combination, in our sectional elevation, Fig. 2605, and in the plan, Fig. 2606. Between the smoke-box and external fire-box, are bolted the four strong malleable-iron beams O O O, called the *inside framing*, and which, besides imparting great strength and rigidity to the whole structure, serve the purpose of giving fixed points of resistance for the bearings of the working parts. Of these, the first that claim our attention are the piston-rods P P. These are made of steel, turned truly cylindrical and smooth, and of the diameter of 2⅛ inches; they are fixed into the piston with a cotter in the manner indicated in the detail, Figs. 2615, 2616, and at the opposite extremity they are terminated each by a cross-head Q′, also attached to them by a cotter, Fig. 2618. On these cross-heads are bearings for the small ends of the connecting-rods Q Q; and concentric, and of the same piece with these bearings, are projecting arms into which the cast-iron guide-blocks *w w*, Figs. 2618, 2619, are fitted. The guide-blocks are formed with flanges, and are accurately fitted and ground into steel slide-bars, also marked *w w*, so as to work smoothly and steadily between them. These latter are set truly parallel and in the same inclined plane with the centre of the piston-rods, and are firmly bolted to the framing-plates O O. By this means, the piston-rods are constrained to move in a rectilinear direction, and secured against any deflection, or undue strain arising from the continual change of position of the opposite ends of the connecting-rods, in obedience to the revolution of the cranks to which they are respectively attached.

The feed-pumps S S, for the supply of water to the boiler, are also set in the line of the piston-rods and their plungers partake of their motion, being each fixed to a small arm *x*, firmly secured by a cotter to the cross-head Q′. The pumps, the internal arrangement of which is fully shown in the longitudinal section, Fig. 2627, are formed of cast-iron, and are firmly fastened to the inside framing O, by bolts passing through the projecting flanges $f''f''$. The plungers g'' are of brass, two inches in diameter, and at each stroke of the engine draw the water from the tender through the feed-pipe *y*, and lower or suction valve h'', forcing it, at the return stroke, through the upper or delivery valve i'', and along the pipe *z*, into the boiler. The valves are prevented from rising out of their seats by the stops $j''j''$, fixed into the covers of their respective chests, and so adjusted as to admit of their rising only to the proper height for the due ingress and egress of the water. At the point where the water is discharged into the boiler is placed a valve-box *a*′, within which is a valve opening upwards, for the retention of the water within the boiler. A small cock, called the *pet-cock*, *b*′, is fixed to the outside of the feed-pump, and by means of a long slender rod, the handle is brought within reach of the engine-driver, so that he may be enabled to ascertain at any time whether the pump is working efficiently.

The connecting-rods Q Q are jointed, as we have before explained, to the cross-heads of the piston-rods. The coupling is effected in the usual way, by means of straps, gibs, and cotters, properly secured against relaxing or falling out. The opposite ends are attached in the same manner to the cranks R R, upon the axle of the driving-wheels. This cranked axle is made of the best forged iron, the cranks being cut out of the solid mass, and the one formed exactly at right angles to the other. In the earlier stages of the locomotive engine, it was usual to provide bearings for the cranked axle upon each of the frames O O, but this practice is now discontinued, and thereby the machinery is much simplified, and the friction considerably reduced.

The eccentrics and valve geer.—This engine is provided with four eccentrics, two for the forward, and the other two for the backward geer. The form and dimensions of these are shown upon an enlarged scale in Fig. 2621, which gives a view of one of the backward eccentrics, but which, with a slight difference, presents an accurate type of the whole set. Each eccentric is formed in halves, for the purpose of embracing the axle, and these are joined immovably together by the two round pins $k''k''$, screwed into one half, and secured, after passing through the other, by cotters. It is fixed firmly to the axle by the two pointed set-screws, $l''l''$. The forward eccentrics for both cylinders are fixed upon the axle a little *in advance* of a line at right angles to their respective cranks, for the purpose of giving the required *lead*, and the position of the backward eccentrics is adjusted upon the same principle, though of course in a diametrically opposite direction. The eccentric-rods $m'' m''$, are bolted firmly to the brass strap surrounding the eccentrics; and their opposite extremities, the form of which is shown in Fig. 2625, are connected together by a double link e Figs. 2623 and 2624, so formed as to admit of either forward or backward eccentric being thrown into geer with the valve-spindle, as may be required. The link which Messrs. Hawthorn employ for coupling the ends of their eccentric-rods is of a new and improved construction, being so formed as to diminish as much as possible the friction and wear upon the slide-rod pin and the eccentric-rod ends. The *reversing geer*, or mechanism by which the engine-driver is enabled to propel the engine in either direction, consists of a system of rods and levers $f' f' f'$, commencing with a stud upon the lower extremity of the coupling-link e', and terminating in a long handle, placed in a convenient position near the foot-plate. The motion of the eccentrics is communicated *directly* to the slide-valves by means of valve-spindles, working through oblong guides at the one extremity, to insure steadiness, and attached at their opposite ends to the slide-valves by nuts and jam-nuts, for the purpose of adjustment. We may here take occasion to remark, in anticipation of the subject upon which we are now about to enter, that by Messrs. Hawthorn's arrangement the ordinary slide-valves, when once properly adjusted, never require to be varied, to whatever extent the expansion geer may be employed.

Auxiliary expansion slide-frame and geering.—On each of the backward eccentrics is fixed a stud h', Fig. 2621, to which is jointed a rod, the other extremity of which is connected with the upper arm of a double lever, working upon a bearing fixed to one of the framing-beams O O. The lower arm of this lever is grooved throughout its length to receive a sliding-pin, attached by a link to a system of rods and levers, terminating in a long handle, working on the same centre with the reversing handle. The sliding-pin is also connected by the rod to the hollow spindle which works through the stuffing-box of the valve-chest L, and incloses the spindle g of the ordinary slide-valve. It may here be remarked, as objections may be urged on the ground of expense, that the hollow spindle is not essentially requisite in this arrangement of valves; the spindle may be made solid, similar to the rod of the ordinary slide, and worked through a separate stuffing-box, either above or on one side of it; the mode represented is, however, the neatest and most compact arrangement.

The expansion slide-frame is worked by the hollow spindle, being attached to it by means of a slender malleable iron frame, embracing it on all sides, and screwed to the end of the hollow spindle. It is fitted to and works upon the same face as the ordinary slide-valve, but is of such a form as, when the frame is in motion, to overlap alternately the ends of the latter, (the back of the slide-valve being accurately planed and fitted for that purpose,) according to the amount of expansion required. This can be varied at pleasure by the mechanism above described; for when the sliding-pin which works in the grooved arm is brought into the centre of motion of that lever, it is obvious that no motion of the slide-frame will ensue, and in this position, when it is not required to work expansively, the geering may be secured so as to obviate all unnecessary wear and tear. If, however, the handle be advanced into the position represented in the general elevation, Fig. 2601, the sliding-pin and rod l', which is attached to it, will then be forced downwards, as shown in Fig. 2605, and the slide-frame will partake of the motion communicated to the lever i' by the backward eccentric, and the amount of this travel will obviously be in proportion to the distance at which the sliding-pin is set from the centre of motion. A graduated sector is placed at the foot-plate in view of the engine-driver, as shown in the general elevation, for the purpose of indicating minutely the amount of expansion, or at what part of the stroke the steam is cut off.

We may remark that Messrs. Hawthorn's expansion geer appears to possess advantages over many of the other methods hitherto employed. The first and perhaps the most important of these we have before adverted to, namely, the complete independence of the motion of the ordinary slide-valve from that of the expansion-frame, rendering any alteration of the latter, after it has been once properly adjusted, unnecessary, whatever amount of expansion may be employed. The admission and discharge of the steam are thus, in all cases, regular, and take place under the most advantageous circumstances attainable by the ordinary valve. Again, the movement communicated by the backward eccentric to the expansion-slide is so regulated, in relation to that of the ordinary valve, as to produce a very peculiar and advantageous effect in cutting off the steam quickly. Thus, the expansive principle may be employed to any extent, between that due to the cutting off of the steam at $\frac{1}{8}$ of the stroke of the piston, to that which would be produced by the action of the ordinary slide alone, without throttling, or what is technically called *wire-drawing* the steam, a defect so much complained of in most of the other modes of expansion hitherto in use. These theoretical advantages have been fully corroborated by the results of experience. Messrs. Hawthorn have successfully applied their expansion geering to the locomotives which they have supplied to ten different railways in England, and the saving of fuel effected by the use of it, in many cases, amounts to 30 per cent.

The wheels and outside framing.—The driving-wheels T T are firmly fixed to the cranked axle, the ends of which, produced beyond the bearings, carry the cranks and coupling-rods $o' o'$. The other extremities of these rods are connected by cranks of exactly the same dimensions with the axle of the fore-wheels U U. By thus connecting the driving and fore wheels, the amount of *traction*, or the surface upon the rails available for the propulsion of the engine, is greatly increased, which renders this species of engine peculiarly suitable for drawing merchandise or other heavy trains, at moderate speeds. The hind or trailing wheels V V, are situated under the fire-box, and the advantages of this disposition have been already pointed out. The dimensions of all these wheels have also been already given, and the mode of their construction will be clearly understood by reference to Fig. 2631, which shows both external and sectional views of one of the driving-wheels, but which, as far as regards construction, may be taken as a type of the whole. The nave is of cast-iron, moulded and poured round the arms, which have been previously prepared with a dove-tail at their inner ends, for the purpose of giving additional security. The arms and rim are of the best forged iron, and the latter is accurately turned in the lathe after being welded together. The tyre, which is also of the best forged scrap-iron, is bored internally to a slightly smaller diameter than the rim, and shrunk on. It is then secured to the rim by a few rivets, and the whole turned accurately to the proper form and diameter.

As the whole weight of the engine rests upon the wheels, it may be expected to suffer from jolting in passing over the irregularities of the rails. To obviate this as far as possible, the springs *p' p' p'* and *q' q' q'* are interposed, the former upon bearings in the outermost of the internal framings O O, and the latter under the axle-boxes *r' r' r'*, of the main external bearings. The springs marked *q' q'*, and the mode in which they are attached to the axle-boxes and to the framing, are clearly represented in Figs 2634 and 2635. They are composed of thin layers of steel, gradually diminishing in length from the centre to the extremities, and bound together by the connecting-hoop *o''*, secured in its place by a small round pin passing through it and the steel plates. The connecting-hoop is formed with a tail projecting upwards into the lower portion of the axle-box, where it is fixed by a round pin *p''* passing through it. The axle-box *r'*, which is of cast-iron, fitted with bearings composed of a metallic alloy favorable for the reduction of friction, slides up and down as the springs bend with the weight of the engine, between the cast-iron axle-guides *q'' q''*, which are accurately planed and fitted to receive it, and bolted firmly to the plates of the external framing. The axle-boxes are formed with a sort of reservoir for oil or tallow, which is constantly supplied to the rubbing surfaces by two small tubes and siphon-wicks. It may here be remarked, that the other rubbing parts of the engine are lubricated in the same manner. The mechanism by which the springs are attached to the external framing is shown in Figs. 2634, 2635. These parts are called the *spring-links*, and consist of a species of small cross-head *r''*, fitted with round pins for passing through the plates of the external framing, and with screwed studs attached by similar round pins to the ends of the springs *q' q'*. The nut *s''* works into these screws, and by means of it the weight which it may be thought expedient to throw upon each spring may be accurately adjusted.

The external framing consists of two strong parallel beams W W, extending somewhat beyond the engine at both ends, and connected in front by the wooden cross-beam or *buffer-bar* Z, and behind by a similar beam, on which rests the foot-plate Y. These beams are firmly bound together at the corners by angular plates of iron bolted through each, and the weight of the boiler is supported upon them by the strong malleable iron brackets or stays X X X, riveted to the boiler, and bolted through the beams W W. These latter are formed each of two parallel plates of iron, cut out into the form shown in the general elevation, with *horns* projecting downwards for the bearings of the wheels. Between each pair of plates a beam of well-seasoned oak is interposed, and the whole firmly bolted together.

To deaden the shocks to which the engine is exposed, it is provided with *buffers*, *s' s'*, fixed to and projecting in front of the buffer-bar Z. These buffers are a species of elastic cushions, formed of horse-hair, surrounded by strong leather, and further strengthened by slender malleable iron hoops. To secure the engine against the effects of the wheels coming in contact with stones or other obstacles which may happen to be lying on the rails, it is furnished with strong malleable iron *safe-guards t' t'*, descending from the external framing to within a short distance of each rail, and so formed at the points as to turn aside any object with which they may come into collision.

Any water which may happen to accumulate in the cylinders, whether from the priming of the boiler or the condensation of the steam, and which, unless removed from time to time, would be very detrimental to the working of the engine, is let off by means of the pipe and stop-cock *u'*, communicating with the discharge passage of each cylinder.

Upon the front of the smoke-box, and towards the top, is fixed a small bracket for supporting the *signal-lamp v'*, by which notice is given at night of the approach of the engine and train.

As a precaution against accident to the engine-driver and his assistant, hand-rails *w' w'* are erected on each side of the foot-plate Y, and these are continued along the whole length of the boiler, so that they may be enabled with comparative safety to walk round the engine, even when it is in rapid motion. The rods forming this latter part of the hand-rail are made hollow, and thus afford a neat and compact guide and protection for the slender rods by which the blast regulator on one side, and the damper on the other, are worked.

When the engine is at rest, the steam which would otherwise escape at the safety-valve and be thrown to waste, is made available for the heating of the water in the tender. This is accomplished by means of the bent pipe *x'*, by which a communication is made between the steam within the fire-box and the feed-pipe *y*, and thereby a considerable saving of fuel is found to be effected.

The connection of the engine and tender is made by means of the strong double link or drag-bar *y'*. one end of which is secured by a strong pin to a bracket fixed under the foot-plate of the engine, while the other is in a similar manner jointed to the drag springs of the tender.

To assist the engine-driver in rising into his place on the foot-plate, the foot-steps *z' z'* depend on each side of it to within an easy distance from the ground.

Having thus minutely described the parts of which this engine is composed, and explained their several uses as we went along, we consider it unnecessary to occupy more space with an account of its mode of action. This is in every respect identical with that of the ordinary high-pressure engine, and to those who have followed us in our previous descriptions will be perfectly intelligible.

Description of the tender.—The tender is an invariable concomitant of the locomotive engine, and as in it, as well as in the engine, there is considerable room for the display of tasteful design and judicious arrangement, we have thought that we should render our engravings more interesting and more acceptable by giving representations of both. The water tank A A forms the principal part of the tender, and consists of a rectangular sheet iron cistern, capable of containing 1200 gallons of water for the supply of the boiler. It is made with a long recess B for the reception of the fuel. The floor *a* of this recess is made with a slope downwards from the front of the tender, by which arrangement the fuel is prevented from being thrown out by any jolting or shaking to which it may be subjected.

Towards the back of the tank it is surmounted by a pipe or opening C, by which water is introduced from the water-crane or other contrivance for that purpose. A wooden cover is fitted over this opening when not in use. At the same point are fixed the wooden tool-boxes D D for containing spanners and other implements which may be required for the engine. At the front of the tank, and on each side, are situated the cocks *b b* for regulating the supply of water to the suction-pipes *c c* communicating between the feed-pumps and the tender. These are connected to the feed-pipes *y y* by means of leather hose screwed on to each by the union-joints *d d*, thus admitting of a considerable amount of vibration or change of position of the pipes, without breaking the connection. The tank is secured to a strong wooden frame E E, forming the body of the tender, and strengthened by numerous cross-beams. Beyond this wooden framing, and on each side of it, the external iron framing-plates F F are fixed by bolts passing through short cross-beams of timber *c c c* abutting against both. The external framing-plates are made of a form symmetrical with those of the engine, as seen in the general elevations, Figs. 2601 and 2603, and their purpose is to afford bearings for the reception of the axle-boxes *f f f*, which slide up and down in them in obedience to the action of the springs *g g g*.

The tender is supported upon six wheels G G G, of the same diameter as the trailing or hind wheels of the engine, and constructed in the manner already described in treating of the latter. The brake apparatus, which is shown on an enlarged scale in Fig. 2636, consists of a train of mechanism by which a great amount of friction can be simultaneously produced upon the peripheries of the tender-wheels, for the purpose of reducing the momentum of the engine and train, when it is required to arrest the motion of the train. The hand-wheel *h* is fixed to the upper extremity of the vertical spindle H, working in a strong bearing attached to the tank. The lower portion of the spindle is formed into a screw, and works through the wrought-iron nut I, on which is forged a double link, jointed at its lower end to the brake-lever *i*. The latter has its centre of motion in the short shaft J, which works in strong bearings attached to the wooden frame, and carries the double-toothed sector *j*. Two longitudinal iron rods *k k* extend the whole length of the tender, and a small portion of each towards the front extremity is formed into a rack, so adjusted as to work into the teeth of the sector *j*. The rods *k k* are supported and guided in their motion by small rollers working in the wrought-iron guides *l l l*, and upon them are bolted the wooden brake-blocks *m m m*, by the contact of which with the exterior surface of the wheels the friction is produced. By this arrangement it is obvious that by screwing the vertical spindle H into the nut I, the latter will be drawn upwards, and carrying with it the lever *i*, the toothed sector *j* will be made to revolve upon its axis J, and consequently the rods *k k* will be drawn each in the opposite direction to the other. Each wheel will therefore be forcibly compressed between the brake-blocks *m m*, and the engine and train be proportionally retarded.

At the point where the engine is connected to the tender, the latter is provided with a system of springs, to deaden the effects of shocks from either direction. This consists of two springs set back to back, and connected together by a socket *n*, which receives the end of the drag-bar. The fore spring *p* comes into action when any force is applied tending to *separate* the engine from the tender, as in starting a train, and the hinder spring *o* when the force is applied in the opposite direction. Both springs are supported upon pieces of thin iron bolted between the beams of the wooden frame, and the extremities of the spring *o* bear upon the two guide-pins *q q*.

For further security, in case of the ordinary connections failing, the safety-chains *r r* are attached between the engine and tender.

For the accommodation of the engine-man and fireman, or stoker, the tender is furnished with foot-steps *s s*, placed at an easy distance above the steps of the engine. By these arrangements, and with the assistance of the handles *t t*, the foot-plate is rendered easily accessible.

At the front of the tender a piece of boiler-plate *u* is fixed by hinges, for the purpose of forming a floor where the engine and tender are connected. At the other extremity of the tender the buffers *v v*, similar in construction and in situation to those formerly described, are fixed to the cross-beam of the wooden framing, for the purpose of deadening the shocks produced by the occasional irregularities of motion between the engine and the train. The drag-chain *w*, which is firmly secured to the same beam, forms the connecting link between the tender and the train.

Literal References to the Engine.

A, the external fire-box.
B, the internal fire-box.
C C, stays for strengthening the roof of the internal fire-box.
a a a, stays between the external and internal fire-boxes.
b, the fire-door.
c c, the fire-bars.
d, the movable portion of the fire-bars.
D, the ash-box.
E, the cylindrical part of the boiler.
e e e, the tubes.
f f, longitudinal stays from the back of the fire-box to the front of the boiler
F, the smoke-box.
g g, the smoke-box doors.
G, the chimney.
H, a brass funnel for inclosing the safety-valves.
h, the spring safety-valve.
i, the lever safety-valve and spring-balance.
j, the water-gage, and gage-cocks.
k, the steam-whistle.
l, the blow-off cock.
I, the steam-receiver.
m, the inverted cone for preventing priming.
J J, the steam-pipes.
K, the regulator valve-chest.
n, the regulator valve.
o, a rod connecting the regulator valve with
p, the handle for working it.
q, the oil-cup and pipe for lubricating the regulator valve.

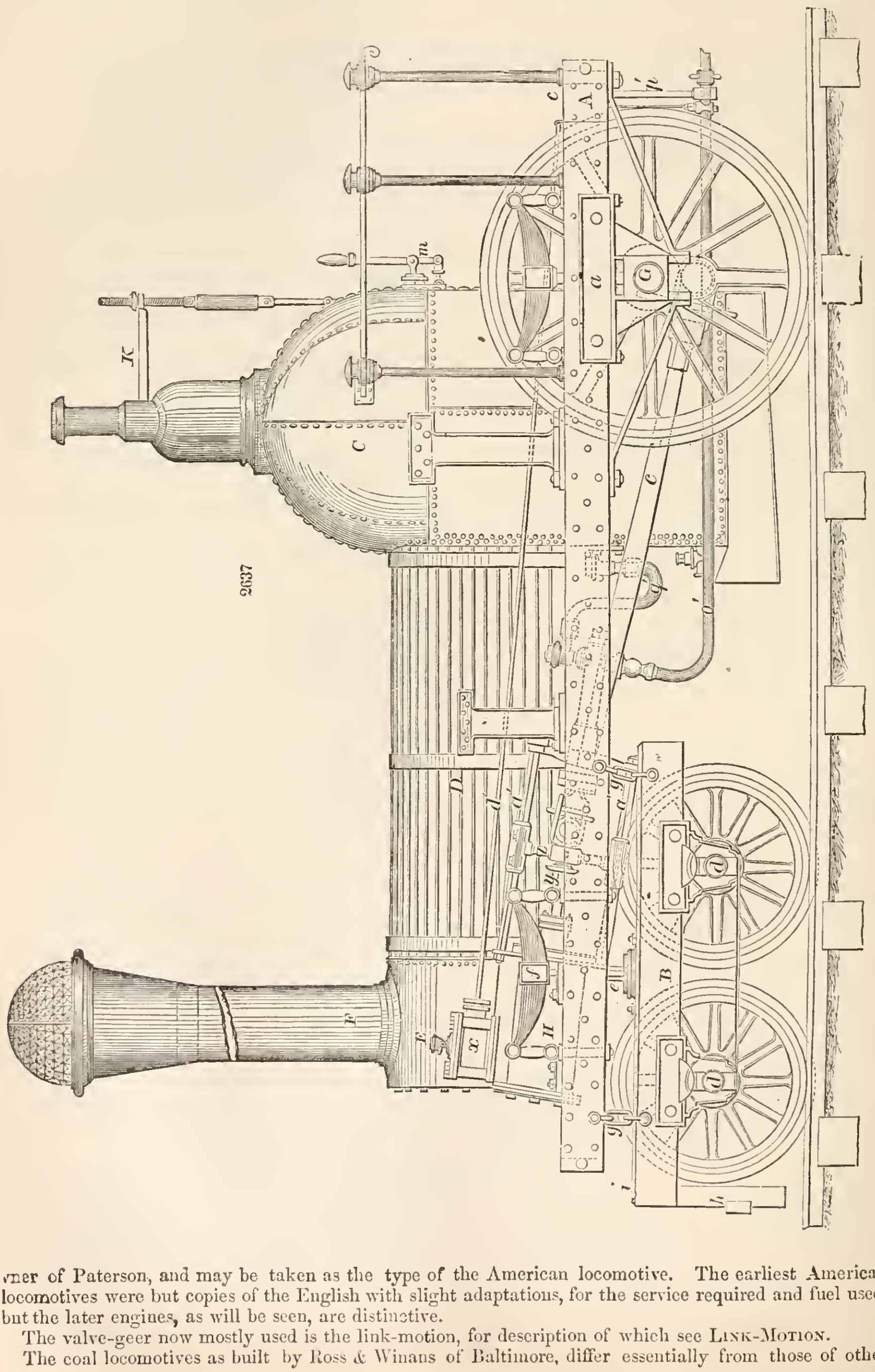
L, the steam-chest of the cylinders.
r r, the slide-valves.
M M, the steam-cylinders.
s s, the steam-ports.
N N, the discharge-ports and blast-pipes.
t, the blast-regulator.
u u, handle, rods, and levers for working the blast-regulator.
v v, the damper, with the handle, rods, and levers for working it.
O O, the inside framing of the engine.
P, the steam-piston.
a'' a'', the packing-rings of the piston.
b'' b'', wedges for tightening the packing.
c'' c'', springs bearing on the back of the wedges *b'' b''*.
d'', the piston-cover.
e'' e'', guards for the bolts of the piston-cover.
P P, the piston-rods.
Q' Q', cross-heads for the piston-rods.
w w, the cross-head slides.
x x, projecting-arms for working the feed-pumps.
Q Q, the connecting-rods.
R, the cranked axle.
S S, the feed-pumps.
f'' f'', flanges for bolting the feed-pumps to the inside framing.
g'' g'', the plungers of the feed-pumps.
h'', lower or suction valve of the feed-pump.
i'', upper or delivery valve.
j'' j'', stops for regulating the lift of the valves.
y y, the feed-pipes from the tender to the feed-pumps.
z z, branch-pipes from the feed-pumps to the boiler.
a' a', valve-boxes at the boiler.
b' b', the pet-cocks and their handles.
c' c', the forward eccentrics.
d' d', the backward eccentrics.
k'' k'', bolts for connecting the halves of each eccentric.
l'' l'', steel pinching-screws for fixing the eccentrics to the axle.
m'' m'', the eccentric-rods.
e' e', coupling links for the ends of the eccentric-rods.
f' f' f', levers, shafts, and rods for working the reversing-geer.
g' g', the main steam-valve spindles.
h' h', studs on the backward eccentrics for working the expansion slide-frames.
n'' n'', connecting-rods between the studs *h' h'* and
i' i', the grooved arms for the variable expansion.
j' j', links between the grooved arms and the levers *k' k'*.
k' k' k', levers, shafts, and rods for regulating the expansion-geer.
l' l', connecting-rods between the grooved arms *i' i'*, and
m' m', the hollow spindles attached to
n' n', the expansion slide-frames.
T T, the driving-wheels.
o' o', the outside cranks and coupling-rods.
U U, the fore-wheels coupled to the driving-wheels.
V V, the hind-wheels under the fire-box.
p' p', springs for the inside bearings of the cranked axle.
q' q', springs for the outside bearings of all the axles.
o'' o'', connecting-hoop for the outside springs of the cranked axle.
r' r', the axle-boxes.
p'' p'', pins for attaching the springs to the axle-boxes.
q'' q'', cast-iron guides for the axle-boxes.
r'' r'', the spring-links.
s'' s'', the nuts for adjusting the weight upon the springs.
W W, the external frame of the engine.
X X, stays from the external frame to the boiler.
Y, the foot-plate.
Z, the buffer-beam.
s' s', the buffers.
t' t', the safeguards.
u' u', a cock and pipe for letting off water from the cylinders.
v', the signal-lamp.
w' w', the hand-railing.
x', a pipe from the boiler for heating the water in the tender.
y', the drag-bar.
z' z', the foot-steps.

Literal References to the Tender.

A, The water-tank.
B, the recess for containing the coke.
a a, the floor of the coke-box.
C, the opening into the tank.
D D, the tool-boxes.
b b, the cocks for regulating the supply of water to the feed-pumps.
c c, water or suction pipes to the engine.
d d, union-joints for connecting the feed-pipes.
E E, wooden frame of the tender.
e e, stays between the wooden and iron frames.
F F, the iron frame for receiving the axle-boxes.
f f f, the axle-boxes.
g g g, the springs.
G G G, the wheels.
H, the vertical spindle and screw for working the brake.
h, the hand-wheel for the brake-screw.
I, the nut and link for connecting the screw with
i, the brake-lever.
J, the short shaft carrying the brake-lever, and
j, the double-toothed sector, working into
k k, the longitudinal rods carrying the brake-blocks.
l l, supports fitted with rollers for guiding the rods *k k*.
m m, the wooden brake-blocks.
n, socket for connecting the drag-springs to the drag-bars.
o p, the springs for buffing and drawing.
q q, bearings for the spring *o*.
r r, the safety-chains.
s s, the foot steps.
t t, handles to assist in rising to the foot plate.
u, a hinged plate between the engine and tender.
v v, buffers for the tender.
w, drag chain of the tender.

Fig. 2637 is an elevation of a small American locomotive built by H. R. Dunham & Co., New York The distinctive part of the engine and of American locomotives in general, is the forward truck consisting of two sets of wheels on one frame, the frame revolving on a centre-pin, which enables the machine to move more easily around corners; this form of engine is called the *bogey* in England.

The locomotive here shown is one of the earlier kind, with inside connection, and but one pair of drivers. At present in this country, engines with outside connections are thought to be safer, steadier and cheaper than inside, and are very generally adopted. The number of driving wheels is seldom less than two pairs. Fig. 2638 is the side elevation of a locomotive as built by Rogers, Ketchum & Gros



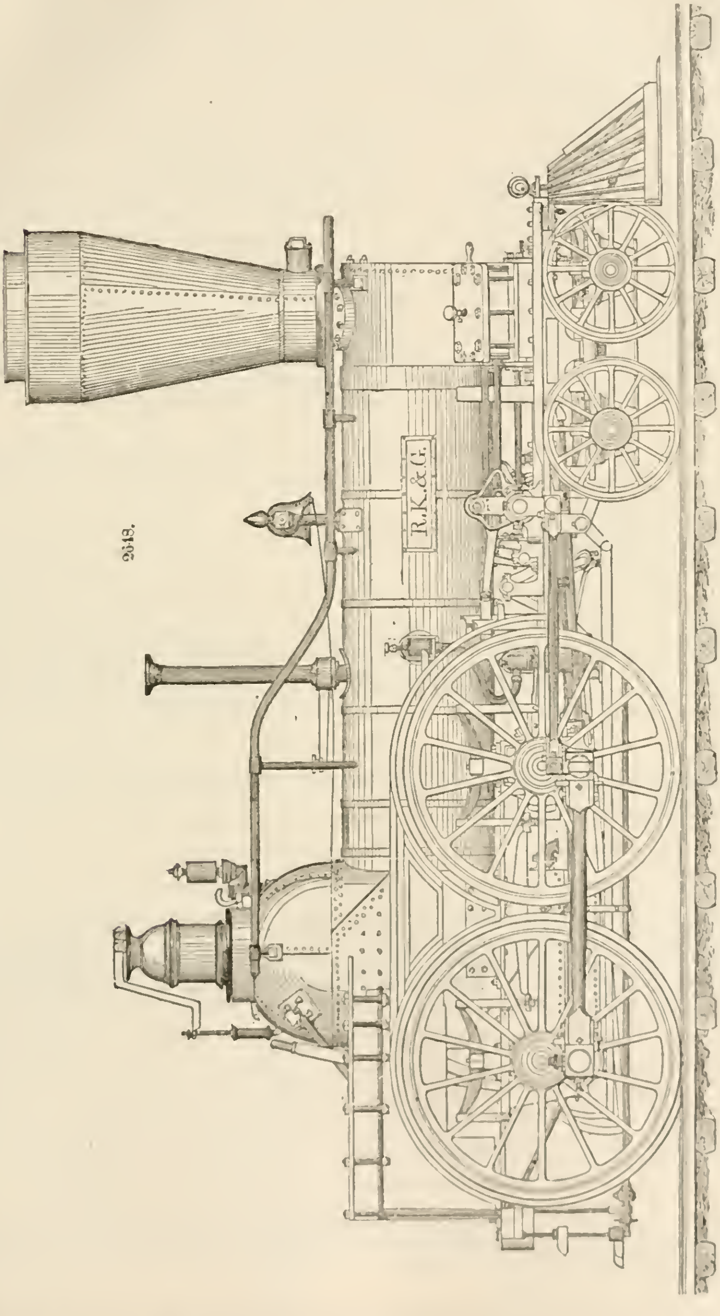
2637

venor of Paterson, and may be taken as the type of the American locomotive. The earliest American locomotives were but copies of the English with slight adaptations, for the service required and fuel used but the later engines, as will be seen, are distinctive.

The valve-geer now mostly used is the link-motion, for description of which see LINK-MOTION.

The coal locomotives as built by Ross & Winans of Baltimore, differ essentially from those of other makers. The freight engines are usually eight-wheeled engines, all connected; the fire-box is extremely long and capacious. The fuel is let down through a hopper above the fire-box, the tender being two-storied, and the engineer is placed on the top of the engine, immediately back of the smoke-stack. For the results of experiments on these engines on the Reading Railroad see BOILER.

2649.



Coal engines, as built by Perkins of Alexandria, have three pairs of connected drivers and a forward truck. The coal engines of other makers are in general appearance similar to the wood engine, the difference being almost entirely in the form of the boiler.

LOGARITHM. The logarithm of a number is the exponent of a power to which another given invariable number must be raised in order to produce the first number. Thus, in the common system of logarithms, in which the invariable number is 10, the logarithm of 1000 is 3, because 10 raised to the third power is 1000. In general, if $a^x = y$, in which equation a is a given invariable number, then x is the logarithm of y. All absolute numbers, whether positive or negative, whole or fractional, may be produced by raising an invariable number to suitable powers. The invariable number is called the *base* of the system of logarithms: it may be any number whatever greater or less than unity; but having been once chosen, it must remain the same for the formation of all numbers in the same system. Whatever number may be selected for the base, the logarithm of the base is 1, and the logarithm of 1 is 0. In fact, if in the equation $a^x = y$ we make $x = 1$, we shall have $a^1 = a$, whence, by the definition, log. $a = 1$; and if we make $x = 0$, we shall have $a^0 = 1$, whence log. $1 = 0$.

These properties of logarithms are of very great importance in facilitating the arithmetical operations of multiplication and division. For if a multiplication is to be effected, it is only necessary to take from the logarithmic tables the logarithms of the factors, and add them into one sum, which gives the logarithm of the required product; and on finding in the table the number corresponding to this new logarithm, the product itself is obtained. Thus by means of a table of logarithms the operation of multiplication is performed by simple addition. In like manner, if one number is to be divided by another, it is only necessary to subtract the logarithm of the divisor from that of the dividend, and to find in the table the number corresponding to this difference, which number is the quotient required. Thus, the quotient of a division is obtained by simple subtraction.

Logarithms apply with equal advantage to the formation of powers and extraction of roots. Let y be a number to be raised to the power m, (m being any number, whole or fractional, positive or negative.) As before, we have $y = a^x$; and, on raising both sides of the equation to the power m, $y^m = a^m x$: whence, by the definition, log. $y^m = m\,x = m$ log. y; that is, the logarithm of the power of a number is equal to the product of the logarithm of the number by the exponent of the power.

If in the equation of log. $y^m = m$ log. y we make $m = \frac{1}{n}$, we shall have log. $y^{\frac{1}{n}}$ (or log. $\sqrt[n]{y}$) $= \frac{1}{n}$ log. y; that is to say, the logarithm of any root of a number is equal to the logarithm of the number divided by the index of the root.

From these two last results it is obvious that by means of a table of logarithms numbers may be raised to any power by simple multiplication, and that the roots of numbers may be extracted by simple division.

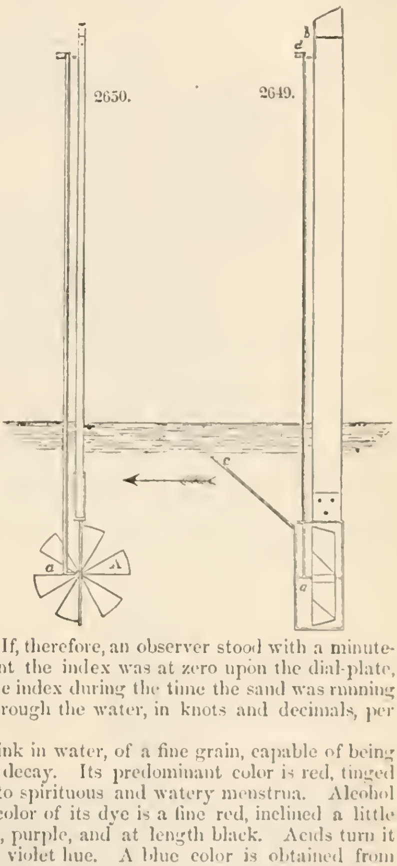
When a table of logarithms has been calculated for any given base, it is easy to find by means of it any other system of logarithms corresponding to a different base. Thus, supposing a system of logarithms has been calculated of which the base is a, or, which is the same thing, that the value of x has been found for every different value of y in the equation $a^x = y$, and that it is required to construct another table, of which the base is b, or to find the values of v corresponding to every different value of y in the equation $b^v = y$, we may proceed as follows: Taking the logarithms of both members of this last equation from the table supposed already calculated, of which the base is a, and recollecting that log. $b^v = v$ log. b, we have v log. $b =$ log. y; whence $v = \frac{\text{log. } y}{\text{log. } b}$. But because $b^v = y$, it follows that v is the logarithm of y in the system of which the base is b; therefore, denoting the logarithms in this new system by L, we have L $y = \frac{\text{log. } y}{\text{log. } b}$. Hence it appears that, in order to find the logarithm of any given number y in the new system, it is only necessary to multiply its logarithm in the system already calculated by the constant number $\frac{1}{\text{log. } b}$. This constant number, by means of which we pass from the one table to the other, is called the *modulus* of the new table with reference to the old.

The logarithms of the particular system of which the modulus is 1, is called the *Napierian system*. But, as has been shown, when the logarithms have been found in any one system, they may be transferred into those of any other system by means of a constant factor. In the common system the base is 10, and the Napierian logarithm of any number is consequently transformed into the common logarithm of the same number by multiplying by the modulus $\frac{1}{\text{L}10}$. This number, which is of great importance in the computation of the logarithmic tables, is found to be 0·4342944819, &c., the Napierian logarithm of 10 being 2·30258509, &c. It may also be remarked that this modulus 0·4342944819 is the ordinary logarithm of the base of the Napierian system; for, calling e this base, we shall have $e^{\text{L}10} = 10$, whence, taking the ordinary logarithm of both sides of the equation L10 × log. $e =$ log. $10 = 1$; therefore, log. $e = \frac{1}{\text{L}10} = 0{\cdot}4342944819$. On passing to numbers, we find $e = 2{\cdot}7182818284$.

The Napierian logarithms are sometimes called the *natural logarithms*, on account of the modulus of the system being unity; and, more frequently, *hyperbolic logarithms*, because they represent the area of a rectangular hyperbola between its asymptotes, and on this account are of immense use in calculations connected with the steam-engine.

Logarithms being of constant use in calculations, the tables which have been published are very numerous. The most complete are those of Vlacq, to ten decimals; but they are very scarce, and can with difficulty be procured. There is an edition of them by Vega, in 1797, also scarce. *Gardiner's Logarithms*, printed in 1742, in 4to, and another edition of them at Avignon, in France, in 1770, are to seven decimals. *Callet's Logarithms*, in 8vo, like Gardiner's, contain the logarithmic sines, &c., for every 10 seconds. *Taylor's Logarithms*, in 4to, and also *Baguay's*, have them to every second. *Hutton's Logarithms*, and *Babbage's Logarithms of Numbers*, are well known. The latter was carefully collated, and is very accurate and convenient. *Hulsse's Sämmlung Mathematischer Tafeln* (8vo. Leipsig, 1840) deserves to be mentioned as a very useful collection. The above (excepting Vlacq's and Vega's) are all to seven decimal figures; but for many purposes, logarithms to a less number of decimals are sufficiently accurate. For navigation and surveying, tables to six fixgures are the most convenient, as they give, in general, the trigonometrical lines correct to single seconds. The best tables of this kind are *Farley's Tables of Six-figure Logarithms*, (12mo, 1840.) For many auxiliary computations in astronomy it is sufficient to have the logarithms to five places. The reprint of *Lalande's Five-figure Table* by the Useful Knowledge Society (18mo, 1839) is convenient, and may be relied on for accuracy.

LOG, *for steam-vessels.* Fig. 2649 is a side view, and Fig. 2650 an end view of this instrument. A is a small wheel, 1 foot diameter, having vanes set at such an angle that, when let into the water, the action upon their inclined surfaces would cause the wheel to revolve once in passing the distance of two feet through the water. Upon the axis of the wheel is an endless screw *a*, into which works a small toothed wheel, having 51 teeth. The instrument should be mounted on the low end of a stiff bar of wood, or other material, of such length as that the top end could be fastened by a joint or hinge *b*, to the side of a vessel, in convenient proximity to a cabin window, or to the deck. To the low end of the rod or bar a small line should be attached, *c*, the other end of which to be secured on the deck of the vessel. The use of this line would be to withdraw the instrument from the water when not required for observation, and to lash it horizontally out of the reach of the waves. When the line was released, the instrument should be so suspended as to fall perpendicularly into the water, and the bar sufficiently stiff to remain perpendicular, and resist the pressure of the water against its front edges, which, however, would be but trifling. The axis of the small toothed wheel should be inclosed in a tube in front of the bar on which the wheel is suspended, and prolonged to a short distance below the hinged joint; and upon the top end of it should be fixed an index *d*, to revolve on a dial-plate decimally divided. The wheel being constructed as before described, this index would make one revolution round the dial-plate in the time that the vessel passed 102 feet through the water, which is about the one-sixtieth part of a knot, or nautical mile. If, therefore, an observer stood with a minute-glass, (or seconds watch,) and turned the glass the moment the index was at zero upon the dial-plate, and noted the number of revolutions and parts made by the index during the time the sand was running out, he would have the rate at which the vessel passed through the water, in knots and decimals, per hour.



LOGWOOD. A hard, compact wood, so heavy as to sink in water, of a fine grain, capable of being polished, and so durable as to be scarcely susceptible of decay. Its predominant color is red, tinged with orange, yellow, and black. It yields its color both to spirituous and watery menstrua. Alcohol extracts it more readily and copiously than water. The color of its dye is a fine red, inclined a little to violet or purple, which left to itself, becomes yellowish, purple, and at length black. Acids turn it yellow, alkalies deepen the color, and give it a purple or violet hue. A blue color is obtained from logwood, by mixing verdigris with it in the dye-bath. The great consumption of logwood is for blacks, to which it gives a lustre and velvety cast; it is also extensively used as a red, purple, or black dye to beech, and various white woods. See Woods, Varieties of.

LOOM, POWER. Fig. 2651 is a front elevation of a power-loom for weaving printing goods, as built in the Lowell Machine Shop, Lowell, Mass.

Fig. 2652 is the driving-end, showing pulleys, geers, shipper, &c.

Fig. 2653 is a view of the other end, showing the take-up motion.

A denotes the cast iron ends, which, with the iron girts that are bolted between, constitute the frame-work to which all other parts are attached.

B is a cast-iron arch, which supports the roll over which the harnesses hang.

C C are the driving-pulleys, one loose, the other fast.

D, large geer or cam shaft, driven by a geer on the crank-shaft.

E, cams for working the harnesses; F, cam for throwing shuttle.

G, lever for taking up the cloth by operating on the ratchet wheel H. This lever is worked by a crank motion attached to the end of cam-shaft.

H, ratchet-wheel, operated by lever G.

I, emery-roll; J, binder roll; K, cloth roll. The cloth, after passing between the rolls I and J, winds up on this roll. This roll is driven from I by a belt.

L, Fig. 2652, is a view of the filling stop motion.

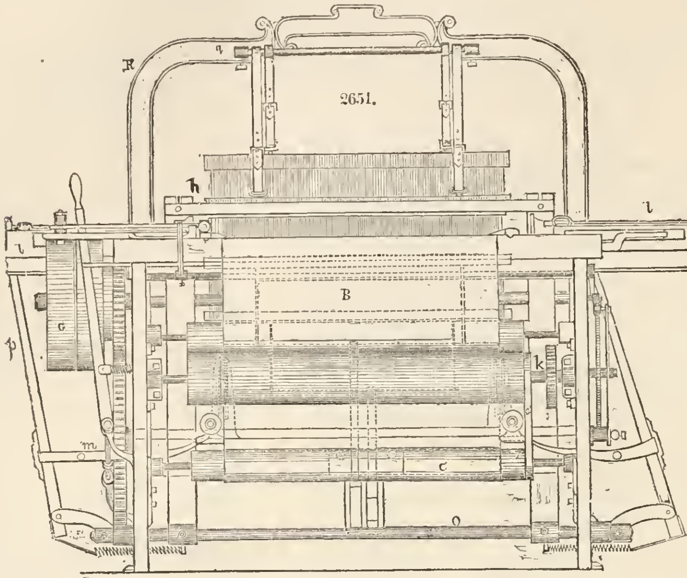
M, head on yarn beam, with a groove for a strap.

N, strap and spring for friction on yarn-beam.

O, lever, operated by cam, on cam-shaft.

P, lever attached to O, which comes in contact with catch L, (when the filling breaks,) and throws the shipper-handle Q out of the notch in which it is held, and stops the loom.

Q, shipper-handle for stopping and starting the loom.



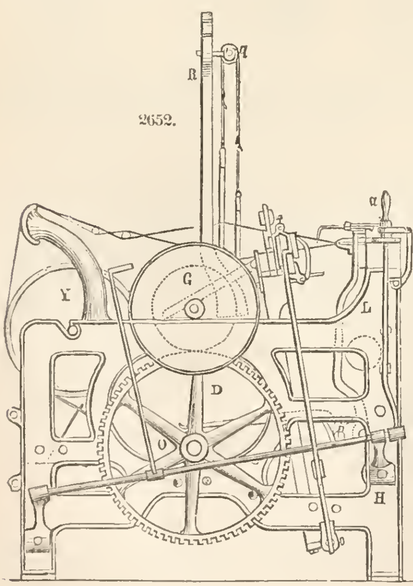
2651.

R, piece attached to the protecting-rod, that strikes a lever under the breast-beam, (whenever the shuttle fails of performing its duty,) and stops the loom.

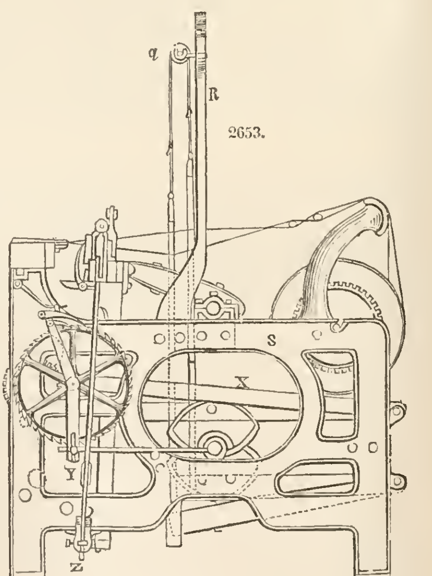
S, picker-staff for throwing the shuttle, which receives its motion from a cam on cam-shaft, communicated by a treadle and strap T.

T, strap for picker-motion.

2652.



2653.



U, harness-treadles, operated by the cams E E.

V, crank-shaft, which gives motion to the lathe or sley. X, sley or lathe, which contains the reed.

Y, harnesses for separating the warps while the filling passes through, which are operated by the harness-cam E alternately.

Z Z are the swords that support the lathe, and are attached to the rocking-shaft at the bottom.

&, rocking-shaft on which the lathe swings.

a' is a geer attached to the yarn-beam, used only when dressing the yarn. *b'*, reed. *c'*, friction roll for picker-lever strap. *d'*, picker-levers or treadles. *e'*, race-rods, on which the pickers slide. *f'*, pickers, made of green hide, dried and pressed. *g'*, temples for holding the cloth in its place and keeping it stretched in width. *h'* is the cloth, as it passes over the breast-beam down between the two rolls on to the cloth-roll.

LOOM, BIGELOW'S COUNTERPANE. This improvement consists principally in the manner in which the shuttles are thrown; the manner of raising and depressing the shuttle-boxes; and the manner in which the picker is relieved from the shuttle.

We copy from the specification of the patentee:

In throwing the shuttles, I cause the two picker-staves to operate simultaneously, so that the shuttle may be thrown from whichever of the boxes is presented to their action. This I effect by the use of one picker-treadle only, which is acted upon by a cam-ball, in the usual way of working such treadles. From this treadle two bands are extended, and pass around the two picker-pulleys in such manner that when the treadle is depressed both the picker-staves will be set in action at the same moment. By this arrangement, two or more shuttles may be successively thrown from the same end of the loom by the action of one treadle.

The shuttle-boxes are raised and lowered in the following manner: a shaft extends along under the race-beam, from one shuttle-box to the other, and carries pinions, which take into racks attached to the shuttle-boxes; it will be manifest, therefore, that by causing this shaft to revolve, the shuttle-boxes may be raised. The revolving of this shaft is effected by the action of a spiral or other spring, one end of which is attached to the frame of the loom at its back, and said spring extends forwards towards the lathe; from this forward end a band attached to it passes round guide-pulleys, the situation of which will be shown in the accompanying drawing, and also round a pulley upon the above-named shaft, to which latter said band is attached. The action of the spring, by its drawing upon the band, will cause the pinion-shaft to revolve, and will consequently raise the shuttle-boxes. Should this spring be thrown out of action, and the band by which the shuttle-boxes are raised be relaxed, they will then descend by their own gravity. To take off the tension of the spring, there is a cam upon the main shaft of the loom, which cam, as the shaft revolves, depresses a treadle, to the end of which a band is attached, which operates in such a way as to relieve the shuttle-boxes from the action of the spring, and they then descend. In relieving the picker from the point of the shuttle, I make use of the protection-rod constituting a part of the apparatus employed in the ordinary power-loom, for stopping the loom when the shuttle does not arrive home in the shuttle-box. From the protection-rod, which extends along below the shuttle-boxes, I allow a small arm or finger to descend, which finger, as the lathe comes up towards the breast-beam, strikes against a stop or pin, attached, for that purpose, to the frame of the loom, causing the protection-rod to rock or revolve to a short distance. This gives motion to two arms which extend out from the extreme ends of the protection-rod, opposite to the outer ends of each of the shuttle-boxes; from these arms motion is communicated to a lever which works on a fulcrum over the outer ends of each of the shuttle-boxes, said arms being connected to the levers by rods or wires. By depressing the outer ends of these levers their inner ends are raised, and to these ends are appended rods which carry pieces of wood or metal, which, when down, rest on and embrace the picker-rod, and in that position they serve to hold the picker at a short distance from the end of the shuttle-box, and to stop the shuttle; the picker is then removed from the point of the shuttle by the raising of the lever, the picker being made to pass home to the end of the box, thus leaving the shuttle and shuttle-box free to be raised or lowered without obstruction, the picker being also ready again to act on a shuttle.

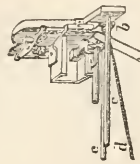
Having thus given a general description of my improvements, I now proceed to exemplify the same by references to the accompanying drawings.

Fig. 2654 is a front view, in perspective, of my improved counterpane power-loom, and Fig. 2655 a back view of one end of one of the shuttle-boxes, this being drawn for the purpose of showing the particular construction and arrangement of this part of the machinery, which could not be exhibited in the front view. In Fig. 2654 the breast beam is not represented, it being removed for the purpose of showing the lathe, and the parts connected therewith, the more distinctly. The jacquard apparatus, which is employed to regulate the figure, and is perfectly well known, being in general use, I also use as heretofore constructed. It is not represented in the drawing, it not being deemed necessary to describe it; but I have fully shown those parts which constitute my improvements.

A A are the picker-staves, and B the picker-treadle; D is the cam-ball for working this treadle, operating in the usual manner. E E are two straps which are attached to the picker-treadle; these straps pass over the pulleys F F, and are attached by their outer ends to the pulleys G G, which carry the staves A A, and these are consequently acted upon simultaneously. The rods or staves A' A' serve to cause the pickers to pass home when the pieces of wood, &c., above referred to, are raised; these rods are drawn towards the outer ends of the shuttle-boxes by the action of the spiral springs C C, the use of which will more fully appear when describing the parts shown in Fig. 2655.

The following is the arrangement devised by me for raising and depressing the shuttle-boxes: a shaft H H is made to extend along under the race-beam, and this shaft carries the pinions I I, which take into vertical racks J J attached to the shuttle-boxes. I sometimes use a single rack affixed at the middle of each box; but I prefer the placing of a rack and pinion at each end of each box, as shown in the drawing. There is a pulley L on the shaft H, and this shaft is made to revolve by means of a band K, one end of which is attached to and laps around the said pulley. The band K passes thence around pulleys *a a'*, the pulley *a* being attached to the frame, and the pulley *a'* either to the frame or to the floor. The spiral spring M affixed to the back of the loom draws on the band K attached to its fore end, so as to cause the pulley L and the shaft H to revolve and raise the shuttle-boxes. When the spiral spring M is relieved from its action on the band K, the shuttle-boxes will descend by their own gravity. When this is to take place, the tension of the spring is taken off by the action of the cam N, placed on the main shaft of the loom, which cam is so formed as to depress the treadle O, which, drawing on the part P of the band K, takes off the action of the spiral spring therefrom, and the shuttle-boxes descend.

The protection-rod Q Q and its appendages, used for stopping the loom when the shuttle does not arrive home, are employed by me in the ordinary way; but I also make use of this protection-rod for the purpose of relieving the shuttle from the picker, in the following manner: R is an arm or finger which is affixed to and descends from the protection-rod, and this, as the lathe approaches the breast-beam, strikes against the stop S attached to the frame of the loom, and causes a partial revolution of the protection-rod. T T are arms on its extreme ends, which arms are connected to two vibrating levers U U, by a rod *z z*, which work on fulcra on the ends of the lathe, above the shuttle-box.



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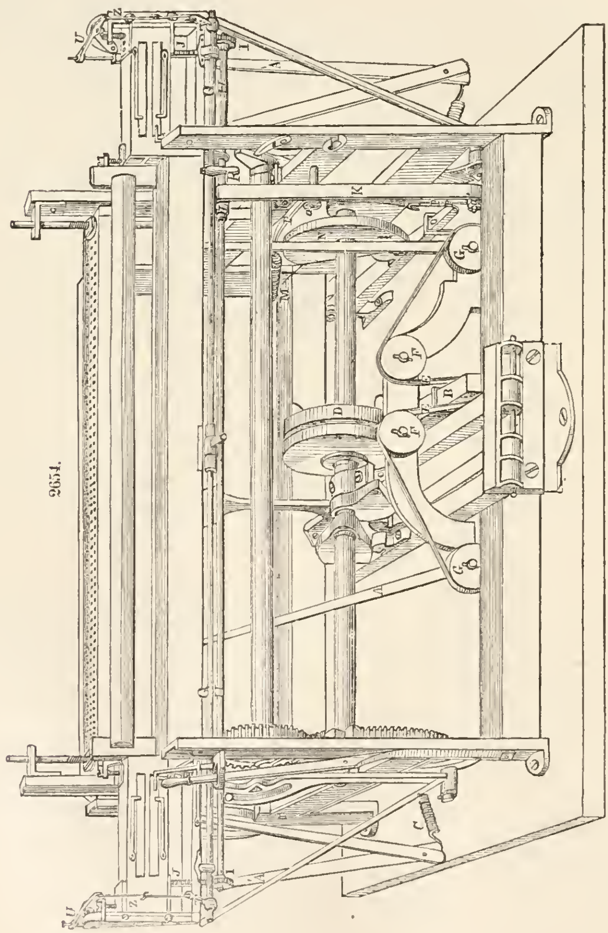
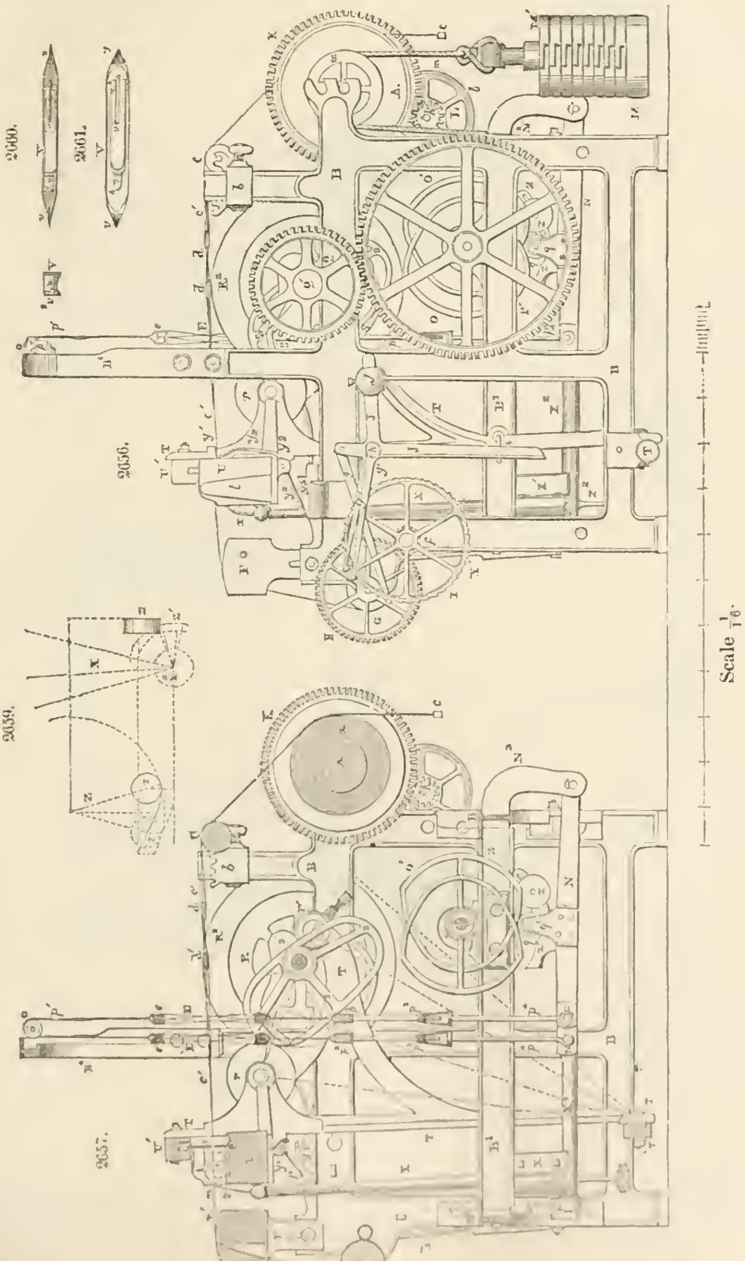


2654.

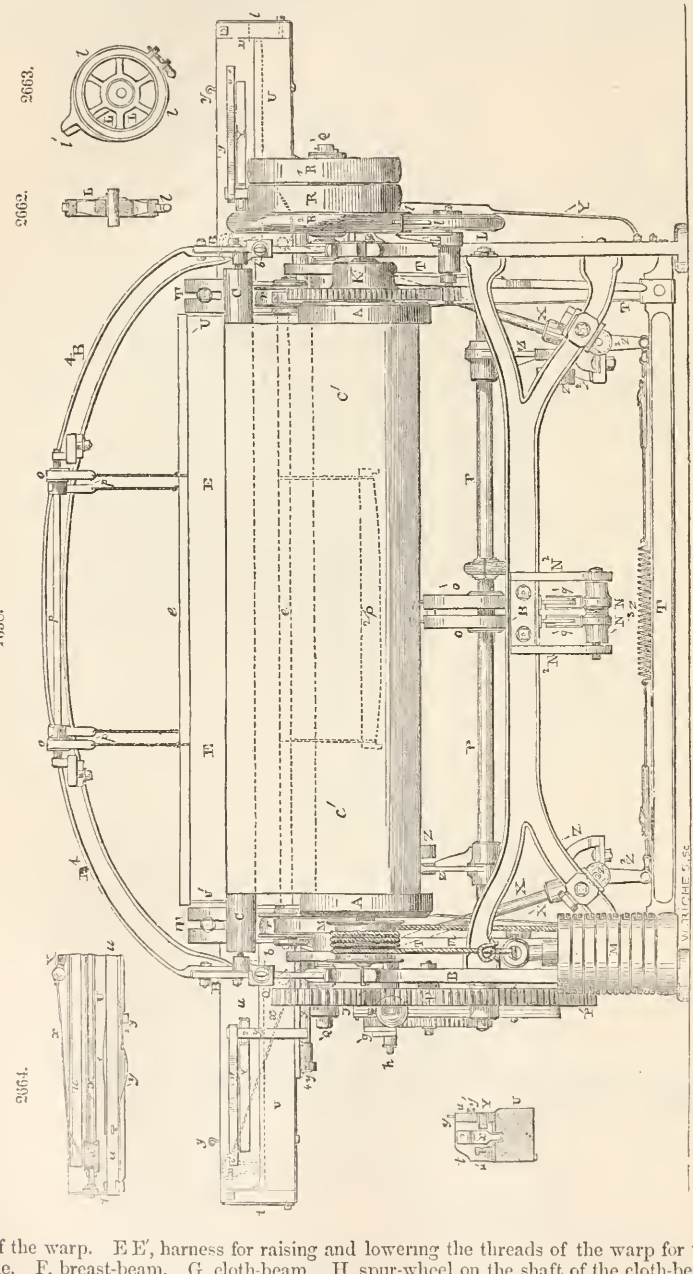
Fig. 2655 is a back view of the outer end of one of the shuttle-boxes, showing the manner in which the lever U and its appendages operate. The piece of wood or metal V which is raised and lowered by the action of the lever U, and which is represented as resting on the picker W, will, when the inner end of the lever U is down, rest upon the picker-rod X, where it serves to arrest the picker and stop the shuttle. When the lever U is raised, the picker is thereby allowed to pass home, and is consequently removed from the point of the shuttle, and this and the shuttle-box are left free to be raised or lowered. The rod A′ bears against the pin *b* projecting from the picker, and serves to remove it from the shuttle when the piece V is raised. The rods *c c* support the pin *b*, and serve as guides to the rod A′; the cord *d* connects the upper end of the rod A′ to the upper end of the stave A, in order that the stave may by its motion move the rod also.

I will here remark, that a weight may be substituted for the spiral or other spring M; that the shuttle-boxes may be raised by springs placed immediately under them, and that the tension of such springs may be taken off by means analogous to those described; but it will be manifest to every competent machinist that any such variation of the respective parts will not substantially change the character of my invention. The manner of constructing and arranging the apparatus as set forth by me, is that which I have deemed the best in practice.



LOOM, DOUBLE-STROKE, *for weaving stuffs of linen, silk, or wool.* Fig. 2656, side elevation of the loom. Fig. 2658, elevation of the loom. Fig. 2657, section.

Fig. 2659, illustration of the movement which operates the picker-staff.
Figs. 2660 and 2661, shuttle. Fig. 2658, elevation of the loom on the side of the warp.
Figs. 2662 and 2663, plan and section of the brake.
Fig. 2664, plan of one of the shuttle-boxes.
A, warp-beam. B B¹ B² B³ B⁴, frame of the loom. *b b*, supports of the shaft of the drum C, fastened to the uprights of the frame by set-screws. C, wooden drum. *d d'*, blocks to preserve separate the



threads of the warp. E E', harness for raising and lowering the threads of the warp for the passage of the shuttle. F, breast-beam. G, cloth-beam. H, spur-wheel on the shaft of the cloth-beam. *f*, pinion working into the wheel H. I, ratchet-wheel, which works with the pinion. J, bell-crank, moving on the centre *n*, and carrying the clicks *g g'* and the counterpoise *j*. *g*, lay-click, serving to give motion to the ratchet-wheel. *g' g'*, stop-clicks, to arrest the movements of the ratchet-wheel. *i*, pin on one of the swords of the lay, to give motion to the bell-crank J. K, spur-wheel on the shaft of the drum A, working with the pinion *k*. *k* pinion of 12 teeth, fixed to the shaft which carries the brake-pulley L, Fig

2658, and also Figs. 2662 and 2663. *m*, cord, fastened at one end to a spiral spring, and passing over the pulley M, supports the counterpoises M′, formed of iron rings. N N′, needles, which give movement to the harness of the treadles, one shorter than the other. O O′, two eccentrics, cast in the same piece, serving to give motion to the treadles, and consequently to raise and lower the harness. P, shaft carrying the eccentrics of the treadles, and also the cranks Z, which give motion to the picker-staff. P′, spur-wheel on the shaft P. Q, pinion, of half the diameter of the wheel P, and giving motion to it. Q′, a driving-shaft of the machine. R R′, fast and loose pulleys on the shaft Q. for the working of the machine. S S′, eccentrics, by means of which a double beat is given to the lay V at each revolution of the main shaft. *t t′*, friction-rollers at the ends of the swords of the lay, to receive the action of the eccentrics S S′. T, two swords of the lay. U, lay or batten, on which traverse the shuttles. V, shuttles; X, picker-staff; *x*, picker strings. *x′*, pickers of hide, serving to throw the shuttle. x^2, guide-rods to the pickers. Y, wooden levers, sunk in the substance of the cheeks of the lay, and turning on the pin *y*. $y\, y^2\, y^3\, y^4\, y^5$, details of the stop-motion by which the loom is thrown out of geer by a failure of the proper motion of the shuttle. Z, two cranks on the shaft P, giving motion to the picker-staff by means of friction-rollers *z* on the ends of the crank, working upon inclines *z′*. Z^2. two levers, connected with the axes of the picker-staffs, and united by means of straps to a spiral spring Z^3.

LOOM, POWER CARPET, *for weaving two or three ply ingrain or Kidderminster carpets, by* E. B. Bigelow. It gives peculiar interest to the description of a valuable and meritorious invention, to precede it by some account of the life and character of the inventor. The mind loves to contemplate the early struggles of genius, to perceive and comprehend its first inspirations, and step by step to trace the development of its powers.

Erastus B. Bigelow was born at West Boylston, Massachusetts, in April, 1814. His father was a cotton manufacturer, which circumstance, we have a right to assume, gave to the son's mind its first tendency towards that peculiar branch of mechanical pursuits in which he has now attained an enviable and undisputed eminence. His parents, however, designed him for the medical profession; but such a misdirection of faculties was not predestined by the "Divinity that shapes our ends." Before he had completed his medical education, his father, in common with many others engaged in manufactures at that time, failed in business, and was unable to complete the education of his son. What appeared at first a severe private calamity, has, under a wise Providence, resulted in great public good.

Finding himself without means to prosecute his medical studies, young Bigelow yielded to that necessity which has so often proved the benign mother of early invention, and determined to direct his ingenuity to the contrivance of some piece of mechanism, from which he might obtain some pecuniary benefit. Whilst his thoughts were directed to that object, he happened one day to be lying on a bed covered with a knotted counterpane, a species of fabric in which the figure on the surface appears as if made by tying into knots the threads of the woof; and as, some years before, an attempt had been made in West Boylston (where he was still living) to manufacture such counterpanes on hand-looms, and abandoned on account of the great labor and expense involved, three or four days being required to make one counterpane, it became evident to his mind that if he could succeed in producing a power loom for this purpose, it would be highly valuable as a labor-saving machine, and that he could derive from it the pecuniary assistance for the want of which his medical studies had been suspended. It was a bold undertaking for one wholly uninitiated in the mysteries of the mechanic art, but his very inexperience was to him a great benefit, by concealing from his sight the enormous mechanical difficulties he would have to encounter, and which, if then fully known, might have deterred him from ever carrying his purpose into execution. We may here notice this remarkable fact, that the most original and important inventions the world has ever seen, were the productions of men who had received little or no previous training in the particular art which they sought to improve. Jacquard, the inventor of the beautiful mechanism which bears his name, for weaving figured fabrics, is the only exception with which we are acquainted. It would seem that in pursuing any avocation steadily, the mind becomes so habituated to a certain practical *routine*, as to make it distrustful of any other; whilst, on the other hand, a mere novice, from the fact of his approaching the subject untrammelled by habit or prejudice, will be better fitted to detect existing errors, and suggest bold and original improvements.

But to return. This new idea, forced by circumstances upon Mr. Bigelow's mind, he prosecuted so vigorously, that in the course of one year he had an automatic loom for weaving knotted counterpanes in successful operation, doing the work in one-fourth of the time required by the hand loom.

The loom was arranged with every fourth dent of the reed adapted to slide vertically in the lathe, and with a hook on the front edge. To the lower end of each of these hooked dents was suspended a wire, attached at its lower end to one end of a lever, and the series of levers were acted upon at the other end by tappets, arranged in a helical line on a barrel or cylinder, for the purpose of depressing the hooked dents in succession from one side of the lathe to the other. The levers and dents were so weighted as to remain in a depressed position, with the hooks below the race beam, to permit the passage of the shuttle, and when elevated they were held up by the pressure of a spring on each one. For the production of the figure, the hooks, or rather that portion of them required each time, were operated every fourth pick or throw of the shuttle, and after the fourth throw of the shuttle, the required portion of hooked dents were elevated above the weft thread, the upper part of the hooks being curved, to admit of its passing by the weft-thread; and then, when drawn down, each hook in succession caught the weft and drew it down below the line of the bottom warps, to form the loop, so that when the weft thread was beaten up by the reed, and the warps crossed, each loop would project to the required distance above the face of the cloth. To insure the proper action of the hooks on the weft thread, there was a plate imbedded in the race-board, and adapted to slide up and down, and having a notch corresponding with each hooked dent. This plate was brought up under the warps just before the hooked dents were depressed, and formed a bed for the hooks to draw the weft thread down. The selection of the hooked dents required to be elevated and depressed, for each operation to determine the figure was effected by a series of needles, on the principle of the jacquard, and governed by punched cards; but these needles, instead of being used to operate knotted cards, were, at their outer ends, joined to wire hooks connected with the levers of the hooked dents, and when the needles were acted upon by the cards, the hooked wires of such of the levers as were to be operated to lift the dents were brought within the range of motion of a lifting-bar, which carried them up where they were held by the spring before described; the lifting-bar was then depressed, and then, as the tappets on the barrel passed around, the lifted hooked dents were each in succession drawn down to form the series of loops.

This loom was so ingenious, and worked so well, that our young inventor soon found capitalists able and willing to furnish the means necessary for the enterprise, and a patent was secured for the invention in the United States, on the 6th day of January, 1838, and in England the same year.

He contracted with parties to build three looms, they to pay a certain price for the invention, but before this contract was fulfilled on either side, he visited New York, and there saw for the first time a new and different species of counterpanes, then just introduced from England, which, from the superiority of the fabric, he perceived must soon supersede the knotted counterpanes. Although being at that time in great pecuniary want, and surrounded by all its attendant privations and temptations, instead of proceeding to the enforcement of his contract, which would have at once relieved his wants, he immediately returned to Boston, and communicated to the parties what he had seen and believed, and advised them to abandon the enterprise, as, in his judgment, the new kind of fabric would be preferred in the market, and that he could produce a loom which would weave it with greater facility than the knotted counterpanes could be woven. His success in his first effort of invention, and the honesty of purpose manifested in this his first business transaction, could not fail to inspire a degree of confidence in his ability and integrity which proved of great advantage throughout his subsequent life, in bringing all his enterprises to a successful issue.

He now entered into an agreement with the same parties to invent an automatic loom for weaving this new species of counterpanes, which was afterwards produced, and patented on the 24th of April, 1840, and put in successful operation. There are now 36 of these looms in operation at Clinton, Massachusetts, which supply the principal demands of our markets.

Before he had completed the counterpane-loom above described, he had incidentally seen in New Jersey the operation of weaving coach-lace in hand-looms, and not having as yet realized any pecuniary advantage from his efforts, he determined, while progressing with the new counterpane-loom, to direct his attention to the subject of weaving *coach-lace.* With this view, he made inquiries of persons engaged in vending this kind of fabric, as to the extent of the consumption and the cost of production, as well as the difficulties of weaving it by hand. The result of his investigation determined him to make the attempt, and, with the pecuniary assistance of an elder brother, he proceeded to the construction of a loom which was completely successful. So urgent were his necessities at this time, and such was the ardor with which he pursued the subject, that he labored day and night, scarcely taking time for food and rest, and in the short space of six weeks from the time that he made the inquiries above referred to, he had the first loom in operation, and in three months after that, another and more perfect one, and the requisite capital under his control for putting up a large establishment. This result, when we consider the youth and inexperience of the inventor, and the peculiar difficulties of the subject, seems to us to have no parallel in the history of inventions.

The figure on coach-lace is produced by raising on the surface of the ground-cloth a pile similar to the Brussels carpet, formed by looping the warps over fine wires, which are inserted under such of the warps as have been selected by the jacquard to determine the figure. The warps are then woven into the body of the cloth, to tie and fix the loops. The wires are then withdrawn and re-inserted. Automatic pincers, as if instinct with life, grasp the end of the wire, draw it out from under the forward loops, carry it back towards the lathe, where the warps are spread apart, forming what is called the open shed, and there introduce and drop it, that the shed may be closed and opened, that by the throw of the shuttle, the weft-threads, which are to tie and weave the warp-threads into the cloth, may be beaten up by the reeds. The pincers then move back to draw another wire from under the formed loops, and repeat the same operation, several such wires being used at the same time in the cloth, to prevent the loops from being drawn out by the tension which is given to the warps to insure an even and regular surface to the fabric; but as there are a number of these wires woven into the cloth, nearly touching one another, it became a matter of great difficulty to contrive a mechanism which would insure the taking of only one of these wires to draw it out, and select the proper one at each operation. The pincers could not practically be made so narrow, and work so accurately, as to insure this. This difficulty was overcome by an ingenious mechanism placed on the opposite side of the loom, which at each operation selects the required wire, and pushes it out sufficiently far beyond the ends of the others to be gripped by the fingers, which then draw it out to carry it back and introduce it in the open shed of the warps.

Some notion can be formed of the difficulties which this subject presented, by taking into consideration that the mechanism which works the wires must operate in connection with the mechanism which weaves the cloth, and the jacquard which produces the figure.

The cost of weaving coach-lace was very much reduced by this invention, and there are now in one establishment in Clinton, Massachusetts, 96 of these looms in successful operation.

Soon after this was in successful operation, Mr. Bigelow completed his second counterpane-loom, to which we have before referred, and he had then accomplished the first purpose which impelled him to exercise his ingenuity—he had acquired the means of completing his medical studies. But by this time he had found much greater attractions in the new career which circumstances had opened before him—it was one for which nature had manifestly intended him, and therefore invention was an occupation no longer ancillary, but paramount, and the success with which he has pursued it up to this day is now distinctly marked upon the pages of our industrial history.*

The coach-lace loom was merely the basis of a series of improvements then contemplated, but which have since been completed, and are now in successful use; these improvements are in looms for weaving Brussels and tapestry carpeting.

The weaving of Brussels and tapestry carpets by automatic machinery was considered by many, a few years back, to be a mechanical impossibility, and, indeed, there were few subjects that presented such formidable difficulties. After constant and laborious exertions, at times snatched from other pressing engagements, Mr. Bigelow succeeded also in this undertaking. There are now 28 Brussels looms in operation in one establishment in Clinton, producing carpets which are pronounced by the ablest judges to be the best Brussels carpets manufactured in any part of the world, and 50 tapestry looms in the establishment of Messrs. Higgins & Co., New York; and when those now in contemplation shall have been completed, there will be 225 looms in operation on his plan, weaving each, on the average, from 18 to 20 yards per day, while from 3 to 4 yards per day is the average product of hand-looms.

The surface of the carpets woven by these looms is more perfect and regular than when woven by hand, the texture of the cloth more regular, and, what is of the greatest importance, the figures are so regularly measured that, when put together, they make a perfect match. This perfection in the quality of the cloth and the regularity of the figure is in part due to improvements which will be described in connection with the ingrain-loom, as they are applicable to the weaving of all kinds of figured fabrics that require regularity in the figure.

Shortly after the completion of his coach-lace loom, Mr. Bigelow called on Mr. Alexander Wright, the agent of the Lowell Manufacturing Company, who was not only a man of great experience in manufactures generally, but possessed an intimate knowledge of the manufacture of coach-lace. From him he obtained valuable information, and in the course of their conversation, Mr. Wright called his attention to ingrain carpets, and suggested to him the importance, as well as the difficulty, of producing a power-loom for weaving that kind of fabric. The hint was not thrown away, for as soon as he had completed his second counterpane-loom, he bent his mind to improving the ingrain manufacture, and in the year 1839, through the instrumentality of Mr. Wright, entered into an agreement with the Lowell Manufacturing Company to accomplish this purpose, and before the close of that year had completed the first power-loom for weaving two-ply ingrain carpets. This loom produced from 10 to 12 yards per day—the hand-loom produced only 8 yards per day.

When his mind was first turned to this subject, it presented these leading difficulties. The mere weaving of the fabric by an automatic loom was easily effected, but to invent a loom which should make carpet fast enough to be economical, one which should make the figures match, and to have a good and regular selvage and a smooth, even face, were very serious practical difficulties. The hand-weaver, by the exercise of his judgment, can, to a certain extent, meet these contingencies; if the weft-thread is too loose after the shuttle has been thrown, he can give it a pull with the fingers to make the selvage regular; if he finds by measurement that by reason of the irregularity of the weft-threads or the ingraining, the figure is being produced too long or too short, he gives more or less force to the lathe in beating-up; and if he finds that the surface of the cloth is getting rough, he regulates the tension of the warps. In this way, by observation and the exercise of skill and judgment, he can approximate, and only approximate, to the production of a good and regular fabric. But to invent an organization of matter which should itself observe, and think, and judge, and do it all with more unerring accuracy than man himself—this was a result almost absurd to contemplate, but which it was reserved for Mr. Bigelow to attain.

In the first loom produced, he approximated more nearly than the hand-weaver to a perfect match in the figure, and this he effected by taking up the woven cloth by a regular and positive motion which was unerring, the same amount for every throw of the shuttle and beat of the lathe, and as the weft-threads are not spun regularly, and the weaving in of the warp-threads and passing the different colors from the upper to the lower ply or cloth, (as ingrain carpets are composed of two or three cloths woven and connected together,) to produce the figures, requiring sometimes more and sometimes less to make a given length, he determined to regulate the delivery of the warps as required by their tension, thereby throwing the irregularities into the thickness, where it cannot be noticed, instead of in the length, where it would destroy the match of the figures. And he accomplished this by suspending a roller on the woven cloth, between the lathe and the rollers that take up the woven cloth, so that when the cloth was being woven too short, which indicates a deficient supply of warps, the roller would be elevated, and by its connection increase the delivery motion to give out more warps; and when the cloth was being woven too long, which indicated too great a supply of warps, the roller was let down to decrease the delivery motion, and thus reduce the supply of warps. In this way the roller was made to act as a measurer and feeler of the quantity of warp demanded, and to direct the supply. But this contrivance, like the mind of the hand-weaver, only came in play to prevent the progress of an evil after it had been observed. If he had applied this yielding roller to the unwoven warps to feel and ascertain the demand of warp beforehand, he could have prevented the evil. He did not then perceive that this could be done, for the reason that this roller must be sensitive to detect and indicate the amount, and at the time the lathe beats up the weft, the warps must be rigid to resist the beat, or else a good fabric cannot be produced. This was, however, accomplished by a subsequent improvement, which will be hereafter described.

* In addition to the establishments at Lowell, Thompsonville, and other places which have been built solely for the use of his improvements, the new town of Clinton, Massachusetts, (which we have mentioned before,) situated twelve miles north of Worcester, and now containing a population of nearly 3000, is virtually the creation of Mr. Bigelow's own mind, it having been built up by business consequent upon his inventions.

A smooth and even surface for the cloth he obtained in the following manner. We have already pointed out that the passage of the warp-threads from one ply or cloth to the other, called *ingraining*, must necessarily be unequal and depending on the figure to be produced, and that in consequence of this the warp-threads that are the most ingrained will be taken up faster than those less ingrained, and as all the warps are of necessity rolled up on the warp-beam with equal tension, they can only be given out equally.

This seeming impossibility he did effectually overcome in the following manner. Each warp-thread in the usual way passes through a loop called a mail, attached to a card suspended from the jacquard, and each card has suspended to it a weight, all the weights being equal. The two trap-boards of the jacquard move simultaneously, one up and the other down, and in these movements they catch or trap such of the cords (determined by the combination of cards) as are required to bring up the proper warp-threads at each operation to produce the figure, leaving down such of them as are not required at that particular operation; and when the two trap-boards are on a level, and all the warp-threads connected with them in a horizontal line, and those not connected with them hanging down with the weights suspended to them, the lathe beats up the weft-thread which lies between the warps that are in a horizontal line, at the same time exerting a force on the weft-threads previously thrown, and beating them up more closely.

Now, as the warp-threads are all connected at one end to the woven cloth, and at the other with the beam, it follows that those which are hanging down in a bent line with the weights suspended to them, will receive a greater proportion of the force of the beat of the lathe than those which are in a straight line; and as all the warp-threads in succession take this hanging-down position, and all of them have an equal weight, it follows necessarily that each warp-thread in succession receives the same pull at the time the lathe beats up, and that therefore all tendency to irregularity in the length of the warp-threads taken up by the ingraining will not tend to produce an irregular surface, but, on the contrary, the surface of the cloth will be as smooth and even as if all the warp-threads were equally taken up in the weaving of the cloth, and were under a constant and equal tension.

At the same time he accomplished the making of a good selvage by a mechanism which handed instead of throwing the shuttle across—an arm carried the shuttle half way across, and another there took it and carried it entirely across. By this means any required degree of tension could be given to the weft to make a smooth and even selvage. But although it accomplished this desirable object, it failed to work with sufficient velocity, and thereupon Mr. Bigelow, nothing daunted, renewed his efforts, and produced another loom with the fly-shuttle, in which he was enabled to make a good selvage by a mechanism which gives a pull to the weft-thread after the shuttle has been thrown, and as the lathe beats up. He also introduced other improvements, which will be hereafter described. This loom, although it produced about 18 yards per day, did not satisfy the inventor, and he again applied himself with renewed energy until he made a third loom, which averages from 25 to 27 yards per day of two-ply, and from 17 to 18 of three-ply carpets. There are now in operation at Lowell, Thompsonville, and Tariffville, 450 of these improved looms.

This brings us to our main purpose, the description of the loom as it is now worked, with all the improvements which have been made in succession from the commencement to the date of the last patent, the 23d day of October, 1849. But before proceeding to the detailed description of this loom, it may be well to state that the improved method of producing figures that will match, which makes part of this loom, was invented in 1844, and patented on the 10th of April, 1845, in connection with a loom for weaving plaids and ginghams, which has gone into extensive use at Clinton, there being now 580 of them in one mill, and 120 in another.

In addition to the various important inventions which have been enumerated, many others have been made by Mr. Bigelow connected with the details of various kinds of looms, and for drying and stretching fabrics and printing warps, some of which have been, and others are to be, patented both in England and in this country, and which are nearly all of decided practical utility. No one man within our knowledge, either in Europe or in this country, has given to the world so large a number of valuable inventions as Mr. Bigelow, and inventions, too, evincing not only great ingenuity, but sound inductive powers of the highest order.

This invention for weaving ingrain carpets, taking it from the commencement, through all its stages, to the date of the last patent, consists:

1. In operating the trap-boards of the jacquard in a power-loom simultaneously, one up and the other down, instead of moving them alternately as in the hand-jacquard, whereby either the time required for the movements of the jacquard, or the velocity of their motion is reduced, the former admitting of more expeditious weaving (if the other operations be accelerated in the same ratio), and the latter reducing the liability to wear and tear. But there are other and important advantages incident to this change, such as balancing the weight of the harness, which in a jacquard is considerable, for that part of the harness suspended to the descending trap-board balances the corresponding harness suspended to the ascending trap-board, thus equalizing the resistance to the moving power, and rendering the operations easier and more regular. And still another change is, that the beat of the lathe takes place after the warps connected with the two trap-boards have passed and are a little crossed, and whilst the remaining warps are in their lowest position, that is, bent down by the weights suspended to their trap-cords, so that these, which like the others are held at both ends and bent down, will receive a greater portion of the force of the beat of the lathe; and as all the warps in turn take this position, and each warp-thread, when in this position, is held down by the weights—all of them equal—suspended to its trap-cord, it follows that all the warp-threads, as before stated, receive an equal tension in beating-up the weft-threads, no matter what may be the variation in their lengths between the woven cloth and the yarn-beam, occasioned by the irregularity of the ingraining. The practical weaver will appreciate this as one of the most important advantages in weaving ingrain carpets, for it presents a principle of compensation and self-adaptation to the irregularity of the ingraining due to the figure never before

attained, and by which alone such fabrics have been made with a regular and measured figure, having a face or surface as smooth and even as a plain fabric.

2d. In taking up the woven cloth by a regular and positive motion, which measures the length of cloth to be produced at each beat of the lathe when employed in connection or combination with a method of regulating the delivering out of the warps by their tension in proportion to the quantity required, and taken up in the process of weaving, and also with the holding of the warps rigid at the time the lathe beats up the weft to prevent them from yielding to the force of the beat. It will be seen that in this way the irregularities of the ingraining and of the weft-threads will be thrown into the thickness instead of the length of the cloth, for as the lathe beats up the weft-threads to the same distance each time, and a given and measured length of cloth is taken up, the same length of cloth will be woven; but if the warp-threads were free to yield at the time the lathe beats up instead of forcing up the weft-threads to the required position, the whole cloth and warp would be forced forward, and produce what is called a sleazy fabric; and this, from its loose texture, would soon accumulate to such an extent as to stop the further progress of weaving. But to prevent this, the moment the lathe begins to beat up the weft-thread, the warps are held firm to resist the force of the beat, and thus insure the carrying of the weft-thread up to the required line. In this way the two opposing or antagonistic conditions—sensitiveness to deliver out the quantity required, whatever may be the irregularity of the demand, and non-yielding to resist the beat of the lathe—are reconciled to produce the important result of weaving ingrained fabrics with a regular and measured figure; a result never before attained, even with the hand-loom.

3d. In mounting the shuttle-boxes in independent frames at the sides of the lathe, which in this way becomes a mere guide to the shuttles as they are thrown from one side to the other. The advantages of this arrangement are, first, the weight of the lathe (which must have a considerable range of motion and a high velocity) is greatly reduced, and will not, therefore, require so much power to operate it; for in weaving two and three ply carpets, particularly such as have a variety of colors, the shuttle-boxes are numerous and heavy, and in proportion to the number and weight would be wasteful of power and liable to derangement if carried by the lathe. Secondly, it affords a surer, easier, and more durable mode of operating the shuttle-boxes to shift the shuttles for the changes in the colors of the pattern and, lastly, it is very efficient in producing a good selvage, for the moment the shuttle is thrown the weft-thread is held on a permanent bed by fingers, so that as the lathe beats it up, the pressure of the fingers affords the required friction to pull the weft-thread to make a tight and regular selvage; and the shuttle-boxes being in independent frames, the weft-thread is not drawn out of its position in the cloth by the back movement of the lathe, as in the ordinary loom. Thus, the weft-threads, when once beaten up, are retained in that position, and their parallelism in the cloth is insured.

4th. In connection with the mounting of the shuttle-boxes in independent frames by the side of the lathe, using one cam and roller to work the lathe, and another to hold it in a fixed position during the throw of the shuttle, one of the said cams being on the lathe-shaft, and the roller which works in connection with it on the lathe, and the other cam on the lathe, and its roller or wrist attached to the first cam; one of the cams being concentric to hold the lathe in a fixed position during a part of the rotation, and whilst the shuttle is being thrown, with its ends eccentric, that the roller may enter and leave it as the lathe is either gradually started or gradually arrested, and the other cam being of any form suitable for giving the lathe the required varying motions.

By this means the cam and roller, which operate the lathe, and which are, in consequence, exposed to all the strain and wear and tear, are not used to hold the lathe in a fixed position during the throw of the shuttle.

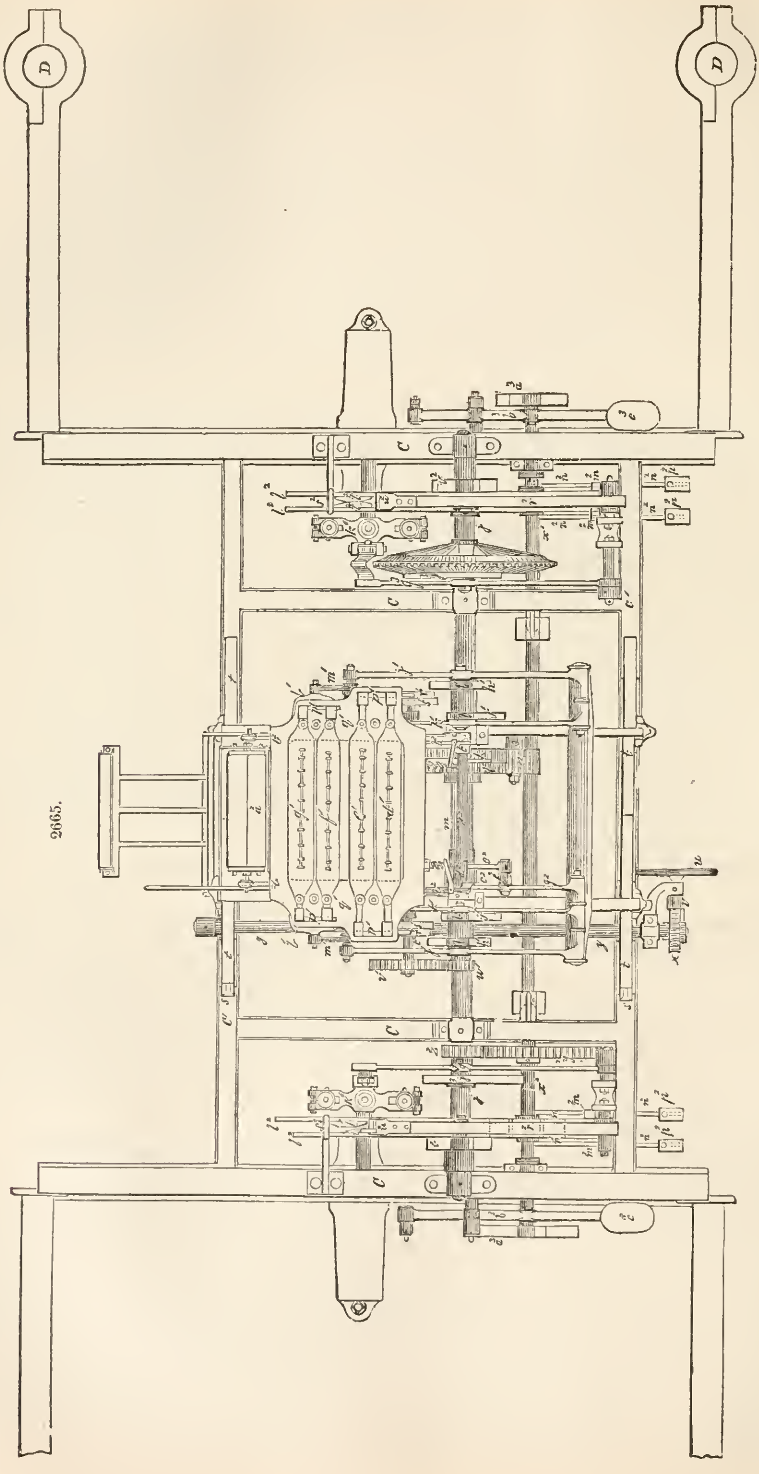
5th. In combining with a power or automatic loom four series of shuttle-boxes, two on each side in separate frames at the sides of, and independent of the lathe, the said four series of shuttle-boxes receiving motion from the loom or from some first mover in connection with, or operating in unison with the loom; one series of these shuttle-boxes on one side being for the purpose of holding all the shuttles of the various colors required for one ply of the carpet, and the corresponding series on the other side to contain the shuttles of the various colors for the other ply, so that by the up and down motions of these boxes, the various changes of colors can be effected, the other two series of shuttle-boxes being merely to receive and return the shuttle from and to the first series. In view of this, for some patterns the second or receiving shuttle-boxes may be single; but for others they are required to be double, as the colors are required to be alternated.

6th. In combining with the lathe and the shuttle-boxes in separate and independent frames by the sides thereof, hinged guides to guide the shuttles from the one to the other, and to yield and thereby prevent breaking whenever a shuttle, or any part of it, fails to enter the shuttle-boxes.

7th. In giving to the jacquard, which determines the figure, a separate organization independent of the loom which forms the cloth, that the various motions of the jacquard may be taken from or given by a shaft or shafts within it, and simply deriving its or their motions from some part of the loom, or from some first mover corresponding with or regulated by the motion of the loom or part thereof, that the motions of the jacquard may correspond with those of the loom. In this way the motions of the jacquard are rendered more accurate and steady, and the weight of the moving parts is greatly reduced

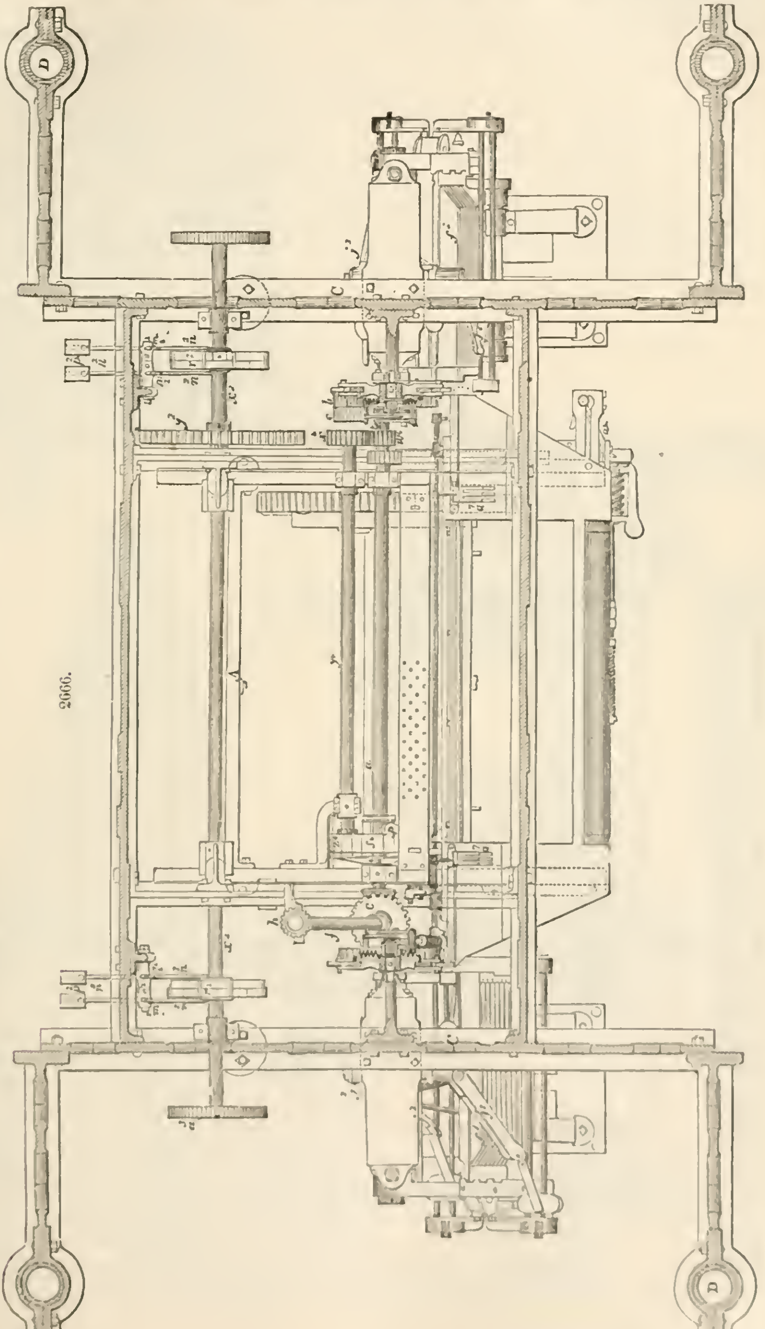
Prior to this invention, in all looms for weaving by power in connection with the jacquard, all the motions of the jacquard were derived directly from some part of the loom and communicated by connecting-rods, which were necessarily of great length. The principal difficulties attending this old mode of construction and organization were the inaccuracy of the motions by reason of the great length of the connecting-rods, the liability to derangement, and the labor and difficulty of adjusting the connections to the varying lengths of the cords of the harness as they are affected by atmospheric changes. All of which difficulties are avoided or greatly reduced by this separate organization.

8th. In making the whole frame of the jacquard adjustable at one operation relatively to the frame of the loom, that the distance between the two may be adjusted to the varying lengths of the cords of



2665.

the harness, whereby the utmost nicety in the adjustment can be obtained, and at the same time, in connection with the separate organization, avoiding the necessity of adjusting the connections when it becomes necessary to adjust the jacquard to the varying lengths of the cords of the harness, for the jacquard, having a separate organization, no change becomes necessary in its own connections.



2666.

9th. In communicating the required motions to the picker-staffs and to the apparatus for shifting the shuttle boxes hung in pendulous frames at the sides of and independent of the lathe, from a shaft or shafts above, whereby is avoided the serious difficulty before experienced of communicating the motions from a shaft or shafts below to the picker-staff and the apparatus for shifting the shuttle-boxes which must be attached to or connected with the shuttle-box frames that vibrate on axes above. By this improved arrangement the motions are derived from a shaft or shafts coincident with or near to the axis of motion of the pendulous frames that carry the shuttle-boxes, instead of being below, where the frames have the greatest motion.

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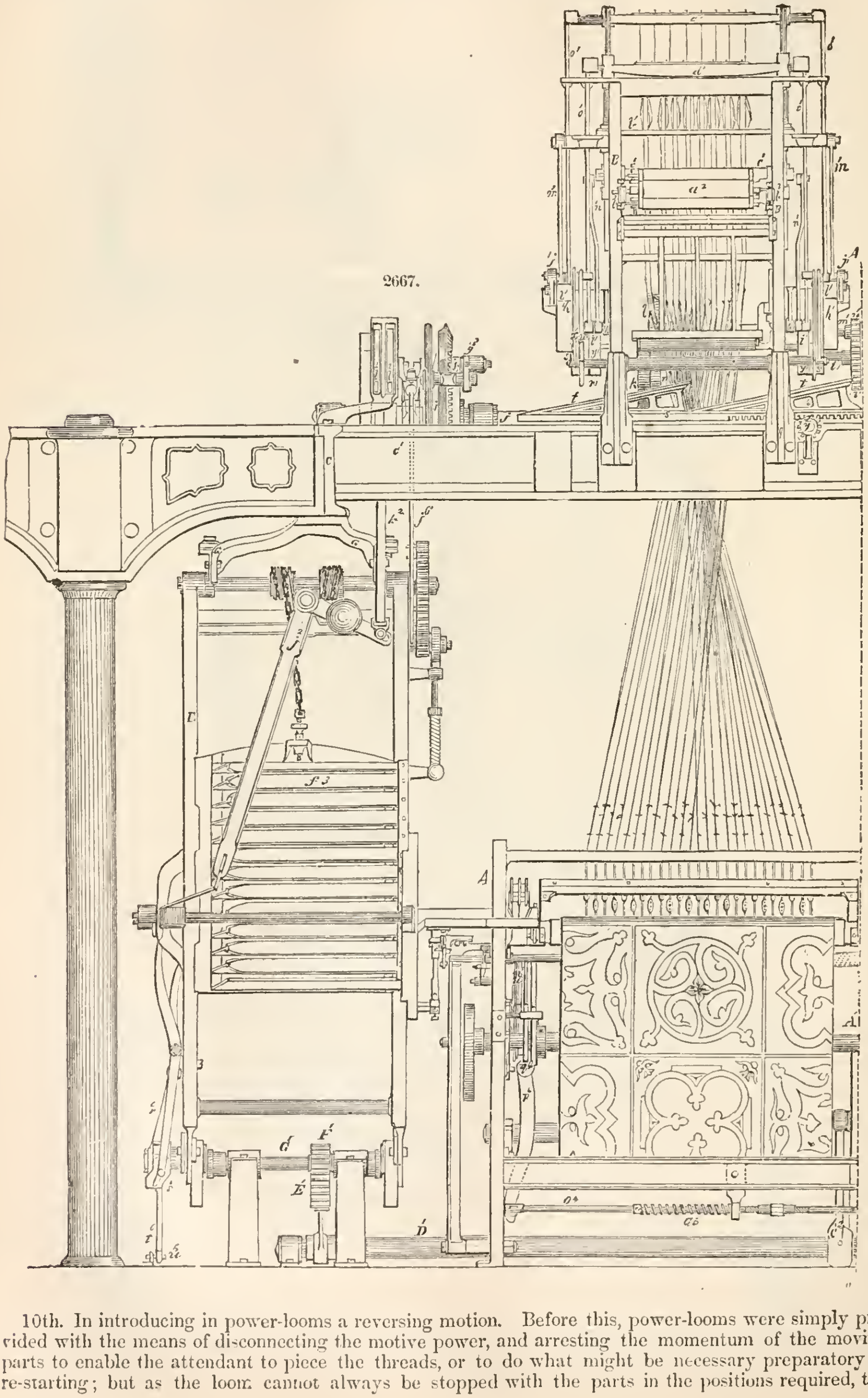


10th. In introducing in power-looms a reversing motion. Before this, power-looms were simply provided with the means of disconnecting the motive power, and arresting the momentum of the moving parts to enable the attendant to piece the threads, or to do what might be necessary preparatory to re-starting; but as the loom cannot always be stopped with the parts in the positions required, the attendant has to reverse the motion of the loom by the application of hand-power to the driving-pulley, a mode of procedure attended with waste of time and great inconvenience, for the attendant must leave his usual position to go to the driving-pulley, and in heavy looms, such as are used for weaving carpets, much strength is required to set the machinery in motion. But by the use of a reversing motion, the attendant, without leaving his place, and by the simple motion of a lever, can operate the mechanism in either direction and to any extent desirable to bring the parts to a proper position for piecing the threads, &c., and re-starting.

In the accompanying drawings, Fig. 2665 is a plan of the loom in the present improved form.

Fig. 2666, a plan of the loom below the jacquard.

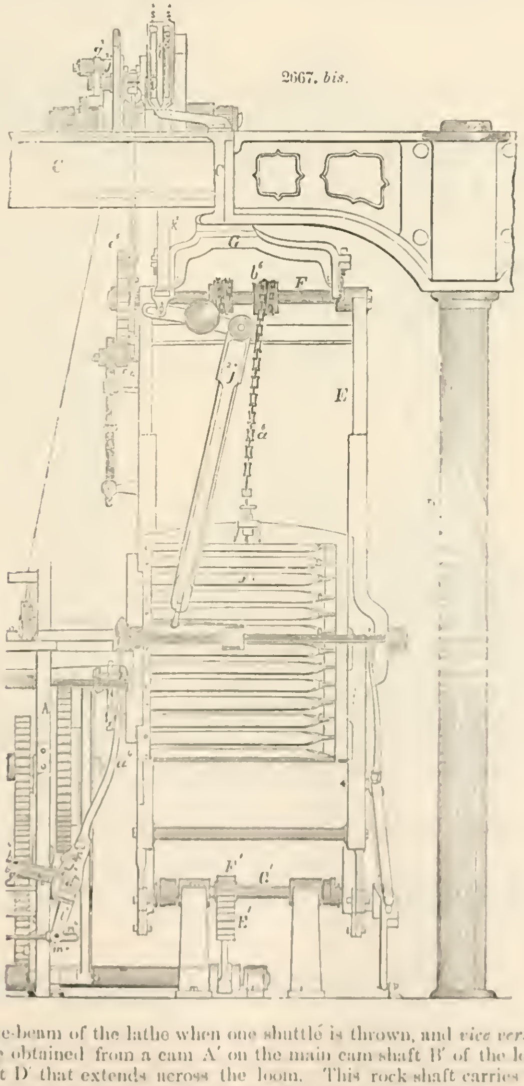
Fig. 2667, a front elevation; Fig. 2668, a back elevation.

Fig. 2669, an elevation of the left-hand side, without the jacquard; Fig. 2670, a vertical section, with the jacquard; and Fig. 2671 another section.

In the said drawings, A represents the power-loom, and B the jacquard-frame resting on beams C C C′ C′, supported on columns D from the main floor.

The pendulous frames E E, which carry the series of shuttle-boxes, are arranged on each side of the lathe, and independent thereof, and are hung on arbors F F, at the top, on which they vibrate. These frames are vibrated back and forth simultaneously, in opposite directions, at each throw of the shuttle, so that the first series of shuttle-boxes on one side, and the second or receiving boxes on the other, shall

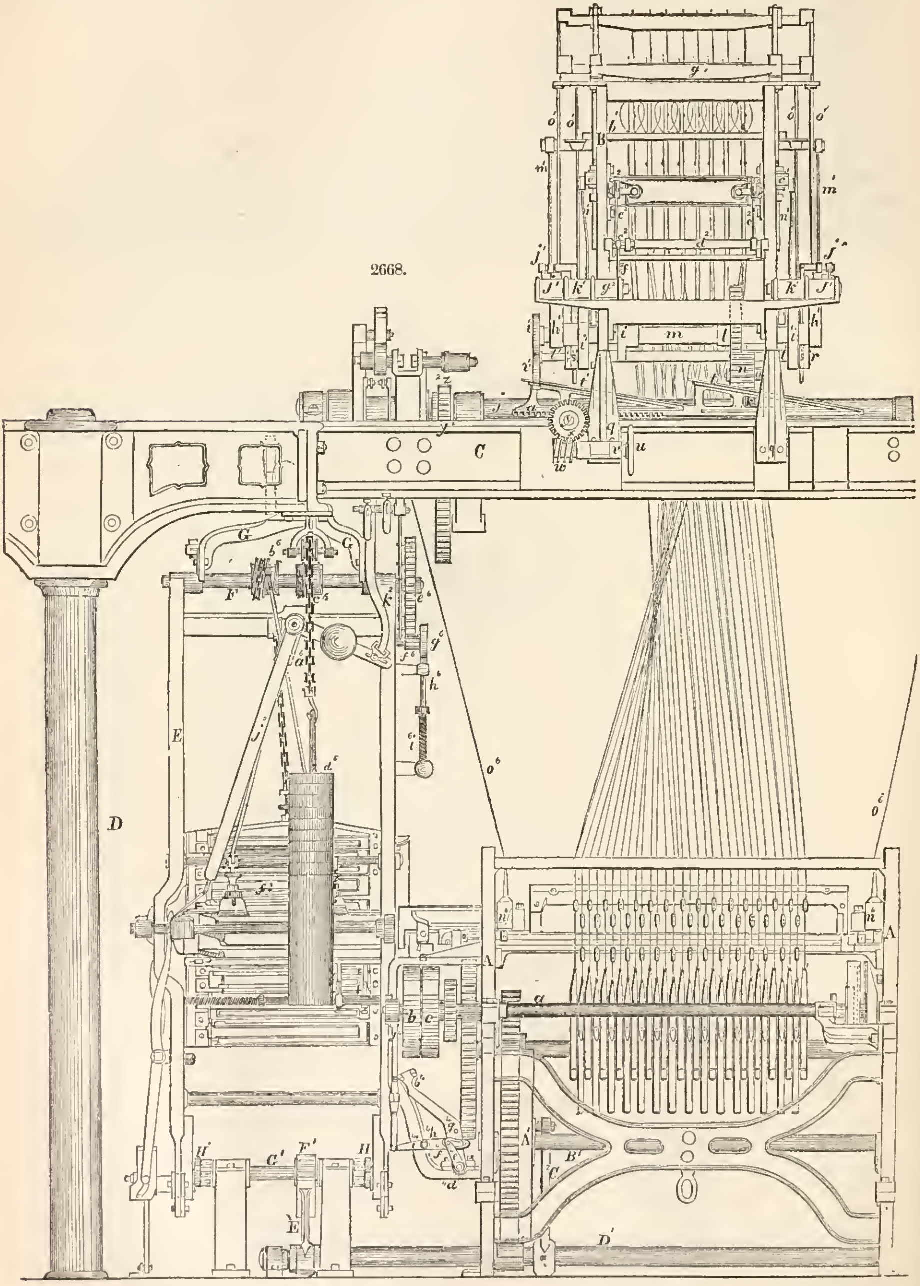
2667. *bis.*



be in line with the race-beam of the lathe when one shuttle is thrown, and *vice versa* for the next throw. And these motions are obtained from a cam A′ on the main cam shaft B′ of the loom, which acts on an arm C^2 of a rock-shaft D′ that extends across the loom. This rock shaft carries at each end a cogged sector E′, which engages a pinion F′ on a short arbor G′ (one on each side) which carries two cranks H′, one at each end, the wrists of which are fitted to grooves I′ I′ in the pendulous frames, so that as the arbors G′ G′ are vibrated by the rotation and peculiar form of the cam A′ and the connections, the pendulous frames are vibrated in opposite directions, and there held during the throw of the shuttle, and then back again.

The driving-shaft *a* of the loom has a fast and loose pulley *b c* on one end, which receives the driving-belt from any first mover in the usual way; and on the other end the said shaft has a bevel-pinion *d*.

2668.



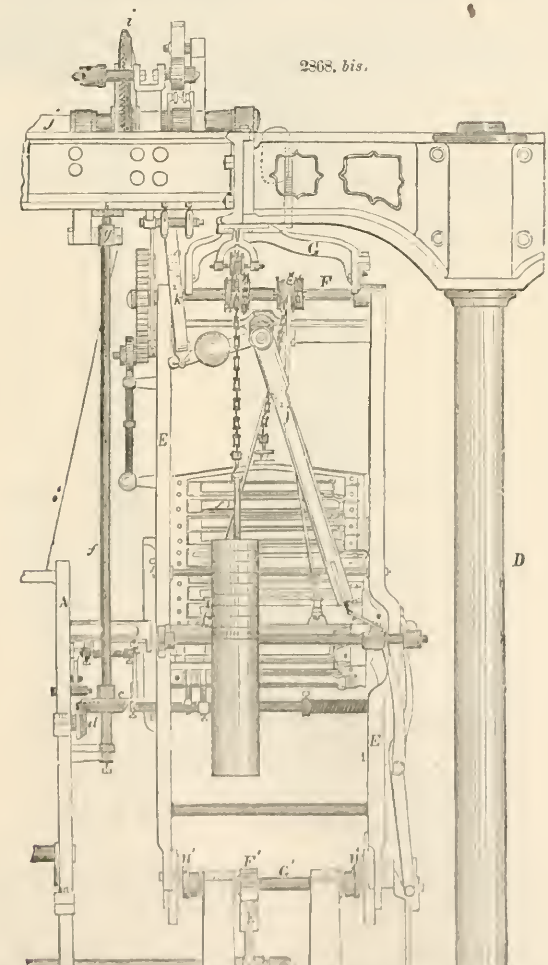
which takes into and drives a bevel-wheel *c* on the lower end of a line-shaft *f*, which extends up to and has its upper bearing in a box *g* attached to one of the beams C′, the upper end of the said shaft having a bevel-pinion *h*, which engages and carries a bevel-wheel *i* on one end of a horizontal shaft *j*, which has its bearings in boxes attached to the tops of the beams C. It is from this horizontal shaft that all the jacquard and shuttle motions are taken.

On this shaft *j* there is a cogged wheel R which communicates motion to a cog-wheel *i* on the jacquard-shaft *m*, by the medium of a connecting pinion *n*, which turns on a stud-pin *o* adjustable in a sector-mortice *p*, the curve of which is struck from the centre of the shaft *m*, that the pitch-line of the said connecting pinion may be always at the same distance from the axis of the wheel *i*, when its stud-pin is shifted. By this means, when the jacquard-frame is adjusted, the connecting pinion can also be shifted and adjusted relatively to the pinion *k* on the shaft *j*.

The frame B of the jacquard, as already intimated, instead of being permanently attached to the beams C′ C′, is free to slide vertically, for the purpose of vertical adjustment, to suit any change in the length of the harness. The side-pieces *q q* of the frame of the jacquard embrace the transverse beams C′ C′, and slide in them accurately, but freely.

The jacquard-frame rests on two horizontal slides S S, which are adapted to slide on the transverse beams C′ C′, the upper surfaces of each being formed with two inclined planes *t t*, one for each of the sides of the jacquard-frame to rest on, so that when these two slides are moved to the one side or the other, the entire jacquard-frame will be elevated or depressed relatively to the loom below, the stud-pin of the connecting pinion *n* being at the same time adjusted in its sector-mortice to adjust the pitch-line of the cogged geering. The slides S S are operated simultaneously by a hand-wheel *u* on a short arbor *v* in front, which carries a worm *w* that engages the cogs of a wheel *x* on a shaft *y* that carries two pinions *z* (only one shown in the figures) that engage the cogs of a rack *a′* on each of the slides.

For the purpose of adjustment, it is only necessary to turn the hand-wheel until the jacquard is

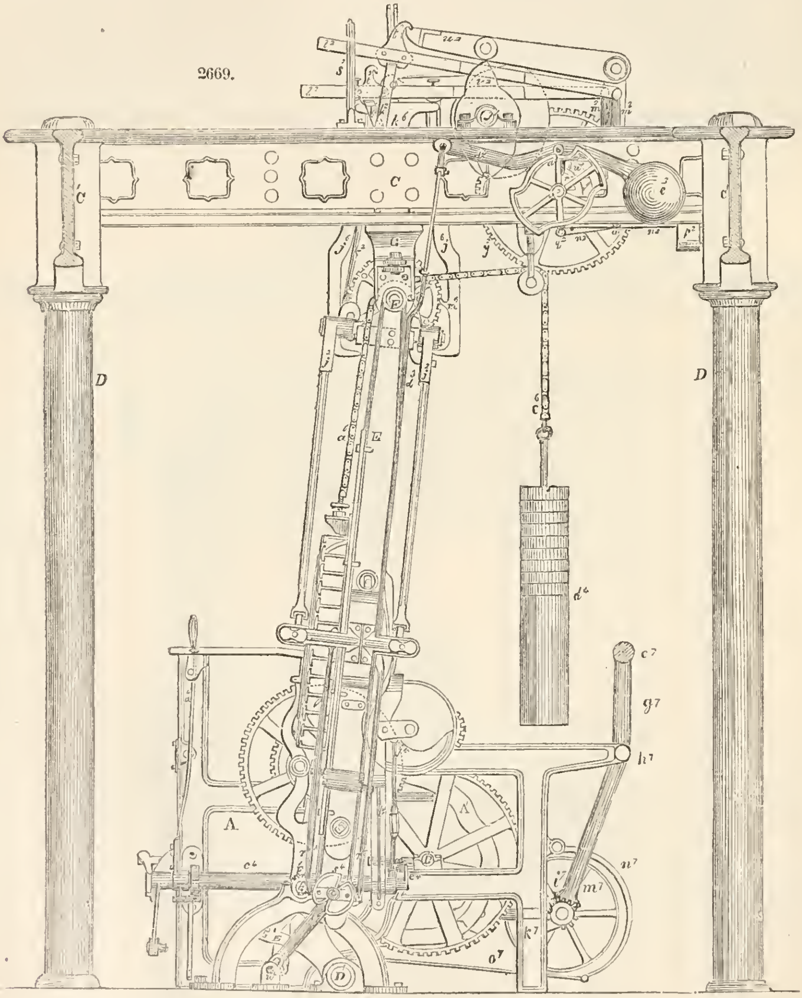


2368. *bis.*

brought to the required position, and then to adjust the geering by shifting the stud-pin of the connecting pinion, the thread of the worm on the hand-wheel arbor and the inclination of the wedges being sufficient to retain the parts in a permanent position.

The required motions of the trap boards *b′* and *c′*, and the journals *d′ e′ f′ g′*, are derived from the jacquard-shafts *m*, which, as described above, receive a continuous rotary motion from the driving shaft of the loom below, and the proportions of the geering, as represented in the figures, should be such as to give to the jacquard-shaft one revolution for every two of the lathe-shaft of the loom. On each end of the jacquard-shaft m there are two cams $h' h'$ and $i' i'$, which are all of the same form as represented in the figures. The cams $h' h'$ are placed on opposite ends of the shaft, and in corresponding positions to work the trap-board b', and the other two cams $i' i'$ are arranged in the same manner, but on the opposite side of the axes of the shaft m, to operate the other trap-board c', as one trap-board descends whilst the other ascends; and the form and position of the cams should be such that one trap-board shall begin to ascend as the other begins to descend. There are four levers $j' j' k' k'$ placed above the cams and operated by them, each lever being hung on a fulcrum-pin at the rear of the frame, and having a roller m which bears on the cam. The two levers $j' j'$ are connected with the ends of the trap-board b' by connecting-rods $m' m'$, that the cams $h' h'$ may communicate the required motions to it; and the

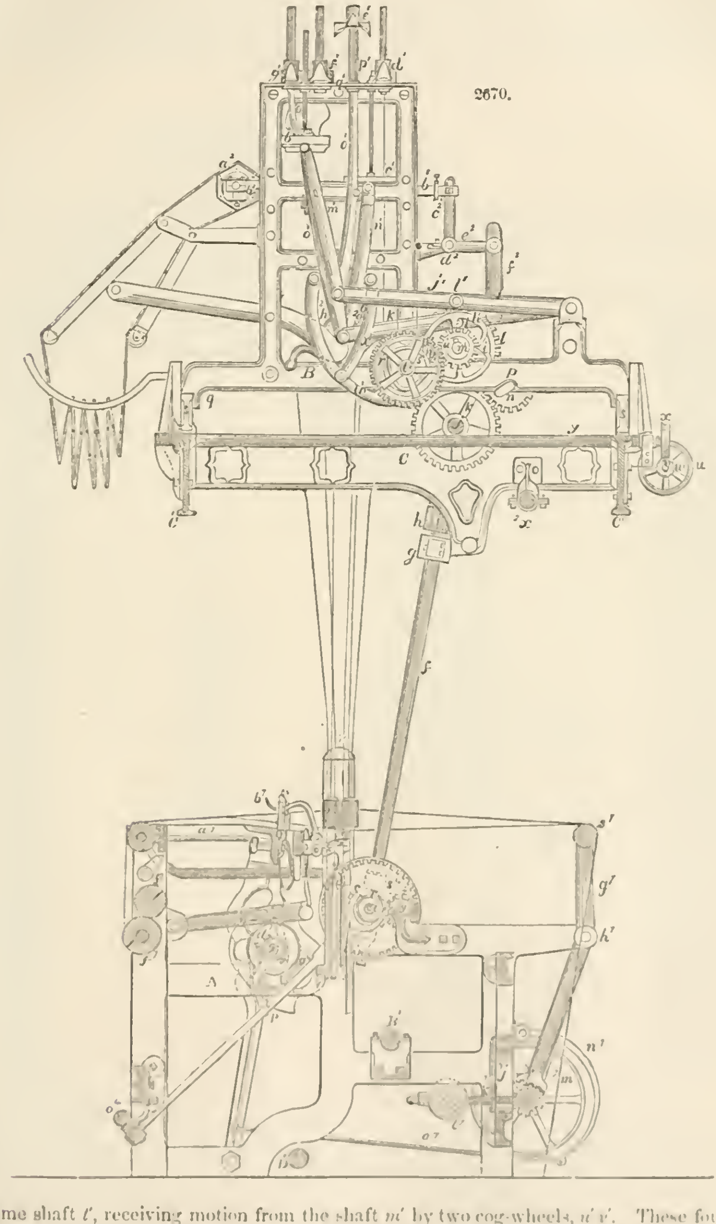
2669.



other levers $k' k'$ are in like manner and for the same purpose connected to the other trap-board c', by similar rods $n' n'$. In this way it will be perceived that the required alternate up and down motions are given to the two trap-boards. The same cams and levers are employed for operating the four journals $d' e' f' g'$. The two journals are alternately elevated with the trap-board b', and the other two $f' g'$ are in like manner operated with the other trap-board c', which is effected in the following manner: To the ends of the four levers j' and k' are jointed four rods $o' o' o' o'$, (one to the end of each,) the upper ends of which play in slots $p' p' p' p'$ in the top plate q' of the jacquard-frame—these slots being of such length that the rods can vibrate sufficiently to pass from one journal to the other. The upper ends of these rods are rounded, and enter sockets in the under face of the ends of the journals, so that when brought under either of the journals, when the levers are raised by the cams, the journals will be elevated. As there are two journals for each trap-board, and these are alternately elevated with the corresponding trap-board, the lifting-rods must be alternately shifted from the one to the other. As the rods are so jointed as to incline outwards, when vibrated they will fall, by gravity, against the outer ends of the slots p', which are so located as to hold the rods in a position to catch under the two outer journals d' ang g'.

In this position, when either of the trap-boards are elevated, one of the journals will be carried up with it; but when the other journals are to be lifted, the rods o' are to be shifted from the outside journals to the inside ones, and this is effected by cams r' r' s' s', two on each side of the frame, and on one

2670.



and the same shaft t', receiving motion from the shaft m' by two cog-wheels, u' v'. These four cams are all of the same form as represented in the plates, and arranged in two sets, one of each set being on each end of the shaft, and the position of the two sets relatively to each other will depend upon the form and position of the levers which they operate. On each side of the frame there are two levers, w' x', (the two sets corresponding in every particular, that vibrate at y' on the same arbor, the one w' of which bears by the disposition of its weight on the periphery of one of the cams r', and the other x' on one of the cams s'. The arm of each of these levers acts against one of the rods o', so that there is one such lever and cam for each rod o'; and as the shaft t' of these cams makes but one rotation for every two of the jacquard-shaft, the levers w' and x' will act upon the corresponding rods o' at every alternate descending motion of each trap-board.

The form of the cams r' and s' is such that during one rotation of the jacquard-shaft m', they elevate one set of levers w' w', to shift the two corresponding rods o' o' from one journal to the other, and during the next rotation of the jacquard-shaft they recede to permit these rods to fall back, whilst the other set of levers x' x' shift the other two rods o' o' from one to the other of the other set of journals, the next rotation liberating these and shifting the first set. In this way it will be seen that during one operation, when the trap-board c' descends, the journal g descends with it, the trap-board b' at the same time being carried up and down with the journal e'. At the end of this motion the cams r' r' throw out the levers w' w', which shift the rods o' o' to the journal f'; at the next operation the trap-board c' is

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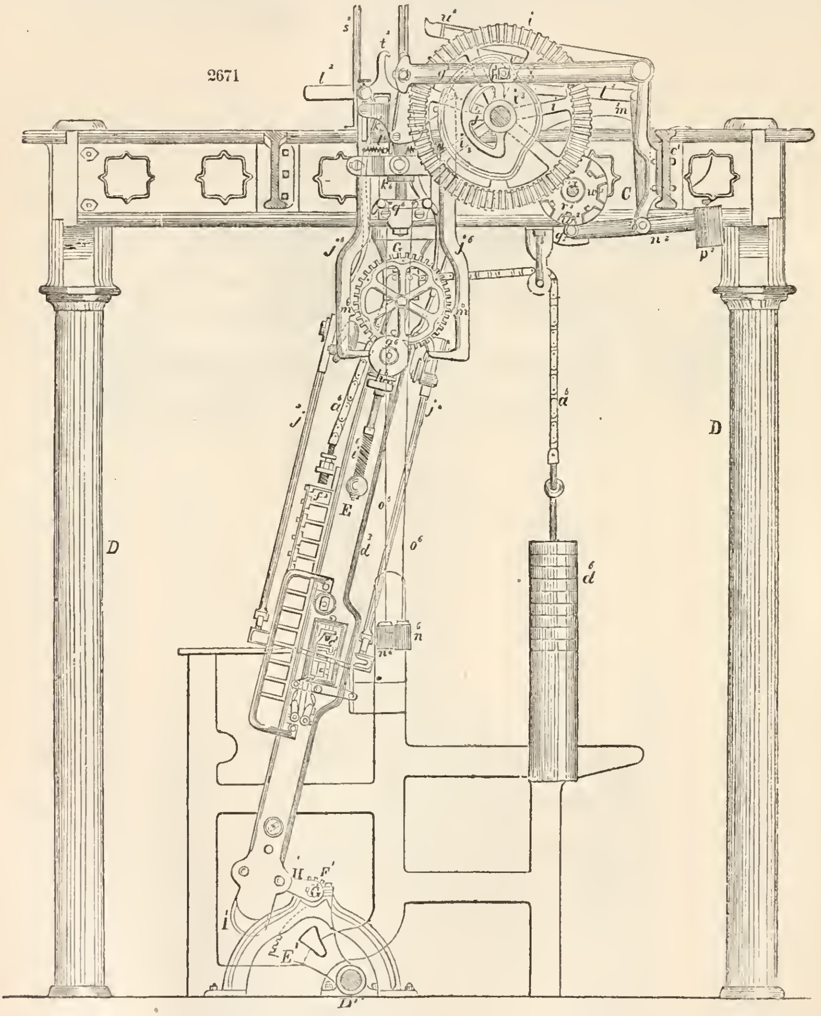


elevated, and with it the journal f', the trap-board b' at the same time descending, and with it the journal e', and when this has reached the end of its down motion, the rods o' o' continue the motion down sufficiently to clear the sockets of the journals, and then by their own weight the rods fall back to the journal d', to be ready to carry it up at the next upward motion of the trap-board b'; and when this takes place the trap-board c' descends, and with it the journal f', at the end of the down motion of which the rods o' o' fall, to come under the journal g', so that at the next upward motion of the trap-board c', this journal may be elevated, during which the trap-board b' descends, and with it the journal d'. and when this is entirely down, the cams s' s' act upon the levers x' x', which shift the rods o' o' to the journal e'. Thus the journals d' and e' are alternately carried up and down with the trab-board b' and the other two journals f and g' with the trap-board c'.

The journals of the card-prism a^2 (of the usual construction) are hung in the rods b^2 b^2, which slide horizontally on the sides of the jacquard-frame, and which at the back are jointed to two arms c^2 c^2 in a rock-shaft d^2, from which projects another arm e^2, connected by a rod f^2 with a treadle g^2 that vibrates on a fulcrum-pin at the back, its front end being provided with a weight h^2 of sufficient gravity to push out the prism, the levers being elevated to draw in the prism by a cam i^2 on the jacquard-shaft m. The form of the cam i^2, and its position relatively to the trap-board cams, must be such as to bring the prism into action while the trap-boards are at rest.

The straps k^2 k^2 k^2 k^2 of the picker-staffs $j^2 j^2$ extend up to, and are secured each to a picker-lever l^2, there being two such levers on each side, which are jointed at their back end to the upper arm m^2 of two levers n^2 n^2 that vibrate on a stud-pin o^2 attached to one of the beams C.

The levers n^2 n^2 constitute each two arms, at right angles with the arm m^2, the back one carrying a weight p^2 which must be sufficient to carry back the picker-lever l^2, and the forward end carries a roller q^2 which bears up against the periphery of a cam-wheel r^2, so that when the roller bears on the periphery of this wheel, the picker-lever is pushed and held forward to the full length of its longitudinal motion; but when, by the rotation of the wheel, the roller is permitted to enter a depression in its periphery, the picker-lever is drawn back. As stated above, and as represented in the plates, there are two picker-levers on each side, one for each picker-staff, and, therefore, two inverted T levers m^2 n^2, and one cam-wheel r^2, for each lever m^2 n^2. The forward ends of the picker-levers l^2 work between vertical guides s^2, to prevent lateral play, and they are each provided with a hook t^2, which, when the lever is drawn back, hooks into the end of the picker-treadle u^2, which is made of sufficient breadth to receive and operate the two, there being one treadle on each side, and operated at the proper periods of time by two cams v^2 v^2, one for each treadle, and placed on opposite ends of the shaft j, as before described.

Each cam has two projections opposite to each other, so as to operate the treadle twice for each rotation, and the projections of the two cams are placed in the same line, so that the two treadles are operated at the same time, and the shaft makes one rotation for every two beats of the lathe of the loom; hence the treadles are both worked once for each beat. This simultaneous working of the treadles is rendered necessary, because two shuttles have frequently to be thrown in succession from the same side. As both treadles are operated for each beat of the lathe, and there are two picker-staffs on each side, at each beat of the lathe one of the picker-levers l^2 must be put in connection with one of the treadles, whilst the other remains disconnected. This is effected by drawing back the picker-lever which is to be operated, until its hook catches into one of the treadles, and this must be done whilst the treadle is down, and at rest. The manner in which the picker-treadles are drawn back to effect the hooking on to the treadle has already been described, as also the manner of pushing them forward to carry their hooks beyond the range of motion of the treadles, and it only remains to explain how the succession is determined. This is done by means of four cam-wheels r^2, which act on the four levers n^2 m^2, as described above. These cam-wheels are formed with a series of cam-like depressions u^2 made at equal distances around the periphery, into each of which the rollers of the levers n^2 enter; and when this takes place, the weights on the levers n^2 draw the picker-levers so far back that the treadles in rising catch under the hooks and elevate the picker-levers, and the further rotation forces out the rollers from the cam-like depression on to the periphery of the circle of the wheels, which forces the picker-levers so far forward as to disengage the hooks. There must be as many of these cam-like depressions in each cam-wheel as the number of changes of shuttle required in the kind of fabric to be woven; eight being the number represented in the plates for eight changes of shuttle. To each of these depressions is fitted a block, which when put in renders the periphery of the wheel cylindrical; and when all are in, the picker-levers will not be engaged or hooked by the treadle, and hence no shuttle will be thrown; and, therefore, in setting the loom for any particular kind of fabric, the operator will leave out of each of the cam-wheels as many of these blocks, and in the order required, as may be necessary for operating the picker-staffs in the order required for the succession of the shuttles. The four cam-wheels r^2 are on a shaft x^2, parallel with, and receiving motion from the shaft j, by a cog-wheel and pinion y^2 z^2, the shaft x^2 making one rotation for four of the shaft j. The plates represent the back, or receiving shuttle-boxes c^3 c^3, as consisting of two on each side, although for some kinds of fabrics but one is required, in which case they are not required to be operated in the pendulous frames. When the two are used on each side, they are adapted to slide in the back of the pendulous frames, and are suspended each to one end of a lever b^3, by a connecting-rod d^3, the rear end of the said levers being provided with a sufficient weight e^3 to lift the boxes, in order to bring the lower box of the series in line with the race-beam of the lathe; and when the upper box is to be let down to receive a shuttle, the weighted end of the lever is elevated by a cam a^3 on the end of the shaft x^2, before described as carrying the cams to determine the succession of the motions of the picker-staffs. The form of the cams a^3 will of course depend on the pattern to be woven, and as they are on the ends of the shaft, they can be removed and other cams of different forms substituted. The front series of shuttle-boxes f^3 f^3 are represented as consisting of twelve shuttle boxes on each side, adapted to work patterns requiring twenty four shuttles. As the two series are operated in like manner, it is only necessary to describe one series.

These shuttle boxes f^3 are all connected together, and slide in the front of the pendulous frame, and are suspended to a chain a^6 that is attached to and winds on a barrel b^6 on the arbor F of the pendulous frame; and this arbor carries another barrel, on which winds another chain c^6 that passes over a guide pulley, and has a counter-weight d^6 suspended to it to counterbalance the shuttle-boxes, the weight being made in sections, that it may be regulated to suit the number of shuttles employed. As the shuttle-boxes are connected with the arbor F, it will be obvious that their weight will carry them down, when permitted so to do by the turning of the arbor in one direction, and that they will be lifted when the arbor is turned in the reverse direction. On the inner end of the said arbor there is a cog-wheel e^6, the cogs of which engage a pinion f^6 of one sixth its diameter, which has attached to its face a wheel g^6 with a portion of its periphery cut off, against which bears a stop h^6 on the end of a rod surrounded by a helical spring i^6, which forces the stop against the periphery of the wheel cut out, so that when the wheel is turned, the pressure of the stop shall have the effect to stop the wheel, to aid in bringing the parts to a state of rest in the proper position, and there hold them. The wheel e^6 has six pins projecting from its inner face, at equal distances apart, and so proportioned that the turning of the wheel the distance of one of these pins shall shift the shuttle-boxes to a distance required for one change. There are two rods $j^6 j^6$, one on each side of the axis of the wheel e^6, and so far apart that when thrown out they will not touch the pins on the wheel. These rods are jointed to a sliding-frame k^6 above, adapted to work on a guide-rod, and suspended to a lever g^3 that carries a roller h^3 working in a cam-groove i^3 on the shaft j^2, which makes two revolutions to each beat of the lathe, so that the lever and rods j^6 will be carried up and down every alternate beat of the lathe; and there being a similar arrangement on each side of the loom, with the cams placed on opposite sides of the axis, one set will be worked for each beat of the lathe. The rods $j^6 j^6$ before described, are drawn together by a helical spring l^6 to bring their inner edges against the pins of the wheel e^6. Their inner edges are formed each with a hook m^6, so that when drawn up the hooks catch under the pins to turn the wheel; and as the two rods are on opposite sides of the axis of the wheel, the wheel can be turned in either direction if the appropriate hook be brought in the required position. The manner in which the rods are drawn inwards has been pointed out. They are kept out so that their hooks shall not engage the pins as they are moved up and down at each operation, by means of weights $n^6 n^6$ (represented by dotted lines) suspended to cards $o^6 o^6$ attached to levers $q^6 q^6$, which by the force of the weights are made to bear against the inner faces of the said rods j^6, and to overcome the tension of the spring which tends to draw them in. The weights $n^6 n^6$ are connected each to one of the cards (not represented) of the jacquard, so that when either weight is lifted by the jacquard, the corresponding rod j^6 will be drawn inwards by its spring, and hence, when drawn up by the rotation of the cam, as before described, its hook will catch under one of the pins and turn the wheel, and hence shift the shuttle-boxes. As these movements are very quick, and it is important that the shifting motion be accurate, the two rods are bent in at their lower ends to such an extent, that when drawn up, with the hook of one turning the wheel at the required extent of motion, the said bent projection of the other comes in contact with another one of the pins on the wheel, and thus effectually stops the movements. In this way it will be seen that by the punching of the cards that operate the needles connected with the cards that control the weights to disengage the hooks, the shuttles can be shifted to suit any variety of changes of color in the pattern.

The connection between the frames that carry the hook-rods $j^6 j^6$ and the levers operated by the cams to give the shuttle-motions, is by means of spring-gripes, which hold by friction surface, so that in case of an imperfect throw of a shuttle, or any other impediment, the connections will yield instead of breaking. This is effected in the rear or receiving shuttle-boxes by the weighted lever, which is sufficient to move the boxes, but not to strain the parts in case of any impediment.

When a shuttle enters either of the boxes, it is arrested in part by its point striking against the picker, which soon becomes so indented as to permit the point of the shuttle to lodge therein, and therefore it will be seen that in this condition of the parts the shuttle-boxes could not be shifted, or rather would be seriously impeded, for the shuttle being in the box which is to rise, and its point imbedded in the picker, which does not move up, the parts would thus be held or strained. To prevent this, at the time the shuttle enters a box the picker is forced inwards by a lever r^6, which is afterwards drawn back to permit the picker to be drawn back clear of the point of the shuttle by the spring of the picker-staff. There are four such levers r^4, one for each series of shuttle-boxes; they turn on fulcrum-pins on the pendulous frames, and at their lower ends carry wrist-pins that work in cam-grooves on wheels s that turn on stud-pins on the lower ends of the pendulous frames, and from each of these wheels extends an arm t^6 with a slot near the end, playing on a pin u^6 attached to the floor, so that as the pendulous frame vibrates, the required vibratory motion shall be given to the cam-groove wheels One such cam-groove wheel answers for two levers, as shown in the plates.

The warps pass from the warp-beam below the floor, and pass over a roller e^7 above the warp-beam, and thence through the mails of the trap-cards in the usual manner of mounting a jacquard loom. The woven cloth from the breast-beam passes between two rollers $f^7 f^7$, one of which is weighted to make pressure against the other, that the cloth may be gripped between the two with sufficient force to prevent it from slipping. And thence the cloth is wound upon the cloth-beam, (not represented,) which is driven by a friction-strap with sufficient velocity to take up the slack, the band slipping on the pulley when the diameter of the beam becomes so large as to tend to wind on the cloth faster than it is carried forward by the two rollers $f^7 f^7$, which constitute what is called a positive take-up motion, and which receive the same motion for each beat of the lathe, that the same length of cloth may be taken up for each operation of the loom, and thus measure the figure to be produced on the cloth. As the mechanism for giving this regular and positive take-up motion to the rollers was not invented by Mr. Bigelow, but was previously well known to weavers, it is deemed unnecessary to give a description of it here.

The mode of operating the yarn-beam is not represented, but it will be understood with sufficient clearness from the description alone.

On the shaft of the yarn-beam there is a cog-wheel operated by a worm on a vertical shaft, which carries a crown ratchet-wheel, the teeth of which are engaged by a pall, or ratchet-hand, on the end of a rod jointed to the sword of the lathe, so that as the lathe beats back, by the connections described, the ratchet-wheel is turned a given portion of a revolution, which shall be sufficient to give out the required quantity of warp-threads for any one operation of the loom. But as the diameter of the beam is constantly varying, beginning with a large diameter, and gradually diminishing as the warps are given out, and the demand for warps is constantly varying, by reason of the irregularities of the weft-threads and the ingraining of the fabric, the regular and positive motion of the warp-beam given by the mechanism requires to be varied to suit the varying conditions above described. This, as before intimated, is governed by the tension of the warps between the beam and the woven cloth. The roller e^7 over which the warps pass from the warp-beam is hung in the upper ends of two levers $g^7 g^7$ which have their fulcra at h^7; and the lower arms of these levers are formed in sector-racks i^7, the cogs of which engage pinions j^7 on the ends of a shaft, and this shaft is provided with an arm which carries a weight l^7, which, by the connections of the pinions and sector-racks, tends always to force back the roller e^7 to keep the warps under the same, or nearly the same tension. This weight is adjustable on the arm by a set-screw, to regulate the degree of tension, to suit the quality of the warps and the fabric to be produced. From this it will be seen not only that the warps will be always kept under the same degree of tension during the operation of weaving, a condition very essential to the production of a fabric of regular texture, but if the quantity of warps given out by the warp-beam be greater than the quantity taken up in weaving, the roller will be carried back by the weight, and that when the quantity is less than enough, the roller will be drawn forward. This motion of the roller is made use of to regulate the motion of the warp-beam in the following manner: On the shaft before described there is another arm, to which is jointed one end of a connecting-rod, the other end of which is in turn jointed to an arm which turns on the arbor just above the ratchet-wheel, and this arm carries a plate that rests on the face of the ratchet-wheel, so that when the roller is carried back by the action of the weight when the supply of warps is too great, the shaft is turned in one direction, which, by the connection described, carries the plate so far over the surface of the ratchet-wheel as to cover all, or only a portion of the teeth which would otherwise have been engaged by the band, and hence the let-off motion of the warp-beam is either entirely or partly prevented; and when, on the other hand, the roller is drawn forward by the amount of warps given being insufficient, the plate is drawn back, which permits the band to engage the teeth of the ratchet, and to operate the warp-beam, to give out the required quantity of warps. In this way the supply of warps is proportioned to the demand, and the cloth being taken up by a positive and measured quantity at each operation, it follows that the irregularities will be thrown into the thickness instead of the length of the cloth, and hence the figures will be produced of a regular and measured length, whatever may be the irregularities of the weft-threads and the ingraining.

But there is still another condition which is important to be observed. The roller e^7 must be sufficiently sensitive to yield to the tension of the warps under the force of the weight suspended to the arm of the shaft connected with the levers that carry the roller; and hence, when the lathe beats up the weft-threads, it would yield to the force of the beat, particularly in weaving fabrics of a close texture, which motion would have the effect to prevent the full action of the reed, and cause the cloth of loose texture to lay up in front of the reed, and in a short time impede the proper working of the loom. To prevent this, the shaft carries a wheel m^7, and around a portion of its circumference passes a friction-brake, n^7; that is, a metal strap jointed to the frame and to a connecting-rod o^7, attached to the sward of the lathe, so that when the lathe beats up, this metal strap is drawn in contact with the periphery of the wheel, and thus by friction holds it firmly so that it cannot turn, by the connections holding the roller firmly, that the warps may be prevented from yielding to the force of the beat of the lathe. In this way the desired effect is produced; viz., that of producing a close fabric of regular texture and measured figure, with the irregularities thrown into the thickness instead of the length of the cloth.

So soon as the shuttle has been thrown the weft-thread lies between the warps in a diagonal line from the selvage on one side to the shuttle-box on the other, and this diagonal line being longer than the breadth of the cloth, it is evident that if the weft-thread were beaten up freely, it would become loose and produce a bad selvage. To prevent this, the sides of the frame at a^7 constitute a bed on each side, grooved to receive a series of fingers b^7, jointed to the frame, and the moment the shuttle has passed a cam d^7, on the lathe-shaft, permits the fingers to fall on to, and gripe the weft-thread, so that when it is carried forward by the reed it is resisted by the pressure of the fingers, which gives the required pull to insure a good selvage. The cam then passes around to lift the fingers, that the shuttle may pass. These fingers are made to answer the purpose also of stopping the loom when the weft-thread has not been carried across; for then, as the fingers descend, not being held up by the weft-thread, they enter the grooves, and the arm at the back acts as catch-levers connected with the shipper to stop the loom.

The manner of operating the lathe has been described with sufficient clearness in pointing out the characteristics of this invention, and it is therefore unnecessary to give a more detailed description of it.

The belt is shifted from the loose to the fast pulley, and *vice versa*, by the belt shipper a^4, and belt-guide b^4, in the usual way; but to adapt this to the introduction of a reversing motion, the shipper and the guide are differently arranged. The shipper a^4, and the belt guide b^4, are on opposite ends of a shaft c^9, hung in appropriate boxes, and this shaft is hollow, and within it there is an arbor d^4, which extends out at each end. From the rear end of this inner arbor projects an arm e^4, which carries a wrist-pin f^4, that fits and slides freely but accurately in a curved mortise g^4, in one arm of a lever h^4, that turns on a fulcrum-pin i^4, its other arm being jointed to the connecting rod of the brake j^4, that works against the inner periphery of the fast pulley b, in the usual way of arranging the brake for arresting the operation of the loom when the belt is shifted from the fast to the loose pulley. When the inner arbor d^4 is therefore connected with the shaft of the shipper, the brake is operated to make friction on the fast pulley when the belt is shifted to the loose pulley, and liberated to relieve the friction when the belt is shifted to the fast pulley, the motion of the shipper to shift the belt from the one to the other of the pulleys being sufficient to move the arm e^4, so that its wrist f^4 shall move over a distance equal to half the length of the curved mortise in the lever of the brakes, the curve and the length of this mortise being such that moving the wrist-pin from either end of the mortise to the middle will force the brake against the pulley to make friction, and moving it from the middle towards either end will remove the brake. As I employ the loose pulley for the purpose of giving the reverse motion, it becomes necessary in the first place to stop the loom, and then to start it in the reverse direction, and therefore in shifting the belt from the fast to the loose pulley, the brake at first must be operated to make friction to arrest the parts, and then liberated whilst the mechanism of the reversed motion is brought into action. This is effected in the following manner: on the front end of the arbor d^4, when it projects beyond the hollow shipper-shaft, there is an arm g^4, which projects out towards the middle of the loom, nearly in a horizontal direction and at a convenient height to be reached by the attendant's foot. On this arm is journalled a treadle h^4, and so connected with the arm g^4, by means of a helical spring i^4, that when no force is applied to it, an arm j^4, which projects upward from its inner end, is held against a projection k^4 of the shipper, so that the arbor of the brake and the shaft of the shipper are kept in a locked condition by the helical spring i^4 to be operated together; but when pressure is applied on the top of the treadle, then the brake is operated separately to remove the friction from the pulley. When the attendant moves the shipper towards him, the belt is shifted from the fast to the loose pulley, the brake at the same time being drawn down to make friction for arresting the momentum of the moving parts, and then the attendant with his foot forces down the treadle which relieves the brake, thereby liberating the parts preparatory to the reversing motion which is brought into action by the same motion. From the bottom of the treadle projects an arm l^4, that carries a pin m^4, that plays freely in a mortise n^4, in the end of a sliding-rod o^4, and the length of this mortise is such that the motions given to the arm l^4 by the ordinary motions of the shipper will not communicate motion to the sliding-rod, but when the treadle is borne down to relieve the brake after the shifting of the belt into the loose pulley, the sliding-rod is drawn in the direction of the arrow.

The sliding-rod o^4 is jointed to the lower arm of a lever p^4, which turns on a fulcrum-pin q^4, its upper arm being forked and made to embrace the collar r^4 of a wheel s^4, which slides freely on the main driving-shaft a of the loom. When the sliding-rod o^4 is drawn in the direction of the arrow, it forces the wheel s^4 against the face of a friction-plate u^4, which is fast on the main shaft, and this friction-plate has the effect of locking it with the main shaft, so that any motion given to this wheel s^4 will drive the main shaft. The hub v^4 of the loose pulley carries a pinion w^4, which engages another pinion x^4, on a parallel shaft y^4, the other end of which has a pinion z^4, which engages cogs on the inner periphery of the wheel s^4, so that the motion of the loose pulley communicates a reversed motion to this wheel, which drives the main shaft in the reversed direction whenever they are locked together by the friction-plate.

The moment the attendant removes his foot from the treadle, the wheel is withdrawn from the friction-plate by the tension of a helical spring a^5, on the slide-rod o^4, and the parts are then in a condition for starting the loom by the shifting of the belt on to the fast pulley.*

MACHINES are instruments employed to regulate motion, so as to save either time or force.

The maximum effect of machines is the greatest effect which can be produced by them. In all machines that work with a uniform motion there is a certain velocity, and a certain load of resistance, that yields the greatest effect, and which are therefore more advantageons than any other. A machine may be so heavily charged that the motion resulting from the application of any given power will be but just sufficient to overcome it, and if any motion ensue it will be very trifling, and therefore the whole effect very small. And if the machine is very lightly loaded, it may give great velocity to the load; but from the smallness of its quantity the effect may still be very inconsiderable, consequently between these two loads there must be some intermediate one that will render the effect the greatest possible. This is equally true in the application of animal strength as in machines.†

1. The maximum effect of a machine is produced when the weight or resistance to be overcome is four-ninths of that which the power, when fully exerted, is able to balance, or of that resistance which is necessary to reduce the machine to rest; and the velocity of the part of the machine to which the power is applied should be one-third of the greatest velocity of the power.

2. The moving power and the resistance being both given, if the machine be so constructed that the velocity of the point to which the power is applied be to the velocity of the point to which the resistance is applied, as four times the resistance to nine times the power, the machine will work to the greatest possible advantage.

3. This is equally true when applied to the strength of animals; that is, a man, horse, or other animal will do the greatest quantity of work, by continued labor, when his strength is opposed to a resistance equal to four-ninths of his natural strength, and his velocity equal to one-third of his greatest velocity when not impeded.

Now, according to the best observations, the force of a man at rest is, on an average, about 70 lbs.; and his greatest velocity, when not impeded, is about 6 feet per second, taken at a medium. Hence the greatest effect will be produced when the resistance is equal to about 31 1-9th pounds, and his uniform motion 2 feet per second.

The strength of a horse at a dead pull is generally estimated at about 420 pounds, and his greatest

* The history of the invention of this machine is so full of instruction to the young mechanic, and the facts of the case coming entirely within our own knowledge, we have been induced to dwell upon them, although by so doing we have departed somewhat from the original plan of the Dictionary, which would confine all description to the machines themselves.

† These conditions are deduced from the following empirical expression, which is adopted by Euler and other writers, to represent the law of the moving power: Let P = the power applied, (or weight which the power, when fully exerted, is just able to overcome;) R = the resistance, or load, or weight to be overcome; c the greatest velocity, or that at which the power ceases to act; v = any other velocity: then the law of the moving power is

$$R = P\left(1 - \frac{v}{c}\right)^2$$

The variables in this expression are R and v, and the effect is represented by the product R v; on making which a maximum, the rules of the differential calculus give $v = \frac{1}{3}c$; whence the formula becomes $R = \frac{4}{9}P$.

From these expressions it follows, that when the moving power and the resistance are both given, if a machine be so constructed that the velocity of the part to which the power is applied is to the velocity of the part to which the resistance is applied in the ratio of 9 R to 4 P, the effect of the machine will be a maximum, or it will work to the greatest possible advantage. The above conditions apply equally to machines impelled by animal force and the agents of nature, as running water, steam, the force of gravity, &c. An animal exerts itself to the greatest advantage, or performs the greatest quantity of work in the least time, when it moves with about one-third of the utmost speed with which it is capable of moving, and is loaded with four-ninths of the greatest load which it is capable of putting in motion.

rate of walking 10 feet per second; therefore the greatest effect is produced when the load = $186\frac{2}{3}$ pounds, and the velocity $\frac{10}{3}$, or $3\frac{1}{3}$ feet per second.

4. A machine driven by the impulse of a stream produces the greatest effect when the wheel moves with one-third of the velocity of the water.

The following may be taken as a general arrangement of machines:

Class I.—*Machines for overcoming inertia.*

Machines for raising weights.
Machines for transporting weights on land.
Machines for raising water.
Blowing machines.
Machinery for ascending and descending in fluids.
Machines for navigation, &c.

Class II.—*Machines for overcoming cohesion.*

Ploughs.
Drilling machines.
Reaping machines.
Threshing machines.
Mills.
Boring machines.
Cutting machines.
Machines for cleaning, or removing impurities.
Grinding machines.
Machines for turning.
Machines which act by compression.
Pile engines, &c.

Class III.—*Machines for combining materials.*

Machines for weaving cloths, carpets, nets, stockings.
Machine for combining materials in brewing, &c.

Class IV.—*Machines for measuring forces.*

Anemometers.
Torsion machines.
Balances and steelyards.
Barometers.
Thermometers.
Hygrometers.
Machines for measuring the elasticity and strength of materials.
Dynamometers for measuring the force of men, animals, and other agents.
Machines for measuring the force of projectiles.
Machines for measuring the force of running water.

Class V.—*Machines for measuring and dividing space.*

Quadrants.
Circles.
Theodolites.
Levels.
Micrometers.
Goniometers.
Dividing machines.
Odometers.
Drawing and copying instruments.

Class VI.—*Machines for measuring time.*

Machinery.—The utility of machinery, in its application to manufactures, consists in the addition which it makes to human power, the economy of human time, and in the conversion of substances apparently worthless into valuable products. The forces derived from wind, from water, and from steam, are so many additions to human power. The difference between a tool and a machine is not capable of very precise distinction, nor is it necessary, in a popular examination of them, to make any distinction. A tool is usually a more simple machine, and generally used by the hand; a machine is a complex tool, a collection of tools, and frequently put in action by inanimate force. All machines are intended to transmit power. Of the class of mechanical agents by which motion is transmitted—the lever, the pulley, the wedge—it has been demonstrated that no power is gained by their use, however combined. Whatever force is applied at one part can only be exerted at some other, diminished by friction and other incidental causes; and whatever is gained in the rapidity of execution, is compensated by the necessity of exerting additional force. These two principles should be constantly borne in mind, and teach us to limit our attempts to things which are possible.

1. *Accumulating power.*—When the work to be done requires more force for its execution than can be generated in the time necessary for its completion, recourse must be had to some mechanical method of preserving and condensing a part of the power exerted previously to the commencement of the process. This is most frequently accomplished by a fly-wheel, which is a wheel having a heavy rim, so that the greater part of the weight is near the circumference. It requires great power, applied for some time, to set this in rapid motion; and when moving with considerable velocity, if its force is concentrated on a point, its effects are exceedingly powerful.

2. *Regulating power.*—Uniformity and steadiness in the motion of the machinery are essential both to its success and its duration. The governor, in the steam-engine, is a contrivance for this purpose. A vane or fly, of little weight, but large surface, is also used. It revolves rapidly, and soon acquires a uniform rate, which it cannot much exceed; because any addition to its velocity produces a greater addition to the resistance of the air. This kind of fly is generally used in small pieces of mechanism, and, unlike the heavy fly, it serves to destroy instead of to preserve force.

3. *Increase of velocity.*—Operations requiring a trifling exertion of force may become fatiguing by the rapidity of motion necessary, or a degree of rapidity may be desirable beyond the power of muscular action. Whenever the work itself is light, it becomes necessary to increase the velocity in order to economize time. Thus, twisting the fibres of wool by the fingers would be a most tedious operation. In the common spinning-wheel, the velocity of the foot is moderate, but, by a simple contrivance, that of the thread is most rapid.

4. *Diminution of velocity.*—This is commonly required for the purpose of overcoming great resistances with small power. Systems of pulleys afford an example of this.

5. *Spreading the action of a force exerted for a few minutes over a large time.*—This is one of the most common and useful employments of machinery. The half-minute which we spend daily in winding up our watches is an exertion of force which, by the aid of a few wheels, is spread over 24 hours.

6. *Saving time in natural operations.*—The process of tanning consists in combining the tanning principle with every particle of the skin, which, by the ordinary process of soaking it in a solution of the tanning matter, requires from six months to two years. By inclosing the solution, with the hide, in a close vessel, and exhausting the air, the pores of the hide being deprived of air, exert a capillary attraction on the tan, which may be aided by pressure, so that the thickest hides may be tanned in six weeks. The operation of bleaching affords another example.

7. *Exerting forces too large for human power.*—When the force of large bodies of men or animals is applied, it becomes difficult to concentrate it simultaneously at a given point. The power of steam, air, or water, is employed to overcome resistances which would require a great expense to surmount by animal labor. The twisting of the largest cables, the rolling, hammering, and cutting of large masses of iron, the draining of mines, require enormous exertions of physical force, continued for considerable periods.

8. *Executing operations too delicate for human touch.*—The same power which twists the stoutest cable and weaves the coarsest canvas may be employed, to more advantage than human hands, in spinning the gossamer thread of the cotton, and entwining the meshes of the most delicate fabric.

9. *Registering operations.*—Machinery affords a sure means of remedying the inattention of human agents, by instruments, for instance, for counting the strokes of an engine, or the number of coins struck in a press.

10. *Economy of materials.*—The precision with which all operations are executed by machinery, and the exact similarity of the articles made, produce a degree of economy in the consumption of the raw material which is sometimes of great importance.

11. *The identity of the result.*—Nothing is more remarkable than the perfect similarity of things manufactured by the same tool. This result appears in all the arts of printing: the impressions from the same block, or the same copper-plate, have a similarity which no labor of the hand could produce.

12. *Accuracy of the work.*—The accuracy with which machinery executes its work is, perhaps, one of its most important advantages. It would hardly be possible for a very skilful workman, with files and polishing substances, to form a perfect cylinder out of a piece of steel. This process, by the aid of the lathe and the sliding-rest, is the every-day employment of hundreds of workmen.

Machines are classed under different denominations, according to the agents by which they are put in motion, the purposes they are intended to effect, or the art in which they are employed.

The reader is referred to the various machines, under their respective heads.

MAGNET—MAGNETISM. The magnesian stone, or *native* magnet, abounds in various parts of the earth, especially in iron mines, where it is found massive, frequently crystallized, and occasionally in beds of considerable thickness. Its constituents are, for the most part, oxygen and iron under the form of two oxides, the black and red. In 100 parts, we have about 73 parts iron and 27 oxygen: it has been termed *magnetic iron ore.* Its color varies from a reddish black to a deep gray. Native magnets from Arabia, China, and Bengal are commonly of a reddish color, and are powerfully attractive Those found in Germany and England have the color of unwrought iron.

The specific gravity of magnetic iron ore is about $4\frac{1}{2}$ times that of water, and affords, when worked, excellent bar-iron.

This remarkable substance has not only the power of drawing apparently towards itself small particles of iron, but it has also the important property of communicating or propagating, as it were, its own attractive power through a series of masses, so as to cause them to hang one on another in a sort of linked chain.

If the magnet be suspended by a delicate silk line from some point between the surfaces of attraction, so as to admit of its turning freely on that point, the mass will rest only in one position: this position will be such as to place its poles either in the line of the meridian, or very near it; one of the surfaces of the mass will have turned towards the north, and the opposite surface towards the south, and, if drawn aside from this position, will continue to vibrate backwards and forwards until it again rests in the same position.

The attractive force of the loadstone or natural magnet cannot generally be considered as of any great amount. Native magnets in their rude state will seldom lift their own weight, and, with some rare exceptions, their power is limited to a few pounds.

The effective power of the loadstone may be considerably improved by means of what is termed an *armature,* which consists of small pieces of very soft iron applied to the opposite polar surfaces of the stone, and projecting a little below it on each side. The attractive force is thus transmitted to the small projecting or artificial poles of iron; this is found not only to augment the power, but also to enable the experimentalist to bring both the poles to bear upon any given mass at the same instant.

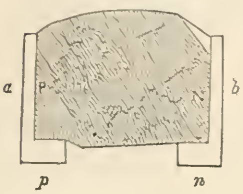
The pieces intended for the armature should be made of very soft iron, and each formed with a vertical face about $\frac{1}{8}$th to $\frac{1}{4}$th of an inch thick, with a projecting solid foot below, as at *a p* and *b n*, Fig. 2672; the vertical face being closely applied to the polar surfaces, and the mass allowed to rest on the projecting feet *p n*, forming the artificial poles. Things being thus arranged, the whole is bound firmly together by a cap of silver or brass, or by plain metallic bands, as represented in A B and C D, Fig. 2673. A ring R is usually fixed in the upper part of the cap for the convenience of raising the whole mass, and a transverse piece of soft iron K, termed a keeper or lifter, furnished with a central hook G, is placed across the artificial poles *p n*, so as to unite them. This keeper is found to preserve and increase the attractive force of the poles, especially if the magnet be suspended by its upper ring R, and weights be attached to the hook G, and by which its power may be roughly estimated.

If the armed magnet be thus suspended, and a small scale-pan attached to the keeper K, an additional weight may be added daily for a considerable time: the loadstone thus armed may be caused to sustain from twenty to thirty times its own weight.

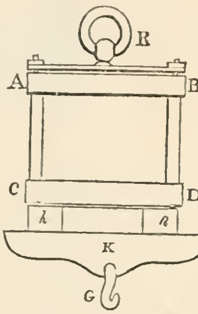
When an armed loadstone is employed for particular experimental inquiries or other purposes, the keeper K may be removed, but it should be replaced when the magnet is not in use.

If we suspend a magnet by a fine silk fibre over another magnet, or near another magnet also suspended, the poles of these magnets will arrange themselves in such a way as to bring the opposite poles together; the similar poles are found so powerfully and reciprocally repulsive, as not to allow the masses to rest with their similar poles in juxtaposition.

2672.



2673.



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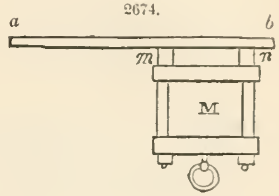


Pieces of common iron, which have been for a great length of time in one fixed position, or underground, acquire considerable polarity—in fact, become magnets. In the "Memoirs of the Academy of Sciences" for 1731, we find an account of a large bell at Marseilles having an axis of iron: this axis rested on stone blocks, and threw off from time to time great quantities of rust, which, mixing with the particles of stone and the oil used to facilitate the motion, became conglomerated into a hardened mass: this mass had all the properties of the native magnet. The bell is supposed to have been in the same position for 400 years.

The artificial magnet.—To make an artificial magnet, procure a small bar of steel about 8 inches in length, $\frac{1}{4}$th of an inch wide, and $\frac{1}{8}$th of an inch thick, or a piece of common steel wire of about the same length, and from $\frac{1}{8}$th to $\frac{1}{4}$th of an inch in diameter. Let the steel be well hardened and tempered by plunging it at a cherry-red heat into cold water; when cold and polished, apply each extremity in succession to the opposite poles of an armed magnet, Fig. 2672, first touching with gentle friction one extremity of the bar, or one of the poles and the opposite extremity on the other pole, or, which is better, draw the bar *a b*, Fig. 2674, a few times, in the direction of its length, across the two poles *m n* of the magnet M, as represented in the figure, and in such a way as not to pass either extremity, *a b*, beyond or off the opposite poles *m n*; finally, bring the bar *a b* so as to rest with its extremity *a b* equally distant from each pole *m n*; that is to say, bring the poles *m n* at the centre of the bar, or as nearly as may be. In this position remove the bar from the poles. The bar will now be found attractive of particles of iron, common steel needles, and other ferruginous matter: when suspended it will arrange itself in the direction of the magnetic meridian, and will, in fact, have all the properties of the loadstone, including the important property of imparting or exciting a magnetic condition in tempered steel.

Take a small bar of steel which has been rendered magnetic by the process just described, apply it with slight friction to a piece of hard steel wire or a similar bar, and in such way that the opposite extremities of each bar may have contact attended by a slight degree of friction: this second bar or wire will be found also to have acquired a similar magnetic condition to the first; and this process may be continued from the second to a third wire of steel, and so on without limit.

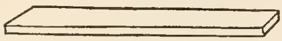
The propagation of magnetism from one bar of steel to another, as illustrated in this experiment, enables the experimentalist to obtain artificial magnets to any given amount; and since the form and magnitude of the steel has not been found to interfere with the generality of the result, we are further enabled to obtain magnets of any required figure or magnitude.

It is to be especially observed that the polarities excited in the opposite portions of a steel bar by this artificial process of magnetizing are the reverse of those of the magnetic poles to which these portions have been applied. Thus in Fig. 2674, if the extremity *b* of the steel *a b* rest on the north, or positive pole *n* of the magnet M, the polarity induced in that extremity *b* will be a south or negative polarity. Reciprocally, if the extremity *a* be brought to rest on the negative or south pole *m*, then the polarity induced in that point of the steel will be a positive or north polarity.

Artificial magnets may be of any required form, or of almost any dimensions, according to the particular views of the experimentalist: for general purposes they are limited to straight bars, such as represented in Fig. 2675, or otherwise to bars bent into a curvilinear form, resembling a horse-shoe, as in Fig. 2676; the branches *c p* and *c n* being longer, and the extremities *p n* nearer than in the common horse-shoe. Many such bars, either straight or curved, form, when combined, what is termed a *compound magnet*, such, for example, as that represented in Figs. 2677 and 2678. The combination of several compound magnets with projecting armatures constitutes a *magnetic battery* or *machine*. The dimensions well adapted to magnetic bars, either straight or curved, are such as to give the breadth about $\frac{1}{14}$th or $\frac{1}{15}$th of the length, and the thickness something less, or not exceeding one half of the breadth.

To magnetize a bar of tempered steel, Fig. 2676, curved into the horse-shoe form, fix the bar, Fig 2679, on a flat board, with its extremities, *p s*, against a straight piece of soft iron, *p s*, of the same thickness and width as the bar. Having secured the whole in this position, place a compound magnet M, or an armed native magnet, on one of the extremities *s*, of the curved bar, taking care that the opposite or marked and unmarked ends are in contact with each other. Continue as before to glide the magnet M several times round the whole series, and in the same direction, *s c p*, finally stopping in the

2675.



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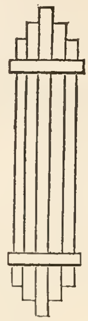

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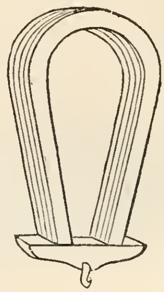

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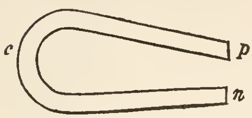
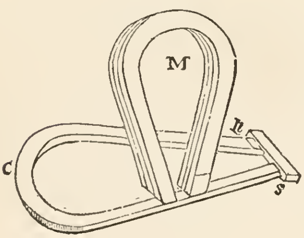


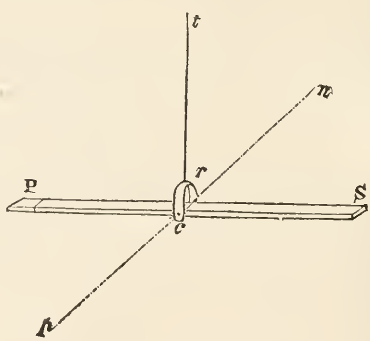
centre, *c*. Repeat this process on each face of the bar, when a high degree of power will have become developed; so much so, that the iron or keeper *p s* cannot be directly pulled away without considerable force, and in some instances cannot be conveniently removed except by sliding it off.

In order to preserve effectually the magnetism thus excited in bars of steel, it is requisite, when not in use, to keep their opposite poles united by means of pieces of soft iron.

2679.



2680.



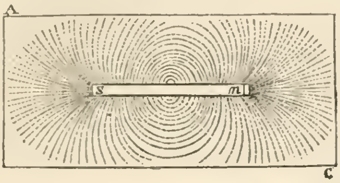
Take a perfectly straight and even bar of steel, P S, Fig. 2680, sufficiently hard to retain a magnetic state. It may be 7 inches long, $\frac{1}{8}$th of an inch wide, and $\frac{1}{10}$th of an inch thick. Drill a clean hole through the centre of the wide surface, and then pass an extremely fine drill also through the centre transversely to this hole, across the thickness of the bar, edgewise, and so accurately as to pass through the centre of gravity of the mass, or as nearly as possible; proceed now to complete the equilibrium of the bar upon a fine needle as an axis, and in such a way as to render it indifferent as to position in a vertical plane or nearly so, and that whether it be placed with one or the other face uppermost. Let the bar be now magnetized, and then mounted on its central axis; run the axis through a small silver stirrup *c r*, and suspend the whole by a fine silk fibre *r t*, attached to a fixed point *t*; the bar P S will be observed gradually to assume a definite and oblique position, *p n*, inclining in these latitudes its north pole, P, nearly 70 degrees below the horizontal line, turning at the same time into a plane deviating from the plane of the meridian by a given angular quantity, called "the dip," the lower extremity having turned towards the north, and the other extremity towards the south; and it may be likewise observed, on the principle already stated, that the extremities which have thus turned, the one towards the north and the other towards the south, will have been derived from the opposite poles of the loadstone or magnet by which it has been magnetized.

The position of the magnetic centre and poles of each surface, together with the general magnetic condition of the bar, and the reciprocal attractions, repulsions, and neutralization of the opposite forces, may be shown in the following way.

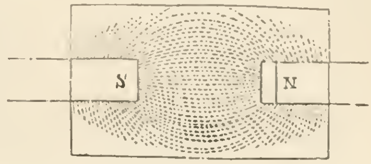
Strain a piece of common drawing-paper on an open frame, A C, Fig. 2681, and place it over a hard steel bar S N, regularly and powerfully magnetic; project on the paper over the bar, through a small muslin or lawn sieve, some fine iron dust or filings; the particles will arrange themselves in a series of curved lines of magnetic force proceeding from homologous or similar points on each side of the middle of the bar, some uniting about the magnetic centre, others standing out at the extremities as if repelled from the poles N S, and tending to turn at considerable distances into other curved lines of force, to unite their branches between the opposite poles. This experiment may be rendered more decisive by slightly tapping the finger on the paper, so as to give the particles a little vibration.

Oppose the dissimilar poles S N, Fig. 2681½, of two powerful bars to each other at about two inches

2681.



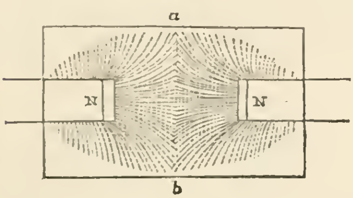
2681½.



distance, and project over them fine iron filings as before; similar results ensue. Magnetic lines of force, both straight and curved, and proceeding from similar points of each bar, will be apparent, uniting the two poles by chains of reciprocal attraction.

Change the position of one of the bars, so as to oppose two similar poles N N, Fig. 2682; the lines of force will then appear to be conflicting lines; the repulsive forces will cause a straight line *a b* to appear on the open space or field between the poles, from which the iron dust stands out transversely. At this line, the opposed forces on either side are apparently struggling with each other, being exerted in repulsive directions from the opposed poles.

2682.



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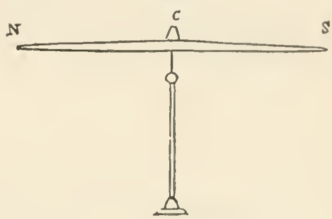


We have in these phenomena satisfactory visual evidence of the existence of two distinct forces—of their reciprocal attractions and repulsions, and their mutual neutralization.

A light magnetic bar N S, Fig. 2683, or a small magnetic steel cylinder, of great comparative length, has been termed a *magnetic needle.* When delicately poised on a central point *c*, so as to retain a horizontal position, and move freely in a horizontal plane, it has been termed the *horizontal needle.* When poised on a fine central axis, so as to move freely in a vertical plane, it has been termed a *vertical* or *dipping needle.* If suspended as in Fig. 2683, so as to have motion in both a horizontal and vertical plane, it has been termed the *horizontal and vertical needle.*

Instruments for ascertaining whether a substance has polarity or not, and for detecting the presence and kind of force in operation, have been termed *magnetoscopes.* The most simple kind of magnetoscope is a small horizontal needle, about an inch in length, delicately suspended by a fine silk fibre, or otherwise set upon a fine point and agate centre, within a small wood or glass case, as represented in Fig. 2684, and so set as to admit of some degree of dip or depression of either pole, as well as a perfect motion in a horizontal plane. From the attractive and repulsive forces of similar and dissimilar poles it is evident, from the kind of effect produced on the poles of the magnetoscope, we may always determine the presence or kind of polarity acting on it. Thus, if such an instrument as that just described, be glided along the surface of any given substance without any attractive or repulsive effect being apparent, such a substance may be considered as non-magnetic. If, on the contrary, we find both poles of the instrument everywhere attracted indifferently, then we may infer that the substance is a magnetic substance: such would be the case with a piece of common soft iron. Should we find certain points attractive of one of the poles of the small needle, and repulsive of the other, then we may infer that not only is the substance a magnetic substance, but that it has also polarity, or is a magnet.

2684.

Magnetic influence or induction.—When a piece of soft iron is brought into contact with a magnetic pole, it immediately acquires an attractive power, as if the magnetism of the pole had spread out and pervaded the iron. In fact, if we examine a piece of iron thus circumstanced by means of the magnetoscope, we find the same polarity continued throughout the iron; it will everywhere attract one pole of the magnetoscope, and repulse the opposite pole. If, however, we separate the iron from the magnet, and retain it at a short distance from the magnetic pole, then a new case appears to arise: that portion of the iron next the magnet will have an opposite polarity to that of the pole to which it is opposed; the two magnetic elements resident in the iron will, in fact, become separated; one of them will be sensible at the extremity next the magnet, and the other at its distant extremity: a result which we might expect to follow from the repulsion of the similar elements and the attraction of the opposite elements. This separation of the latent magnetism of the iron into its constituent elements has been termed *magnetic induction.* It is altogether a temporary state or condition of the iron sustained by the influence of a magnetic pole, and vanishes so soon as that influence is withdrawn.

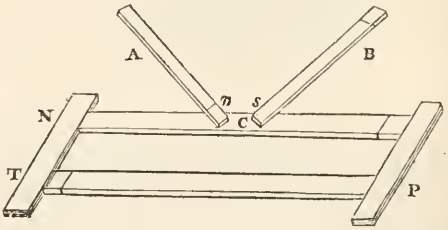
In the communication of magnetism by the loadstone to hardened steel, and from one piece of steel to another without limit, neither the loadstone nor the artificial magnet loses any of its inherent power, nothing, therefore, appears to be communicated; the whole result is entirely a species of molecular excitation, or a calling into sensible activity certain forces already existing in the magnetic substance, and which, under ordinary circumstances, remain in a quiescent or neutral state. No means yet devised have ever insulated these forces in such way as to enable us to obtain one of them only, independently of the other. We cannot, for example, produce a magnetic bar having a single pole; for although we touch one extremity of the bar only with one pole of the loadstone, still two poles will appear in the bar, although the one induced by the presence of the other may not be so forcible.

Methods of communicating magnetism to steel bars.—The first means of imparting magnetism to steel was, as we have already described, by contact with the armed loadstone or other magnet. A more efficacious method, however, of magnetizing small needles or bars by simple contact, consists in placing the bar or needle between the opposite poles of powerful magnets, as, for example, in the magnetic field S N, Fig. 2681, immediately between the poles S N.

We are indebted to Dr. Gowan Knight, F.R.S., a London physician, for the first important step in the communication of magnetism to bars of steel. His method, as given in the Philosophical Transactions for the years 1746 and 1747, vol xliv., is as follows: two powerful magnetic bars M M′, Fig. 2685, are placed in the same straight line, with their opposite poles N S very near each other; the needle or bar *n s* to be magnetized is laid flat on the surface of the bars, immediately over the opening N S, between them. If the bar *n s* be a magnetic needle, having a cap for suspension, then the cap is allowed to rest between the bars: if the surface be unimpeded by this, the bars M M′ may be brought very near each other. Things being thus disposed, the bars M M′ are gradually withdrawn in opposite directions, and immediately under the bar *s n*; the result of which operation is, on the principles already explained, that each half of the bar *s n* being acted on by opposite polarities, the two magnetic forces resident in it become separated; the pole N of the bar M attracts all the south polarity and repels the north, whilst the pole S of the bar M′ attracts all the north polarity and repels the south: hence a final and permanent magnetic state is imparted to the bar *s n*, the position of the poles *s n* being the reverse of the poles N S of the bars.

2685.

2686.



Small needles will become magnetized to saturation by one operation of this kind performed on each of its surfaces; for larger bars, two or three, or more, repetitions are desirable. This method is very effectual, especially for single bars, and there is not, perhaps, any better for certain purposes, even at the present day.

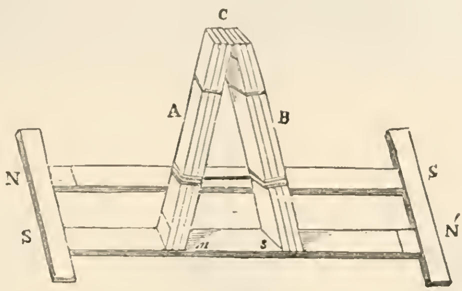
After this method of Dr. Knight's had become known and practised, M. Du Hamel, member of the Royal Academy of Sciences at Paris, was led, about the year 1749, to a further and still more extensive application of it. Two bars N S and T P, Fig. 2686, required to be magnetized, are laid on a table parallel to each other, and their intended opposite poles united by pieces of soft iron N T, S P, so as to form a closed rectangular parallelogram, as seen in the figure. The opposite poles *n s* of two powerful magnets A B, either simple or compound, are then applied to the centre C of one of the bars N S, and drawn away from each other in opposite directions C N, C S, being held all the while at an inclination of about 40°: this operation is repeated several times; the magnets A B are now either reversed, or their relative positions changed, by turning them round; they are then applied in a similar way to the other bar P T, so as to bring the poles *s n* opposite to their former position: the same operation is now repeated on the bar T P, and this process is to be further repeated on each surface of the bars T P, N S. M. Du Hamel's method is effective and expeditious; the elementary forces resident in the bars being by the joint operation of the magnets easily separated, whilst the union of the opposite poles N T and S P by soft iron, further tends to increase the effect, by holding together, as it were, the two separated magnetic elements, and thus allowing the exciting magnets A B to operate with more considerable effect.

Bars of the horse-shoe form may be rendered magnetic in a similar way, by uniting their near extremities or intended poles with soft iron, and then drawing the magnets away from each other, commencing at the centre of the curve, and terminating at each extremity.

A high magnetic development may be obtained in a series of straight bars, without the aid of powerful magnets, by a successive touching in combination one with the other. We are indebted to Mr. Canton for this process, which is as follows:

Having a set of 12 bars, however slightly magnetic, two of the series S′ N′, N S, Fig. 2687, are laid with reverse poles parallel to each other, and the rectangle closed by pieces of soft iron S N′, N S′, about one-half the length of the bars, and of the same breadth, as in the method of Du Hamel; the remaining 10 bars are separated into two combined systems A B, of 5 bars each, placed on one of the bars N′ S′, with their remote and opposite poles C in contact, and their lower poles *n s* somewhat open. This arrangement being made, the bars S′ N′ and N S are rubbed with these systems in the way already described, and being thus strengthened by the united powers of all the rest, are now removed,

2687.



and placed at the back of the others, as at A B, whilst the two interior bars of each system C *s*, C *n*, are withdrawn, and subjected to the same operation as the preceding; in this way we continue to strengthen each pair of bars by the acquired power of those last touched, until the whole become magnetized to saturation. This process is very useful when powerful magnets are not at hand; for however weak may be the magnetic state of the bars, even although two of them only be slightly magnetic, we may from these render the whole series very powerful.

The combined systems A B may be temporarily bound together by a little common tape, and a small block of wood placed between them, so as to support the whole in position during the process of magnetizing.

Besides these direct methods, we have other processes for obtaining a magnetic development in steel and iron, of much practical importance. Marcel, so long since as the year 1722, observed that a bar of iron acquired a temporary magnetic state by position alone; and he succeeded in imparting magnetism to a piece of hard steel placed on an anvil, merely by rubbing it with the lower end of a bar of iron about 33 inches long, set upright upon the steel. The temporary magnetic state thus induced by position in the iron bar is such, that the lower extremity, in these latitudes, becomes a south pole, and the upper extremity a north pole; and the forces are much increased by placing the bar in the direction of the inclined needle: in southern latitudes the reverse of this occurs—the lower extremity is then a north pole, and the upper end a south pole. Mr. Canton, by an ingenious manipulation of this kind, succeeded in communicating a weak degree of magnetism to steel by means of a common poker and a pair of tongs, and from this magnetized his series of bars to saturation by the process we have described: the bar to be rendered weakly magnetic was attached to the upper end of the poker by means of thread, and the whole placed in the direction of the dipping needle; whilst in this position the bar was repeatedly touched with the closed extremities of the tongs, carried from one end of the bar to the other, from below upward, the marked end of the bar being below.

Another method of developing magnetism in steel bars, without the aid of common magnets, consists in subjecting the bar to sharp concussion. This principle was well known to Gilbert so long since as the year 1570, who, in his celebrated work "De Magnete," represents a blacksmith hammering a steel bar in the position of the inclined needle. Smiths' tools, such as drills, broaches, &c., which have undergone pressure and motion, are generally magnetic. When a steel punch is driven hard into iron, the punch is not unfrequently rendered magnetic by a single blow.

In the Philosophical Transactions for 1738 we find an account, by Desaguliers, of iron bars rendered magnetic by striking them sharply against the ground whilst in a vertical position, or otherwise striking them with a hammer when placed in a horizontal position at right angles to the magnetic meridian. Such bars attract and repulse the poles of the needle. According to Du Faye, whose experiments are quoted, it is no consequence how the bar is struck: all that is required is to impart to the bar a vibratory state whilst in a vertical position.

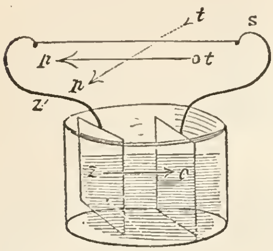
Availing himself of these facts, Scoresby, after a further and critical examination of the subject, succeeded in obtaining magnetic bars of extraordinary power by percussion. In the course of these inquiries, a considerable advantage was found to arise by striking the bar whilst resting in a vertical position upon a rod of iron. A cylindrical bar of soft steel, 6½ inches long, and ¼ of an inch diameter, resting on stone, and struck with a hammer weighing 12 ounces, could only be made to lift about 6½ grains; whereas when resting on a bar of iron, and struck in a similar way, it lifted 88 grains. Scoresby, in developing magnetism in this way by percussion, first struck a large iron bar in a vertical position, and then laid it on the ground with its acquired south pole towards the north; he then proceeded to strike sharply with a hammer a soft steel bar, 30 inches long and an inch square, resting vertically on the south pole of the iron bar. A second similar bar was treated in the same way; then, placing one of these steel bars vertically, he proceeded to strike upon them, as supports, a series of flat bars of soft steel, 8 inches long, and ½ an inch broad, and in a few minutes they had acquired a considerable lifting power. The series of bars being now touched one with the other, after the manner of Canton became very soon magnetized to saturation; each pair readily lifted 8 ounces.

Dr. Scoresby observes that large iron and steel bars are not absolutely requisite to the success of this process, common pokers answering the purpose very well.

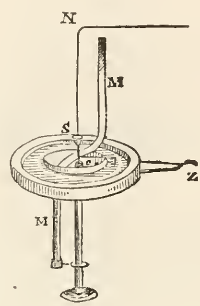
The next series of phenomena claiming attention, arise out of a property peculiar to natural and artificial magnets, by which they tend, when freely suspended, to arrange themselves in a certain relative position to a wire carrying a current of Voltaic electricity. These phenomena have been hence termed *electro-magnetic*, and although of sufficient moment and extent to come under a separate and peculiar branch of physical science, yet so far demand a brief notice here, as constituting a very important property of the natural and artificial magnet.

With a view to a clear conception of these reciprocal magnetic and Voltaic actions, it is requisite to understand that two plates of zinc and copper, *z c*, Fig. 2688, placed near each other in a vessel of dilute acid, and connected by a metallic circuit *c′* S N *z′*, turned or directed in any manner, give rise, during the solution of the zinc in the acid, to a peculiar electro-chemical action, by which a current of electricity is supposed to flow from the zinc plate *z* in the direction of the small arrow, through the acid upon the copper plate *c*, and from thence through the metallic circuit *c c′* S N *z′ z* back again upon the zinc plate *z*. A combination of this kind has been termed a Voltaic circle, and the metallic circuit *c′* S N *z′* the uniting wire.

2688.



2689.



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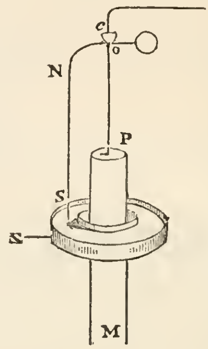


This understood, let S N be a perfectly straight portion of this circuit, which, as a standard of reference as to position, we will suppose to be in the direction of the magnetic meridian. Let *p t* be a magnetic needle, suspended below and parallel to N S; then, directly we complete the communications N *z′ z*—S *c′ c* with the zinc and copper plates *z c*, the needle *p t* varies from the meridian, and tends to place itself across the wire N S, and in such way that whichever pole of the needle is next the copper plate *c*, that pole moves to the right hand, or towards the east. If, therefore, the current flow over the needle from *c* to *z*, through the wire S N, from south to north, and the observer be looking over the wire in the same direction, then the south pole *t*, next the copper plate *c*, turns to his right hand, or to the east, and the north pole *p* to his left hand, or west. If we suppose the position of the plates *c* and *z* to be changed, and the direction of the current reversed, by connecting the extremity N with *c*, and the extremity S with *z*, so as to cause the current to flow from north to south, then these deflections are also reversed. The south pole *t* now goes to the left hand, and the north pole *p* to the right hand—that is to say, the north pole *p* being now next the copper plate, goes to the right hand.

Place the needle above, and parallel to the wire S N, then the reverse of all the former deflections will be obtained; whichever pole of the needle is now next the copper plate, that pole moves to the left hand, or west When the current, therefore, flows from south to north, the south pole *t*, which before went to the right hand, or east, now goes to the left hand, or west, whilst the north pole turns to the right hand; if we reverse the current, and cause it to flow from north to south, as in the last experiment, then these deflections are again reversed; the north pole of the needle, being now next the copper plate of the battery, goes to the left hand.

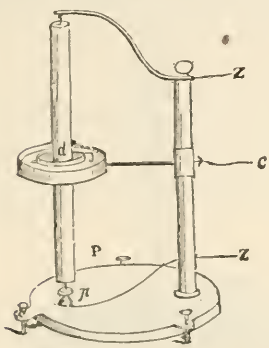
If the needle be immediately in the plane of the uniting wire, on either side of it, no motion is obtained in that plane; but if it be suspended in a vertical plane, on a horizontal axis, so as to admit of a deflection of inclination, then it tends to place itself across the wire as before. If the needle be on the east side of the uniting wire, that is, on the right hand, taking the current and direction as at first, then the south pole, next the copper side of the battery, dips below the horizontal plane, and the north pole, next the zinc plate, rises. If the current be reversed, the deflections are also reversed. If the needle be placed on the left hand, or west side of the uniting wire, then the south pole, next the copper plate, rises, and the opposite north pole dips. By reversing the direction of the current, these deflections are again reversed.

It is apparent, from the successive directions of the bar as it becomes placed above, at the sides, or below the wire S N, that the force affecting the magnet is a force transverse to the pole of the bar, by which, if the bar had complete freedom of motion in every direction, the poles would actually turn round the wire, but in different directions; and, conversely, supposing the bar fixed, and the wire S N carrying the current free to move, then those parts of the wire parallel to the magnet would rotate about the magnetic poles in opposite directions, in a similar way. If both are supposed free to move in any direction, then the wire and magnet would turn round each other, and such is really found to happen, giving rise to a very important series of electro-magnetic actions.

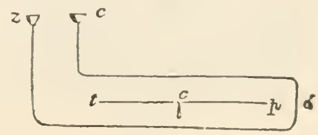
Let a magnetic bar M M′, Fig. 2689, be bent so as to produce a short oblique portion at the middle of the bar, with two vertical arms M M′; poise it on a fine central point *c*, and let a wire N S be placed near and parallel to one of the arms M. Then, supposing a descending current to flow from the copper plate *c*, Fig. 2688, through the wire in the direction N S, upon the zinc plate Z, the magnet M revolves about the wire N S, upon the central point *c*; and if the north pole of the bar be uppermost, the motion will be direct, or from the left hand to the right.

Conversely, if the magnet M be fixed as in Fig. 2690, and the wire N S be movable on a fine centre *o*, then, on transmitting the current as before, through the wire N S, it immediately revolves about the pole P of the magnet, with a direct screw motion, supposing the current to descend the wire, and the pole P to be a north pole. To enable these motions to go on without disturbing the progress of the current and the connections with the Voltaic plates, the movable parts dip into small cups and cisterns containing mercury, and with which the plates of the Voltaic circle, Fig. 2688, communicate, as indicated in the figures.

2691.



2692.



The tangential or transverse force, by which a magnetic pole is caused to revolve about a wire transmitting a current of Voltaic electricity, is equally apparent when the magnetic bar itself becomes the conjunctive wire of the battery; so that an electrical current flowing over or through a magnetic bar from one of its poles to the equator, or from the equator to either of the poles, causes such a bar to revolve upon its axis, the requisite mechanical arrangements for motion being complete.

Let a magnetic bar, S P, Fig. 2691, be mounted vertically between two delicate centres; the bar may be about 18 inches in length, 1 inch wide, and ¼ of an inch thick. Let an electrical current be caused to flow from either of the poles P S to the equator *d*, or from *d* to either of the poles P; the bar will immediately revolve upon its axis P S, the direction of the motion being such, that supposing the bar to rest upon its north pole P, the centre *d* being in communication with the copper plate of the battery C, and either or both of the poles P S in communication with the zinc plate Z, electrical currents will flow from the equator *d* to the poles, and the bar will revolve from left to right, as in the motion of the hands of a watch, or a common right-handed screw. By reversing the communication with the Voltaic plates, that is, placing the poles P S in connection with the copper plate, and the centre *d* with the zinc plate, the electrical current will flow from the poles to the equator *d*. In this case, the direction of the motion will be the reverse of the former; it will be from right to left, or backward, as it were.

If the position of the magnet be changed, that is, if we place it to rest with its south pole below, then, the communication with the Voltaic circle remaining as in the first instance, we also reverse the motion. If now the communications be changed, as in the last instance, we again reverse the motion, and obtain, as at first, a motion from left to right.

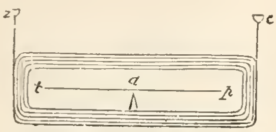
To facilitate the passing of the electrical current over the magnet, the bar is supported between fine centres P S by a light vertical column fixed on a firm base; a small ring or cistern of mercury *d*, also supported from the vertical column, surrounds the equator of the bar; the bar turns within this, and it is connected with the mercury in turning by a small bent wire dipping into the cistern; the lower centre P turns upon an agate contained in a small cup at P, connected with the point Z′; this cup contains a small globule of mercury, to keep up the metallic connection with the magnet; there is a similar globule in a small cavity at the upper end of the bar for the centre S; this upper centre is supported by a wire extending from tho head of the pillar Z Z′. It is here evident, that in connecting the points C Z or C Z′ with the plates of the Voltaic circle, an electrical current will flow between these points through C *d* S Z, or C *d p* Z′, the direction depending on the respective connections with the zinc or copper plate of the circle.

A recollection of the relative direction of the motions we have been describing will be facilitated by keeping in mind the following simple formula: a descending current moves a north pole to the right hand, or will give rise to a direct screw-motion; from this simple fact all other relative motions are easily determined.

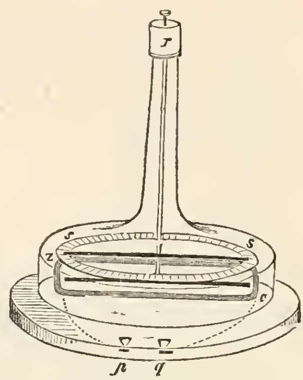
The reciprocal action of a magnetic needle and uniting wire, together with the series of deflections in given directions, have led to the invention of a very important magnetical instrument, termed the Electro-magnetic Multiplier, or *Galvanometer*, by which extremely small magnetic and electro-magnetic forces may be detected and measured.

It will be apparent, as already observed, that a current flowing both above and below a needle, ir opposite directions, deflects the needle in the same direction; hence it follows that if a magnetic needle *p t*, Fig. 2692, be suspended on a delicate centre *c*, within the bite of a returning wire *z d c*, and the extremities *z c* of the wire connected with the zinc and copper plates of the Voltaic circle by means of two little cups containing mercury, then a current will flow longitudinally round the needle, both above and below it, and in opposite directions, that is to say, in the direction *c d* above the needle, and in the direction *d z* under it; the effect of this will be to deflect the needle with twice the power by which it would be deflected with a single current only, as in Fig. 2688.

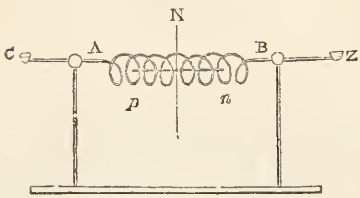
If we imagine the wire *z d c* to be several times turned longitudinally about the needle, as in Fig. 2693, then the effect would be still further increased; it would, in fact, become multiplied in proportion to the number of turns of the wire, which would represent so many additional currents. It is only requisite to cover the wire with silk thread, or some other imperfect or non-conducting matter, so as to avoid metallic communication between the coils, and oblige the current to traverse the whole length of the wire. This is the principle upon which the electro-magnetic multiplier rests, and the delicacy of the effect is such that the needle will become deflected by the immersion of two pieces of zinc and platinum wire less than $\frac{1}{8}$th of an inch long, and $\frac{1}{50}$th of an inch in diameter, in water slightly acidulated. Fig. 2694 represents this instrument under one of its most perfect and delicate forms. Two



2694.



2695.



magnetic needles, with their poles reversed to each other, are fixed on a central rigid axis, so as to neutralize the directive power of the needles, merely allowing a sufficient force to bring the whole into the meridian. This system is suspended by two parallel threads of unspun silk *r n*, one of the needles being within a rectangular coil of wire *z d c*, and the other needle immediately without it, and over the upper part of the coil. The wire *z c* is covered with silk thread, so that the coils may not have metallic communication, and the extremities *p q* are brought out near each other, and terminate in small cups *p q*, containing a little mercury, for the better convenience of communicating a current to the coil from any given source. The coils are separated a little near the centre, to allow the axis of the astatic system of the two needles to pass through them.

The slightest current transmitted through the coil from *p* to *q*, or *q* to *p*, causes the needles to deviate from their constant position. Both the needles, as is evident, will be impelled in the same direction; the lower needle being in the position just described, Figs. 2692 and 2693, whilst the upper needle, its poles being reversed, is impelled in the same direction by the upper side of the coil.

The threads of the double or bifilar suspension *r n*, in tending to cross each other as the needles turn, give rise to a reactive force, which may be set against the deflective force employed to measure it; for this purpose a graduated circle *s s* is fixed under or round the upper needle, so that the angle of deflection may be accurately estimated. If the earth's directive force be completely neutralized by the reversed positions of the needles, then this would be the only force opposed to the deflective force; i not, then it becomes mixed with the little directive power left in the system, but which is generally so small as not to be of much moment.

The instrument is set upon a convenient stand, and may be inclosed within a glass shade, the bifilar suspension being sustained within a tube of glass.

Steel magnetized by the electrical current.—One of the many important results of these discoveries is the means of imparting a high degree of magnetism to iron and steel, and to so great an extent as to give a soft iron rod a lifting power of more than a ton.

We have seen that the electrical and magnetic forces are so related that the one is exerted at right angles to the other. We derive from this elementary principle a means of disturbing the latent magnetic forces resident in magnetic substances, by which these forces become separated, and the body rendered magnetic, precisely in the same way as effected by the contact of an ordinary magnet.

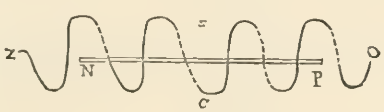
Let a long piece of copper wire be wound round a piece of glass tube of about $\frac{1}{2}$ an inch or less in diameter, and from 6 to 10 inches in length, so as to produce a helix or spiral, A B, Fig. 2695, and mount this spiral between two vertical supports, as represented in the figure. Place a perfectly neutral piece of hard steel wire *p n*, of about $\frac{1}{10}$th of an inch in diameter, or a large sewing needle within the helix, and connect the extremities A B with the zinc and copper plates of the Voltaic circle, the steel *p n* will become immediately magnetic; in fact, each turn of the spiral causes electrical currents to flow in reverse directions above and below the steel. If the coils of the spiral be numerous and close, they may be regarded as parallel circles standing at right angles to the direction of the inclosed wire, and with which the axis of the helix may be made to coincide. The effect of a helix of this kind on a fine magnetic needle placed within it is so powerful, that with a strong Voltaic current the needle is frequently caught up and retained on the axis of the spiral, as if liberated from the trammels of gravity.

The kind of polarity given to steel or iron thus circumstanced will depend on the direction of the current with reference to the axis of the helix, and this again will depend on the connections with the plates of the Voltaic circle and the direction in which the helix is turned. Now, the spiral may evidently be turned either direct, like the threads of a common cork-screw, forming what is termed a right-handed helix, or they may be turned in the reverse direction, in which case we have a left-handed helix.

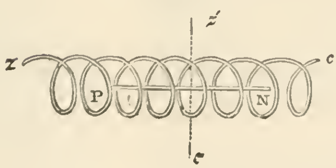
If we suppose the helix to be a reverse or left-handed helix, as in Fig. 2696, the current flowing from *c* to *z*, round a small cylindrical steel needle or wire P N, and the coils standing in the direction of the magnetic meridian *c' z'*, so that the current may flow under the wire in the direction *c' z'*, from south to north, as indicated by the dotted lines, and over the needle in direction *z' c'*, from north to south, as indicated by the full lines, then the positive pole P will be determined to the right hand, and the extremity P, of the wire next the copper plate *c*, will be a north pole: by similar reasons the opposite extremity N will be a south pole, and next the zinc plate of the battery.

If we take a direct or right-handed helix and an inclosed wire P N, as in Fig. 2697, and transmit the current as before from *c* to *z*, then the reverse of all this occurs; the currents flow *under* the wire from north to south in direction *z' c'*, and over the wire from south to north in direction *c' z'*. Under these conditions the positive pole P is determined to the left hand, so that the extremity P of the steel cylinder P N next the zinc plate becomes a north pole, and, by similar reasoning, the opposite extremity next the copper plate *c*, a south pole. Supposing the current to be reversed and to pass through a direct helix from left to right, the copper plate of the battery being to the left hand, and which is the ordinary form of the experiment, the north pole will be always determined next the zinc plate, that is, to the right hand.

2696.



2697



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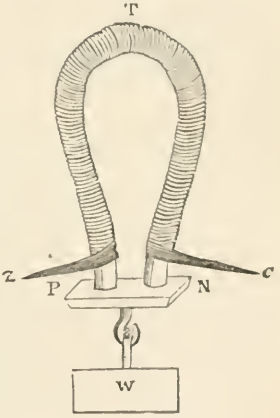


It will be useful to the student to remember as a general fact, that supposing, Fig. 2695, the observer to be facing the north, N, and the helix A B placed transversely before him so that its axis may lie east and west, then if the current be *descending* the coils of the spiral directly before him, the north pole is determined to the right hand, and the south pole to the left. Reciprocally, if the current be *ascending* the coils of the spiral directly before him, then the south pole is determined to his right hand, and the north pole to the left. Hence, with a direct helix, the north pole will be always found next the zinc plate, and with a left helix next the copper plate.

The magnetic power developed in soft iron closely surrounded by heliacal coils transmitting electrical currents all in the same direction is so great, that a curved iron rod, during the action of the battery, may be caused to sustain an enormous weight. The usual form of the experiment is as follows:

A cylindrical bolt of soft iron P T N, Fig. 2698, about an inch or more in diameter, and from 30 to 40 inches long, is bent into the horse-shoe form, as indicated in the figure. It is then surrounded by several long coils of copper wire *z* T *c*, covered with silk or other insulating thread, so as to interrupt all metallic communication or coil with the other; one set of coils is superposed on another, and all the ends of the wires P N on each side united into common terminations *z c*, to be connected with the battery.

If, when the currents are passing through the coils, we apply a soft iron keeper P N, and cross the projecting poles, it will be held fast with an enormous force, so that several hundred weight, W, may be suspended without breaking the contact. An electro-magnet of this kind may become so powerful as to support upwards of 2 tons.

Instruments for indicating the presence and determining the polarity of magnetic forces, and measuring their quantitative power under various conditions.—Instruments for indicating the mere presence of magnetic force, and determining its peculiar polarity, may be termed, as before observed, magnetoscopes; those for its quantitative measurement, under various conditions, may be considered as magnetometers.

Magnetoscopes generally consist of light bars or needles, either suspended by a delicate flexible thread, or attached to an agate or metallic cap, and set on a fine central point. Of these two forms of suspension, the filar suspension is the most sensitive. The Rev. A. Bennet, F. R. S., employed filaments of a spider's web, which proved so extremely delicate, that two small pieces of straw, placed at right angles to each other, in the form of the letter T inverted, would, when thus suspended under a closed receiver, turn towards a person coming within 3 feet of the glass, and would move so decidedly towards wires merely heated by the hand, as much to resemble magnetic attraction. A fine and weakly magnetic steel wire, suspended from a spider's thread of 3 inches in length, would admit of being twisted round 18,000 times, and yet continue to point accurately in the meridian—so little was the thread sensible of torsion.*

Magnetometers.—The quantitative measurement of magnetic forces may be either direct applications of equivalent weight, or any species of equivalent reactive power, as in the reactive force of torsion; or may consist of indirect determinations of force, through the medium of certain relative effects, as in the amount of deviation of a suspended magnetic needle from its line of direction by the influence of a magnet placed at a given distance from the needle.

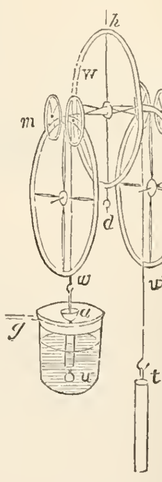
Scale-beam magnetometer.—The common scale-beam has been occasionally applied to the measurement of magnetic forces. A small cylinder of iron or a magnet is to be suspended from one arm of the beam, and counterpoised by weights in a scale-pan suspended on the opposite arm. The beam being sustained on any convenient support in the usual way, a second magnet or iron is placed on the table, immediately under this, and the attractive force at any given measured distance is estimated by additional weights placed in the scale-pan.

Much care is requisite in effecting this experiment. The beam should not be allowed any very considerable play, but be limited in its motions by two vertical forked stops, one under each arm. If the beam, with a given added weight in the scale-pan, be overset by the attractive force, and rest on the stop, we may either increase the distance of the attracting bodies, or increase the weight, so as just to catch the instant of the balance of the force. Or, supposing a given added weight in the scale-pan, we may continue to approximate a magnet towards the suspended iron or other magnet over a divided scale of distance, and catch the point at which the beam turns.

The bent lever, or any self-adjusting balance, may be also employed in a similar way to the measurement of magnetic force.

The hydrostatic magnetometer.—This instrument, shown in its general form in Fig. 2700, and partially explained in the following figures, is of such convenient and universal application to the measurement and exhibition of elementary magnetic phenomena and forces, that a particular description of it appears essential.

2699.



A light grooved wheel, W, Fig. 2699, about two inches in diameter, being accurately poised on a firm axis, *m n*, is mounted on the smooth circumferences of two similar wheels, *m w*, *n w'*. The extremities of the axis *m n* are turned down to fine long pivots, and whilst resting on the friction-wheels *m w*, *n w'*, pass out at *m n* between other small check-wheels, two at each extremity of the axis, so that the wheel W cannot fall to either side: great freedom of motion is thus obtained. These friction and check wheels are set on points or pivots in light frames of brass, and the whole is supported on short pillars screwed to a horizontal plate or stage, as shown at A B, Fig. 2700. The stage is sustained on a vertical column, A E, fixed to an elliptical base of mahogany, E, supported on three levelling screws.

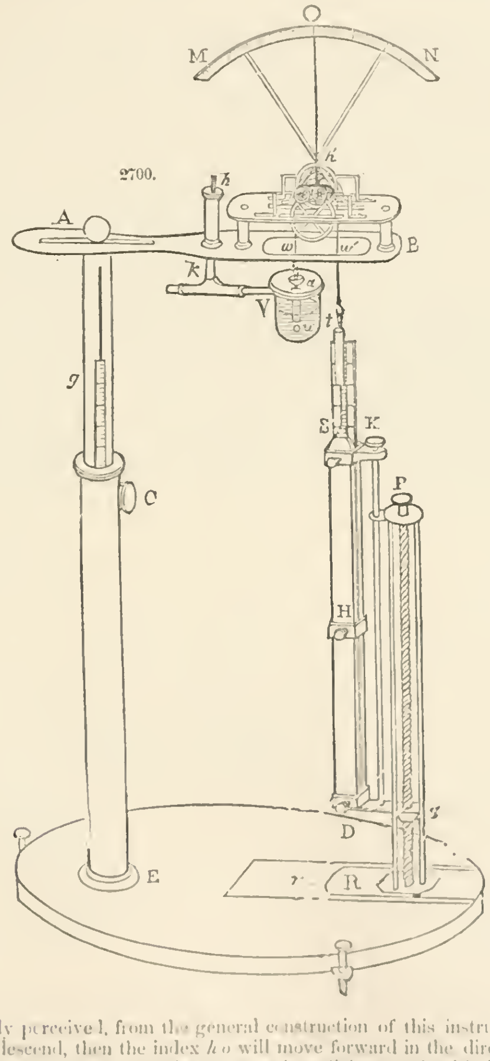
There is a short pin *h*, Fig. 2699, fixed in the circumference of the wheel W, to receive an index of light reed, cut to a point, and movable over a graduated arc M N, placed behind the wheel, as represented in Fig. 2700: the weight of this index is balanced by a small globular mass *d*, movable on a screw in the opposite point of the circumference; so that the wheel alone with the index would rest in any position, or nearly so. The arc M N is a quadrant divided into 180 parts: 90 in the direction I M, and 90 in the direction I N, the centre 0 being marked zero. Two fine holes are drilled through the wheel, one on each side of the point *h*, for receiving and securing two silk lines, *w w'*: these lines pass over the circumference on opposite arms of the wheel, and terminate in small hooks, *t* and *w*. A cylinder of soft iron *t*, or a small magnet, rather less than 2 inches in length and $\frac{1}{4}$th of an inch in diameter, is suspended by a silk loop from one of these lines, *w'*, and a cylindrical counterpoise of wood, *a u*, weighted at *u*, and partly immersed in water, is hung in like manner from the other line, *w*. The weights, and altitude of the water, and of the vessel *q* containing it, are so adjusted, that when the whole system is in equilibrio, the index *b o* is at zero of the arc M N. With a view to a perfect adjustment of the index, the water-vessel *q* is supported in a ring of brass at the extremity of a rod *q*, movable in a tube *k*, Fig. 2700: this tube is attached to a sliding piece *b h*, acted on by a milled head at *h* and a screw within the cylinder, which is fixed to the stage A B, so that the water-vessel may be easily raised or depressed by a small quantity, and thus the index be regulated to zero of the arc with the greatest precision; for it is evident, by the construction of the instrument, that the position of the index will depend on the greater or less immersion of the cylindrical counterpoise *a u*, the weight of which being once adjusted to a given line of immersion, and a given position of the wheel W and index O, any elevation or depression of the water-vessel *q* must necessarily move the wheel. The counterpoise *a u* is about $1\frac{1}{2}$ inch in length and full ·3 of an inch in diameter: a small ball of lead is attached to its lowest part, in order to give it a sufficient immersion, and at the

* Phil. Trans. for 1792, p. 86.

same time balance the iron cylinder *t* when the float is about half immersed in the water. With a view to a final regulation of the weight, a small hemispherical cup *a* is fixed on the head of the counterpoise for the reception of any further small weights required. This counterpoise is accurately turned out of fine-grained mahogany, and is freed from grease or varnish of any kind, so as to admit of its becoming easily wetted in the water.

The column A E supporting the stage A B consists of two tubes of brass, one, G, movable within the other, E C, so that by a rack on the sliding-tube G, and a pinion on the fixed tube at C, the whole of the parts just described may be raised or lowered through given distances, as shown by a divided scale G, adjustable to any point by means of a slide and groove in the movable tube G. The brass tubes composing the column are each about a foot in length and an inch in diameter.

2700.



It will be immediately perceived, from the general construction of this instrument, that if any force cause the cylinder *t* to descend, then the index *h o* will move forward in the direction O N, until such a portion of the counterpoise *a u* rises out of the water as is sufficient to furnish, in the fluid it ceases to displace, an equal and contrary force. In like manner, if any force cause the cylinder *t* to ascend, then we have the reverse of this—the counterpoise obtains an equivalent increased emersion, and the index moves in the opposite direction, O M. Thus if we place a weight of 1 grain, for example, on the iron cylinder *t*, the index will indicate, in the direction O N, a given number of degrees equal to a force of 1 grain. If we double this weight, we obtain a force of 2 grains, and so on. The converse of this arises on placing the weights in the cup of the counterpoise *a u*. We may thus reduce the indications to a known standard of weight. It is further evident, that, whether we operate on the system by gravity or by the attractive or repulsive force of a magnet, the indications of force are equally true.

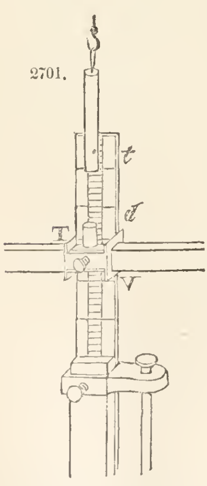
If the instrument be well constructed, and the counterpoise freely wetted in the water, the march of the index in either of the directions O N or O M will correspond to the added weights. Thus, if 1 grain gives 3 degrees, 2 grains will give 6 degrees, and so on. And thus we obtain a continual and known measure of the force we seek to examine, within a given range of degrees of the arc, which will be more or less extensive according to the dimensions of the cylindrical counterpoise, the intensity of the force, and the rate of its increase. When we require to examine very powerful forces, or forces operating on the suspended iron *t* at small distances, it is requisite to increase the size of the counterpoise float, the indications of which we may always find the value of in grains, as before.

Previously to suspending the cylindrical counterpoise *a u*, the iron cylinder *t* should be placed in equilibrio on the wheel W, with an equal and opposite weight, as previously determined by an accurate scale-beam, in order to observe if, when loaded with the whole, the wheel W and index are indifferent as to position on any part of the arc, or nearly so. The instrument will be sufficiently delicate, if, when loaded in this way with 350 grains, it is set in motion by something more than ½ a grain added to either side.

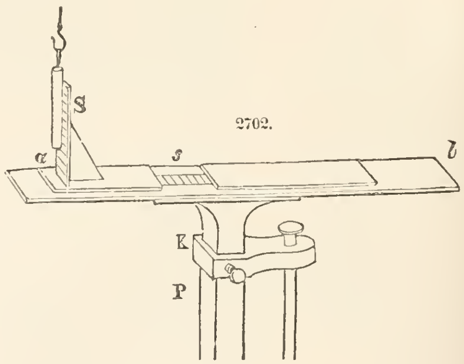
In order to retain the wheel W, Figs. 2699 and 2700, in its position at the time of removing either of the suspended bodies, a small brass prong is inserted at *h* into the arms of the circular segment M N, so as to inclose the pin *h* carrying the index: the wheel is thus prevented from falling to either side.

The forces requiring to be measured are brought to operate on the suspended cylinder *t* through the medium of induction on soft iron, or by a magnetic bar placed immediately under it, either vertically or horizontally. In the vertical arrangement, shown in Fig. 2700, the magnet or iron is fixed against a graduated scale S, by which the distance between the attracting surfaces or bodies is estimated. This scale, together with the magnet H, is secured by light bands *s*, of brass, united by a rod D K. The lower band and rod D are both fixed to a stage D, movable between guide-pieces, and acted on through a nut at *q* by a vertical screw P *q*, about 6 inches in length and ⅜ths of an inch in diameter; so that the whole may be raised or depressed, and hence the suspended cylinder and magnet placed at any required distance apart. The regulation of this important element in the operation of magnetic forces is hence provided for in two ways, viz., by the rack at G and the milled head at P, either of which may be employed, as found most convenient. The scale S is of boxwood, 1 foot in length, ⅜ths of an inch wide, and ¼th of an inch thick: it is divided into inches, subdivided into tenths and twentieths of an inch. About 6 inches of the upper part is divided in this way, viz, 3 inches on each side of a central division which is marked zero; the rest of the piece extends to the stage D. The magnetic bar H is tied to the scale by compressing screws and simple brass bands, either fixed, as at D and K, or movable, as at H. This adjusting apparatus is secured to a stout brass plate R, fitted by a dovetail into a sliding piece *v*, forming part of the mahogany stand E, so that it may be removed at pleasure. The brass bands and frames at D H K are sufficiently capacious to inclose two bars together if required, the superabundant space being filled when only one magnet is employed, either by a bar of wood or small wedge pieces in the brass frames.

2701.



2702.



When we require to examine the forces in different points of a moderate-sized magnetic bar, the bar is laid in a small frame piece T V, Fig. 2701, temporarily fixed by a compressing screw to the divided scale S, in the way already described, the force on the suspended cylinder *t* being caused to operate through a small cylinder of soft iron *d*, accurately fitted to the surface of the bar; and thus, by sliding the bar along in the holding-frame, we may get, approximatively, by induction on the iron *d*, the force of any point in the bar.

When the bar is of considerable magnitude and weight, or we require to examine inductive forces, the magnets may be placed on a narrow table, *a b*, Fig. 2702, supported on a central square pillar P, fitted to the frame-pieces, K P, of the adjusting apparatus already described, so that the whole may be raised or depressed through any given distance. In this case the divided scale S, which measures the distance *a* between the attracting or repelling surfaces, is a detached piece fixed against one of the perpendicular sides of a right-angled triangle, so as to be anywhere placed upright on the bar: the table $a\ b$ also has a divided scale s, movable in a wide groove through its centre, by which any distance s between magnetic masses may be also shown. When the bars are very ponderous, two supports are required, one at each end of the table $a\ b$.

Inductive forces are examined vertically by fixing the masses by compressing bands against the scale S, Fig. 2702, and of which we may have, if requisite, two or three in succession.

These arrangements put us in a position to note readily and simultaneously all relative distances and forces under a great variety of magnetic and apparently complicated conditions.

We have been somewhat prolix in our description of this instrument, but not unnecessarily so. There is scarcely any elementary experiment in magnetism which it does not completely and satisfactorily illustrate, besides furnishing quantitative measures of great importance to the mathematical inquirer into the laws and operations of magnetic force. See Electro-Metallurgy.

MAHOGANY. The beautiful reddish-brown colored wood, of which household furniture is now chiefly made. It is a native of the warmest parts of America and the West Indies. It thrives in most soils in the tropical climates, but varies in texture and grain according to the nature of the soil. On rocks it is of a smaller size, but very hard and weighty, of a close grain, and beautifully shaded; while the produce of the low and richer lands is observed to be more light and porous, of a paler color, and open grain; and that of mixed soils to hold a medium between both. The tree grows very tall and straight, and is usually four feet in diameter. On account of the difficulty of transporting the mahogany timber from the forests, when the tree is of great thickness they cut it into short logs, otherwise the great weight and bulk would be unmanageable with the restricted means available on the spot; and with the view of equalizing the burden or draft of the cattle, (oxen,) the logs are long in proportion to their diminished thickness. The largest log ever cut in Honduras was of the following dimensions: length 17 feet, breadth 57 inches, depth 64 inches; measuring 5421 feet of plank, of one inch in thickness, and weighing upwards of 15 tons.

MANOMETER. An instrument for measuring the rarefaction and condensation of elastic fluids, but especially that of the atmosphere. It differs from the barometer, which shows only the weight of the superincumbent column of air; whereas the manometer shows the density, which depends on the combined effect of weight and the action of heat. It is sometimes called manoscope. Among the various contrivances of this kind may be mentioned that of the Hon. Robert Boyle, which he calls a statical barometer, which consists of a bubble of thin glass, about the size of an orange, which, being counterpoised in an accurate pair of scales, rises and sinks with the alterations of the atmosphere. This instrument, however, does not show the cause of the difference of density in the atmosphere, whether it be from a change of its own weight, or its temperature, or both. The manometer constructed by Mr. Ramsden, and used by Capt. Phipps in his voyage to the North Pole, was composed of a tube of small bore, with a ball at the end; the barometer being 2·97, a small quantity of quicksilver was put into the tube, to take off the communication between the external air and that confined in the ball, and the part of the tube below this quicksilver. A scale is placed on the side of the tube, which marks the degrees of dilatation arising from the increase of heat in this state of the weight of the air, and has the same graduation as that of Fahrenheit's thermometer, the point of freezing being marked 32°. In this state, therefore, it will show the degrees of heat in the same manner as a thermometer. But if the air becomes lighter, the bubble inclosed in the ball being less compressed, will dilate itself, and take up a space as much larger as the compressing force is less; therefore the changes arising from the increase of heat will be proportionably larger, and the instrument will show the differences in the density of the air, arising from the changes in its weight and heat. Mr. Ramsden found that a heat equal to that of boiling water increased the magnitude of the air from what it was at the freezing point by $\frac{414}{1000}$ of the whole. Hence it follows, that the ball and part of the tube below the beginning of the scale, is of a magnitude equal to almost 414 degrees of the scale. If the height of both the manometer and thermometer be given, the height of the barometer may be determined also.

When used for measuring pressure above that of the atmosphere, the instrument (as usually constructed) is in all respects the same, except that the tube is not filled with mercury, but inverted, while full of atmospheric air, into a reservoir of mercury, and the scale is differently marked. When the pressure on the surface of the mercury in the reservoir is that of the atmosphere, the mercury will rise in the tube nearly to the level of that surface, (but slightly lower, owing to the resistance of the air in the glass tube.) As soon, however, as the pressure communicated exceeds that of the atmosphere, the mercury will be forced up into the tube, and the inclosed air condensed, until its elastic resistance is just equal to the pressure. The height of the mercurial column will of course vary with any variation of pressure, and thereby indicate the degree of pressure at every moment by means of the scale, which is divided, according to Mariotte's law, into atmospheres, pounds, or the like.

The high degree of pressure to which the last described form of manometer may be subjected without error from friction or loss of mercury, the permanent elasticity, and the every where existing and exactly defined qualities of the material of resistance, atmospheric air, or other fluids of the same nature, its comparatively small dimensions and convenient form, make it a very desirable instrument for measuring the pressure of steam. As usually constructed, however, it has defects, which have prevented its general use as a steam gauge. Among these defects were the coating and consequent opacity of the glass tube, by the deposition of an oxide of mercury when acted on by the inclosed atmospheric air, the expansion and partial loss of air from within the tube whenever any partial vacuum was produced in the boiler, and so allowing the mercury to rise higher in the tube with the same pressure; its oscillation, especially when there is a varying pressure, as in engines working expansively, the almost constant tendency of the condensed steam to insinuate itself between the mercury and the glass, and to find its way into the tube above the mercury; and the great inequality in the divisions of the scale, arising from the peculiarities of the law that governs the volume of aeriform fluids under pressure.

The improvements by which these defects have been remedied, at the same time rendering it more serviceable for determining pressures less than that of the atmosphere, have recently been made the subject of a patent to Mr. Paul Stillman, of New York.

Fig. 2703 is the usual form of the patent manometer for showing a pressure up to eight atmospheres Fig. 2704 represents the form of one for showing a pressure up to twenty atmospheres.

Fig. 2705 is the form used for showing less than one atmosphere. The arrangement of the glass tube is quite similar in all the forms usually given to the instrument.

Fig. 2706 is a longitudinal section through the centre of the glass tube, in which A is the tube; B is an iron piece in which the tube is firmly secured by means of the stuffing-box G. It is screwed at one end to receive the brass case C, and in the middle to confine it in the reservoir of mercury into which the lower end of the tube is to be immersed. D D are scales divided into atmospheres, pounds, or inches of pressure, as desired. E E are blocks to secure the scales in their proper places. F is a gland which protects the lower end of the tube, and compresses the packing in the stuffing-box G. H is a cap or plug loosely screwed into the gland to facilitate the operation of charging the tube, and also, by admitting the mercury into the tube only through the interstices of the screw, prevent its oscillation, and at the same time allow the orifice to be made the full size of the tube whenever it may be necessary to clean the tube.

In Fig. 2703 the reservoir for mercury is a deep cell, with an iron tube communicating from the

2706.

2704.

2703.

2705

cock at the bottom to the middle of the chamber above the surface of the mercury. In Fig. 2704 it is divided, the glass tube being inserted into a cell of greater depth, while the reservoir of mercury is in the bulb, to which a sufficient elevation is given to compress the gas within the tube to two or three times the density of the atmosphere, according to the density of the steam of which it is to serve as the gage. In this, as in the other form, an iron tube communicates the pressure from the cock below to the surface of the mercury in the bulb above. The subdivisions of the scale are by this means much more uniform and distinct than when used at atmospheric pressure only.

In all cases, the mercury should be seen above the junction of the tube with the tube-holder, so as to indicate the initial pressure, or 0. In Fig. 2703 it is brought up by partially exhausting the tube at the time it is erected. In Fig. 2704 it is forced up by the superincumbent weight of the mercury in the bulb. The oxidation of the mercury within the tube is prevented in the latter form of the instrument by charging the tube with nitrogen or hydrogen gas; but in the former, on account of the difficulty of preventing the admixture of atmospheric air, while exhausting a portion of the contents of the tube, for the purpose above referred to, atmospheric air only is used, and a drop or two of naphtha or other fluid answering the end, is introduced within the tube, on the surface of the mercury, to prevent the oxidation.

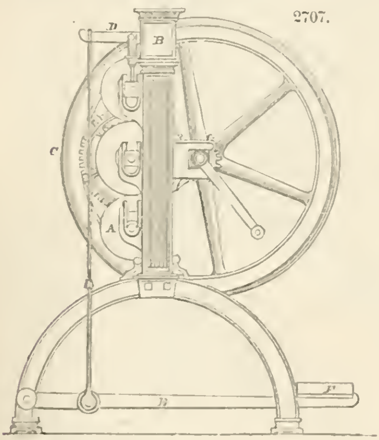
When designed to show a pressure less than atmospheric, but not less than that shown by two inches of mercury, the tube is to be perfectly filled with mercury, and inverted in the reservoir, and the pressure will be determined by the number of inches sustained above the level of the mercury in the reservoir below; but if it is to be used for a pressure less than the weight of two inches of mercury—that being the distance from the lowest visible part of the glass tube to the surface of the mercury in the reservoir—it will be necessary to use the bulb shown in Fig. 2704, but with such an elevation only as will bring the surface of the mercury in it to a height equal to the lowest visible part of the glass tube; or it may be done equally well by using the form shown in Fig. 2704, if a scale is properly made for the purpose, and the bulb elevated so as to compress the air so high in the tube as to allow the mercury to have sufficient fall without going out of sight, when the pressure of the atmosphere is removed from the surface of the mercury in the bulb above.

It will be seen that either of these arrangements would resist the tendency of such partial vacuum as is generally formed in steam-boilers, when they are allowed to cool down, from disturbing the quantity of air within the tube of the manometer.

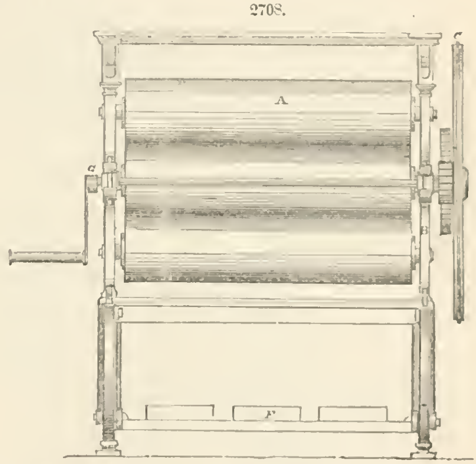
If the initial quantity of air or gas in the tube be deranged by a change of temperature, or by any other cause, it becomes necessary to know the extent of the variation occasioned thereby. To ascertain this, (if inexpedient to correct it at once,) a simple arrangement is adopted, viz., 1st, to remove the pressure by closing the stop-cock and opening the small waste-cock between it and the reservoir—this will allow the mercury to fall to a place in which it will be at equilibrium with the atmosphere; 2d, to note the point to which it descends. The variation from the original place of 0 will be, in addition to the pounds shown on the scale-plate, such part of the whole as the variation from 0 bears to the whole length of the tube above 0. To determine this proportion, a series of decimals is placed on the scale at fixed distances, and the one of these nearest to where the base of the column of air within the tube rests, is to be used as a multiplier, by which the pressure of steam indicated on the scale is to be multiplied. Their product, less the pounds of variation shown on the scale, will be the true pressure. Thus, for example, if the mercury in the tube falls until the base of the column of air rests at the decimal ·96, which would be near to the place due to 1 pound pressure, and if, on opening the communication to the boiler again, it should rise to 130 pounds, this apparent pressure of 130 pounds is to be multiplied by ·96, and deduct from their product the 1 pound, thus giving as the true pressure 123·8 pounds, showing a variation of 6·2 pounds. See GAGE, INDICATOR.

MANGLE, *house.* Figs. 2707 and 2708 exhibit a house mangle for swathing cloth, the action of which is obvious.

2707.



2708.



MAPLE-WOOD, is found growing in mountain districts, is indigenous to the United States, and valuable for its lightness; and not being subject to warp or split, it will take any color, and a fine polish. When green, it weighs 61 lbs. 9 oz. a cubic foot; and when dry, 51 lbs. 15 oz.

The *bird's-eye maple*, from the beauty of its grain and the shades of its spots, is much employed for veneering; by sawing the timber nearly parallel with the concentric rings, the effect of its marking or pencilling is much improved. In this country wheelwrights employ it, after giving it a seasoning for two or three years; and when constantly under water it will not readily perish.

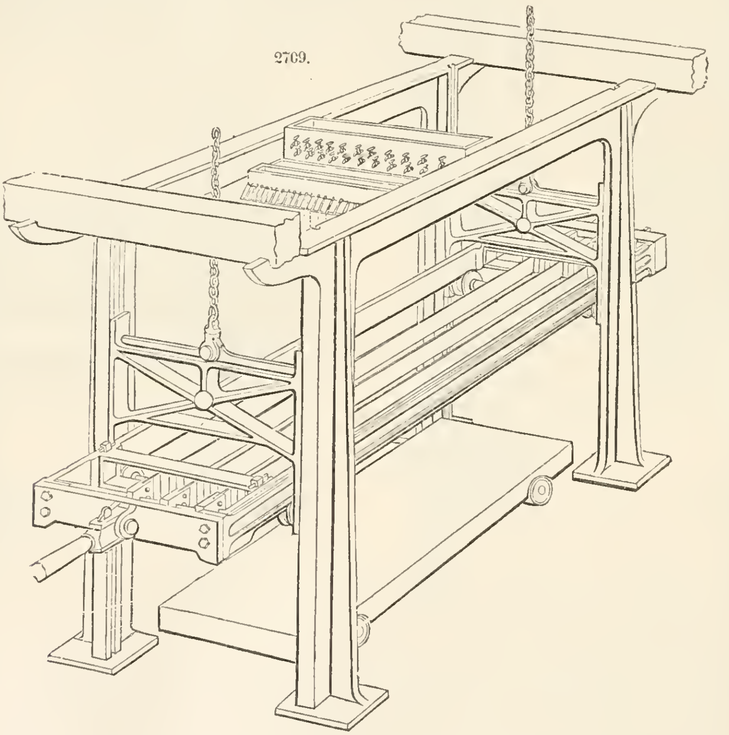
MARBLE-SAWING AND POLISHING MACHINERY, *worked by steam-power.* Marble has of late years been extensively worked by machinery driven by steam-power; the processes are closely analogous in principle to those pursued by hand, but with various modifications of the apparatus, and it is proposed to explain briefly some of the peculiarities of the machine processes.

In the simplest application of machinery to sawing marble, as for making one or two cuts in a large block, the construction of the ordinary stone-saw is closely followed, but the frame is made much stronger, of squared timber firmly bolted together, and stayed with chains; to constitute three sides of a rectangular frame, the place of the pole and tightening chain of the saw is occupied by two fixed beams, and the saw is held and stretched by means of two clamps with screws passing through the ends of the frame, and tightened by nuts on the outside. The saw frame works between vertical guide posts to keep it upright, and it is reciprocated horizontally by a connecting-rod fixed to a crank driven by the engine. The connecting-rod is attached to the frame by a loop, which can be placed at various heights, so as always to keep the stroke of the connecting-rod nearly horizontal, notwithstanding the gradual descent of the saw in the cut.

These saw frames are sometimes made as large as 16 feet long and 10 feet high, for cutting huge blocks of marble; and to prevent the great weight of these frames from pressing on the cut, they are suspended at each end by chains or slings which vibrate with the saw, and are connected with a counterpoise weight, that is adjusted to allow of the necessary pressure for the cutting, which is effected with sand and water supplied in the same manner as for the stone-saw used by hand, but the introduc tion of the guide principle renders the chasing of the stone for the entry of the saw unnecessary. In some cases smaller saws of similar construction are used for cutting thick slabs into narrow slips, and sometimes several cuts are made at once by an equal number of saw-blades, arranged in a rectangular frame that is suspended horizontally by vibrating slings, and works between vertical guide-posts.

In the horizontal sawing machine for marble patented by Mr. James Tulloch, in 1824, the entire arrangements are combined in a very effective manner, for cutting a block of marble into a number of parallel slabs, of any thickness, at the one operation. The iron frame-work of the machine, shown in Fig. 2709, consists of four vertical posts strongly connected together at the top and bottom, to form a stationary frame from 10 to 14 feet long, 4 to 5 feet wide, and 8 to 12 feet high, within which the block of marble to be sawn is placed. The two upright posts at each end of the stationary frame have, on their insides opposite to each other, perpendicular grooves, within each pair of which slides up and down a square vertical frame; to the lower end of each of these slides is affixed a spindle carrying two guide-pulleys, or riggers, upon which the horizontal saw-frame rests, and is reciprocated backwards and forwards. The saw-frame is thus traversed within the fixed framing, and supported upon the four guide-pulleys of the vertical slides, which latter are themselves suspended by chains coiled upon two small drums placed overhead. On the same spindle with the drums is a large wheel, to which a counterpoise weight is suspended by a chain. The weight of the counterpoise is so adjusted as to allow the saw-frame to descend when left to itself, and which thus supplies the necessary pressure for causing the penetration of the saws.

2709.



The saw-frame is made rectangular, and from two to three feet longer than the distance between the vertical slides, in order to permit of the horizontal traverse of the saws, which is from 18 to 20 inches. To allow of the blades being fixed in the frame with the power of separate adjustment, every blade is secured by rivets in a clamp or buckle at each end. The one extremity of the buckle embraces the saw, the other is made as a hook; the buckle at one end of the saw is hooked upon a horizontal bar fixed across the end of the saw-frame, and the opposite end of the frame has a groove extending its entire width, through which a separate hook, provided with a vertical tightening wedge, is inserted for every saw, which thus admits of being replaced without deranging the position of the neighboring blades.

The distances between the saws, and their parallelism with the sides of the frame, are adjusted by means of iron blocks made of the exact thickness required in the slabs of marble; the blocks and blades are placed alternately, and every blade is separately strained by its tightening wedge until it is sufficiently tense; the blocks are sustained between two transverse bars, called *gage-bars*, and are allowed to remain between the blades to give them additional firmness.

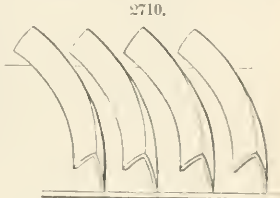
The traverse of the saw-frame is given by a jointed connecting-rod, attached by an adjustable loop to a long vibrating pendulum, that is put in motion by a pair of connecting-rods, placed one over the other, and leading from two cranks driven by the engine. All three connecting-rods admit of vertical adjustment on the pendulum. The connecting-rod of the saw-frame is placed intermediately between the other two, but its exact position is regulated by the height at which the saws are working, as it is suspended by a chain and counterpoise weight, which allow it to descend gradually downwards on the pendulum with the progress of the cut, so as always to keep the connecting-rod nearly horizontal.

In the London Marble Works four of these sawing-machines of different sizes are grouped together, with the driving-shaft and pendulums in the middle, and so arranged that each pair of saw-frames reciprocate in opposite directions at the same time, in order to balance the weight, and reduce the vibration.

Another mode of traversing the saw-frame sometimes adopted, is by means of a vertical frame that is reciprocated horizontally on slides, and the connecting-rod, instead of being jointed, is fixed rigidly to the saw-frame, and slides upon a vertical rod. Various other unimportant modifications in the construction of the machines are also adopted.

One of the most difficult points in the application of these machines, was found to be the supplying of the sand and water mechanically to the whole of the cuts at the same time. This is now successfully effected by the following arrangement. Above the block of marble to be sawn is fixed a water cistern, or trough, extending across the whole width of the frame, and measuring about 1 foot wide, and 1 foot deep; about 20 small cocks are arranged along each side of the cistern, and a small but constant stream from each of the cocks is received beneath in a little box; a sloping channel leads from every box across the bottom of a trough filled with sand, which mingles with the water, and flows out in separate streams, that are conducted to each of the saw-cuts. In the first construction of this apparatus for the feed, the sloping channels were led straight across the bottom of the sand-trough, but it was then found that the water excavated little tunnels in the sand, through which it flowed without carrying the sand down. This difficulty was overcome by leading the channels across the bottom of the trough in a curved line, when viewed in plan. The form of the channels is shown in Fig. 2710, which represents four channels cut across the middle of their length, to show their section, from which it will be seen that the channels are made as a series of Gothic shaped tunnels, supported only on one side, and open on the other for the admission of the sand; the water flows through these tunnels, and continually washing against the convex side of the channel, undermines the sand, which falls into the water and is carried down: to assist this action the attendant occasionally stirs up the sand to loosen it. There is a sand-trough and set of channels on each side of the water cistern, so that every saw-cut receives two streams of sand and water in the course of its length.

2710.



The saws having been adjusted to the proper distances for the required slabs, the saw-frame is raised by means of a windlass and the suspended chains attached to the vertical frames, and the block of marble to be sawn is mounted upon a low carriage, and drawn into its position beneath the saws, and adjusted by wedges. The saws are then lowered until they rest upon the block, the counterpoise weights are adjusted, and the mixed sand and water allowed to run upon the saw-blades, which are put in motion by attaching the connecting-rod to the pendulum. The sawing then proceeds mechanically until the block is divided into slabs, the weight of the saw-frame and connecting-rod causing them gradually to descend with the progress of the cutting.

To allow the sand and water to flow readily beneath the edges of the saw-blades, it is desirable that the horizontal frame should be slightly lifted at the end of each stroke. This is effected by making the lower edges of the frame, which bear upon the guide-pulleys, straight for nearly the full length of the stroke, but with a short portion at each end made as an inclined plane, which on passing over the guide-pulleys lifts the frame just sufficiently to allow the feed to flow beneath the saws.

For cutting slabs of marble into narrow pieces, such as shelves, and which is effected by hand with grub-saws, a machine called a *ripping bed* is employed, in which as many cuts as may be required in the one slab are effected simultaneously, by an equal number of circular saws with smooth edges, revolving vertically, and fed, as usual, with sand and water. This machine consists of a bench about 12 or 14 feet long, 6 or 7 wide, and about 2 feet 6 inches high; upon the top of the bench is fixed two rails, upon which a platform, mounted on pulleys, is drawn slowly forward by a weight. The horizontal axis carrying the saws revolves about 9 inches above the platform, and to insure the rotation of the saws, the axis is provided with a projecting rib or feather extending its whole length. The saws are made as circular plates, about 17 inches diameter when new. The saws, or cutters, are clamped between two collars about 6 inches diameter, fitted so as to slide upon the spindle, and be retained at any part of its length by side screws.

The saws having been adjusted to the required distances for the widths of the slips to be cut, and fixed by the side screws, the slab of marble is imbedded in sand upon the platform, and the edge of every saw is surrounded on one side with a small heap of moist sand. The saws are then set in motion, so as to cut upwards, and the platform is slowly traversed under the saws by the weight, which keeps the slab of marble constantly pressing against the edges of the revolving saws, until the slab is entirely divided into slips.

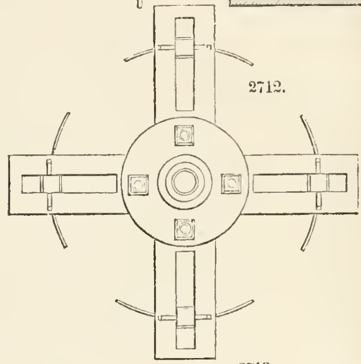
When the saws are new, they nearly reach the upper surface of the platform, and a moderate thickness of sand, just sufficient to form a bed for the slab of marble, raises it high enough to allow the saws to pass entirely through the thickness of the slab; but as the saws are reduced in diameter by wear, it becomes necessary to employ a thicker layer of sand, or to use a supplementary platform to raise the slab to the proper height. To avoid this inconvenience, an improvement has been recently introduced by mounting the axis of the saws in a vertical slide, which is adjusted by a rack and pinion, so as to allow the edges of the saw to penetrate exactly to the required depth.

Circular pieces of marble, such as the tops of round tables, and other objects, from about 6 feet diameter to the small circular dots sometimes used in tesselated pavements, are sawn to the circular form by means of revolving cylindrical cutters, constructed on much the same principle as the crown saws for wood. The slab to be sawn is placed horizontally on a bench, and the axis of the machine works vertically above it in cylindrical bearings, which allow the spindle to slide through them, so as to be elevated or depressed according to circumstances. The spindle is suspended at the upper end by a swing-collar attached to a connecting-rod, that is jointed to the middle of a horizontal lever. The weight of the vertical rod and cutter supplies the pressure for the cutting, and the whole is raised for the admission of the work by a rope attached to the end of the lever, and passed over a pulley.

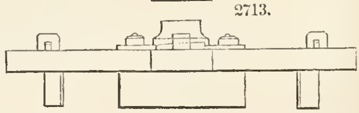
For circles of small diameter, the cutters are made as hollow cylinders of sheet-iron, of various diameters, and each attached by screws to a circular disk of cast-iron, as shown in section in Fig. 2711. The cutter is screwed on the lower end of the spindle, just the same as a chuck on a lathe mandrel, except that the spindle is placed vertical instead of horizontal. To insure free access for the sand and water beneath the cutter, one or two notches, about three-quarters of an inch wide, are generally made in the lower edge.

2711.

2712.



2713.



For large circles, the apparatus is made strong, and the vertical spindle is fitted at its lower extremity with a circular plate, to which is bolted a wooden cross, shown in plan in Fig. 2711, and in elevation in Fig. 2713; the cross has radial grooves about 18 inches long, near the outer extremities of the four arms. The cutters consist of detached plates of iron, from 6 to 18 inches long, of various widths, according to the thickness of the work. The cutters are curved as segments of a cylinder, of the particular diameter they are required to cut, and are each riveted to a clamp that passes through the radial groove, and is retained by a wedge. The number and length of the cutters is solely a matter of convenience, as a single cutter, when put in rotation, would make a circular groove, and several cutters are only employed in order to expedite the process. But every different diameter requires a different curve in the cutters, and which must all be placed at exactly the proper distance from the centre of rotation.

The horizontal bench upon which the marble is laid, is generally a temporary structure, adjusted to suit the thickness of the object to be sawn. Works of large diameter are seldom more than one or two inches thick, but those of small diameter are frequently much thicker, and sometimes three or four thin pieces are cemented upon each other, and cut at one operation. Short pillars are sometimes sawn out of an irregular block in a similar manner, instead of being chipped and turned. And it has been proposed that long cylinders, and tubes of stone, should be cut with cylinders of sheet-iron of corresponding length, put in rotation, and supplied with sand and water.

Marble works of small and medium size, are ground flat upon horizontal revolving laps, after the same general method as that pursued by the lapidary, but with a proportionate increase of size in the lap, which is supplied as usual with sand and water. The laps for marble works are made as circular plates of cast-iron, from 6 to 14 feet diameter, and about 3 inches thick when new; they are mounted in various ways upon vertical spindles, so that their upper sides or faces may be about 2 feet 6 inches above the ground. Across the face of the lap, or, as it is called, the *sanding plate*, one or two strong square bars of wood, faced with iron, are fixed so that their lower sides may just avoid touching the face of the lap, and their edges present perpendicular faces, from 5 to 6 inches high, at right angles to the face of the lap. The wooden bars serve as stops to prevent the work from being carried round by the lap, and also as guides to insure the work being ground square.

The piece of marble is laid flat upon the lap, with the face to be ground downwards, and the side of the work in contact with the guide-bar. Water is allowed to drip upon the plate from a cistern fixed above, and small quantities of sand are thrown on as required. During the progress of the work the workman leans upon the marble, the position of which is shifted occasionally to expose both the work and the lap to an equal amount of wear, and prevent the formation of ridges, but which is less likely to occur with iron laps used for grinding large surfaces of marble, than when small objects are applied upon lead laps, as by the lapidary and mechanician.

The one side of the marble having been reduced to a flat surface, the work is turned over to grind the adjoining face, and the first face is held in contact with the perpendicular side of the guide-bar, in order to present the second face of the work to the lap exactly at right angles to the first. When two pieces of similar size are to be ground each on the one face and two edges, as for the upright sides of a chimney-piece, the two pieces of marble are cemented together back to back with plaster of Paris, (a process that is called *lining*,) and the pair are ground as one piece on all four faces; in this case the flat sides are first ground parallel to each other, or of equal thickness on the two edges, and the latter are then ground square by placing the sides in contact with the guide-bar.

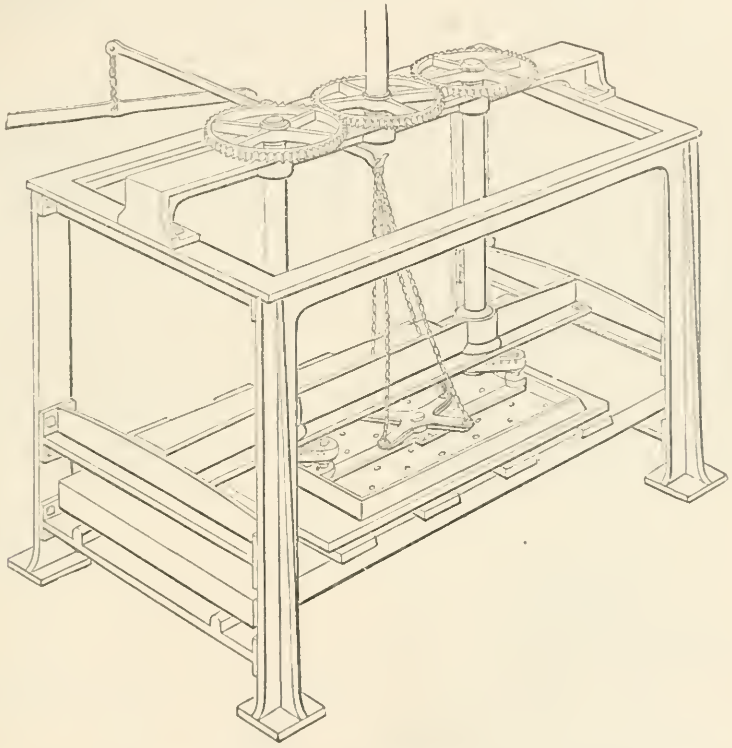
When the lap is of moderate size, one guide-bar only is employed, and it is fixed across the diameter of the plate, which then allows of two workmen being employed on the opposite sides; but large grinding plates sometimes have two or three bars placed at equal distances across the face, and four or six workmen may then be employed at the same time upon separate pieces of marble.

The sand and water are continually thrown from the lap by the centrifugal force, and the large size of the works sometimes applied prevents the use of a rim standing up above the level of the lap to catch the wet, as used by lapidaries. Every workman, therefore, stands within a kind of trough like a box, about three feet high, without a top or back; the troughs serve as a protection to the workmen, who would otherwise be exposed to a continued shower of sand and water.

The surfaces of large slabs are in some cases ground upon revolving plates; in this case the axis is placed entirely beneath the surface of the plate, somewhat as in Fig. 2714, and the slab is traversed by two men over the face of the plate to grind it equally, but the machine next described is better adapted for large slabs of marble requiring tolerable accuracy.

Large slabs of marble and stone are ground very accurately in a machine patented by Mr. Tulloch, and called a grinding bed. In this machine, represented in Fig. 2714, the slab to be ground is placed

2714.



horizontally upon a moving bed, and the grinding is effected by sand and water, by means of a large flat plate of iron resting upon the surface of the slab. The two surfaces are traversed over each other with a compound motion, partly eccentric and partly rectilinear, so as continually to change their relative positions. The machine consists of a frame about 9 feet long, 6 feet wide, and 8 feet high; about 2 feet from the ground is mounted a platform, that is very slowly reciprocated horizontally for a distance of from 1 to 2 feet, according to the size of the slab, by means of a rack and pinion placed beneath, and worked alternately in both directions.

Above the platform are fixed vertically two revolving shafts, having at their upper extremities horizontal toothed wheels of equal diameter, which are driven by means of a central toothed wheel keyed on the driving-shaft. The two vertical shafts are thus made to revolve at equal velocity, or turn for turn, and to their lower ends are attached two equal cranks, placed parallel to each other; the extremities of which, therefore, describe equal circles in the same direction. To these cranks the iron grinding plate or runner is connected by pivots fitting two sockets placed upon the central line of the plate. The cranks are made with radial grooves, so that the pivots can be fixed by wedges at any distance from the centre of the cranks. When the machine is put in motion, the grinding plate is thus swung round bodily in a horizontal circle of the same diameter as the throw of the cranks, which is usually about 12 inches, and consequently every portion of the surface of the grinding plate would describe a circle upon the surface of the slab being ground, if the latter were stationary. But by the slow rectilinear movement of the platform, the slab is continually shifted beneath the plate, so as to place the circles, or rather the cycloids, in a different position; and it is only after many revolutions of the cranks that the same points of the surfaces of the grinding plate and slab are a second time brought in contact.

The grinding plate is raised for the admission of the slab by means of four chains suspended from a double lever. and attached to the arms of a cross secured to the centre of the upper surface of the plate, which is thus lifted almost like a scale pan. For slabs that are much thicker or thinner than usual, the principal adjustment is obtained by the removal or addition of separate beds, or loose boards, laid upon the platform to support the slab at the proper height. Slabs that are too large to be ground over the whole surface at the one operation, are shifted once or twice during the grinding, to expose the surface equally to the action of the grinding plate.

The necessary pressure for grinding, is given by the weight of the horizontal plate, which is supported almost entirely by the work, as the pivots of the cranks merely enter the sockets, and allow the plate to descend when left to itself. For delicate works a counterpoise weight is attached to the double lever so as to regulate the pressure on the work.

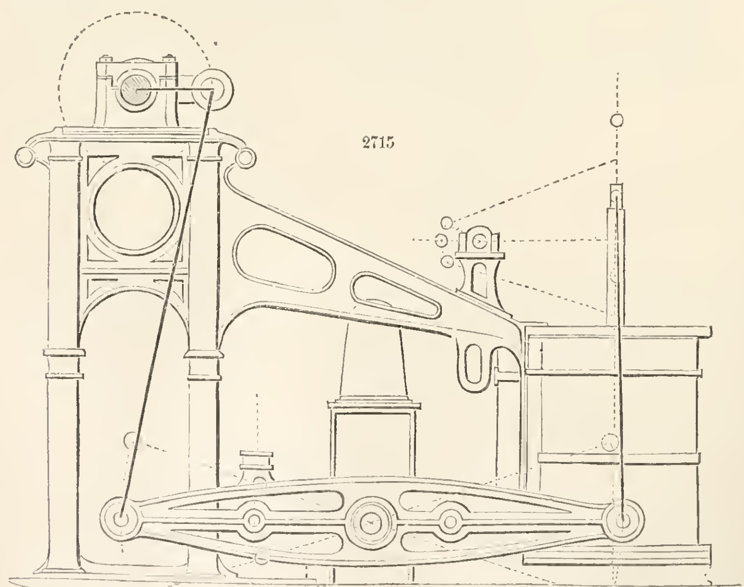
The sand and water are applied to the grinding surfaces in much the same manner as in the iron runners used by hand, previously described. The grinding plate is made on the upper side with a raised rim like a tray, and the bottom of the tray is perforated with numerous holes about 1½ inch diameter arranged at equal distances apart. The sand and water are thrown into the tray at intervals in small quantities, and run through the holes and between the surfaces of the slab and grinding plate, which are thus uniformly supplied with the feed that ultimately makes its escape around the edges of the grinding plate.

Various qualities of sand may be employed according to the perfection of surface required, and very flat surfaces are produced by this machine. The *grounding* or smoothing of the best works is effected with a succession of fine emeries, with which the surfaces may be made very smooth, and almost polished; but from motives of economy, the grounding of ordinary works is more frequently completed by hand, with grit-stone and snake-stone, before the work is finally polished on another machine.

Rectilinear mouldings in marble are wrought by machinery in a manner altogether different from the hand process of working mouldings, in which, as previously described, nearly the whole of the material is removed with chipping chisels, and the surfaces of the mouldings are only smoothed by abrasion. In the machine process, on the contrary, the whole of the material is removed with revolving grinders, by which the work is reduced to the required form, and left smooth at the one operation.

The machine for working rectilinear moulding, or as it is called *the moulding bed*, closely resembles in its construction the ripping bed described previously, except that the frame carrying the revolving grinders is provided with the power of vertical adjustment by a screw placed beneath, in order to raise the grinder to the proper height to suit the thickness of the marble, and that instead of the grinders being thin circular sheets of iron, they consist of solid cylinders of cast-iron turned to the counterpart forms of the required mouldings. Indeed the ordinary ripping bed is occasionally used for working mouldings on large works, and when it is provided with the vertical adjustment for elevating or depressing the axis to any required position, the ripping bed is equally suitable for working mouldings; but as the latter are in general only required on slips of marble only a few inches wide, a narrow machine is usually employed for the purpose.

2715



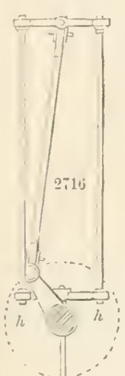
MARINE ENGINES, *Steam.* Marine engines may be divided into two broad classes, viz: beam or lever engines, and direct acting engines. These may be either condensing or non-condensing engines, the former, however, are the most extensively used. With the exception of small screw-propellers and tow-boats, and steamers on the western waters, the condensing or low-pressure engines are almost wholly used in this country. The terms high and low pressure are in general used to designate respectively the non-condensing and condensing engine, although the terms are not in truth sufficiently distinctive, as the condensing engine may be, and in connection with the expansion principle, frequently is, used with what may be called high steam. What would be considered in this country a low pressure steam, say 40 lbs. to the inch, would be considered in England as high-pressure.

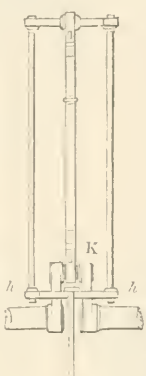
These two classes admit of subdivision into many varieties, but may, for all practical purposes, be confined to the following system of arrangement:

Beam-engine..Side-lever.

Direct-acting engine...
- Vertical..
  - Square engine.
  - Steeple engine.
  - Trunk engine.
  - Gorgon.
  - Fairbairn.
  - Double-cylinder engine.
- Oscillating,
- Rotatory.

The Direct-Acting Engines differ from the beam-engine simply in the method of taking the power from the piston-rod. In the one the head of the piston-rod is connected either directly with the crank, or by means of a connecting-rod or rods; in the other, the working-beam or great lever, vibrating on its centre, receives at one end the power from the piston-rod through the modifying action of "parallel motion" rods, or plain slides, and communicates it to the crank-shaft by a connecting rod attached to its other extremity.





The Side-Lever Engine is a modification of the beam-engine. In our river and coast boats the walking-beam or lever is above the engine, and single; but in the sea-going steamers two of these beams are used instead of one, and instead of being above the engine they are brought down to the bottom, one on each side, and being connected by a cross-tail, they act as a single beam or lever. Hence is derived the name from this disposition of the working-beam, the "side-lever engine."

The Beam-Engine, illustrated in fig. 1511, is the engine of the "Osceola," running on the North River, and may be taken as the type of a large class of engines in use on our coast and rivers. The boats worked by these engines are frequently on an immense scale, with engines of the most perfect construction, and are managed with great skill, very frequently attaining a speed of over 20 miles an hour. They have been employed successfully for sea-going steamers, as in the North Star and Vanderbilt, and come properly under the head of marine engines.

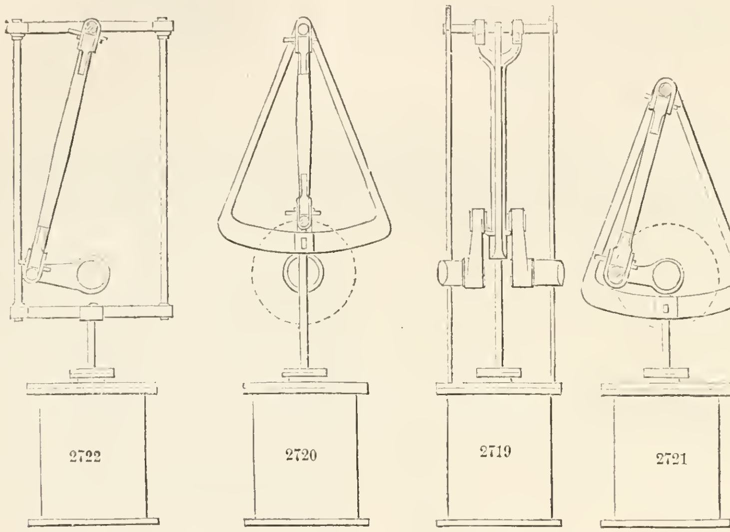
Fig. 2715 will give an idea of the general appearance of the *side-lever engine*, in outline. Of this character are the engines of the Collins line of steamers, as also the Cunard, the Havre, Charleston, New Orleans, and Chagres steamers, and in fact a very large majority of all sea-going steamers are of this description of engine. So universal indeed is its use, that when we speak of the marine engine, this form of engine is ordinarily understood, unless otherwise specified. For although other forms of engines may become of as much importance to steam navigation, certain it is that at this day no engine has been found to equal it in point of general efficiency. The description of engine called *oscillating* is, however, coming into favor, from other considerations to be noticed subsequently.

Passing to the varieties of the direct-acting engine, already defined, we find that the attempt to produce engines more compact and of less weight and bulk, has extended the examples of this class of engines into an almost endless variety of modifications. Scarcely any two are alike; and in our classification above, we have retained only those whose features are sufficiently distinctive to admit of generalization. Some engineers regard those engines only as direct-acting, where the piston itself seizes the crank, without the intervention of any connecting-rods. Such are the trunk and oscillating engines; but the classification we have used is simple, and sufficiently minute for all purposes.

In the first species of the direct acting engine, namely, the vertical, the paddle-shaft is directly over the axis of the cylinder; but the method has the disadvantage of admitting only a short stroke and a short connecting-rod, and requires that the height of the axis above the bottom of the cylinder should be at least three times the length of the stroke. Thus one of the extremes, too short a connecting-rod, too short a stroke, or a paddle-axis too high above the floor of the vessel is incurred.

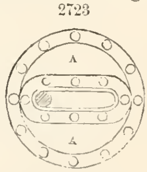
In this country the square engine, the first variety of the vertical engine, has its cylinder immediately over the axis and cranks, to which motion is communicated from the cross-head of the piston by means of side-rods, the air-pump being worked by a separate beam connected with the cross-head by proper links; but this is equally unsuited to sea-going steamers on account of the height of the cylinder above the paddle-shaft.

To obtain the object sought without incurring these evils, many descriptions of engine have been contrived; among others the steeple engine, so called, where the piston-rod is made forked, so as, passing round the shaft, to rise above it to a considerable height, from which again descends the connecting-rod to the crank. Figs. 2716 to 2721 illustrate the principle. The top of the piston-rod carries a four-armed cross-head *h h*, on each end of which stands a pillar *h h;* these four pillars again unite in another quadruple cross-head, sustained upright by a vertical guide; and it is from this summit that a connecting-rod descends to the crank K.



After passing through a great variety of phases the steeple engine appears to have settled down into the two following shapes. In figs 2720 and 2721 the piston-rod is seen united to a triangular frame, from the apex of which the connecting-rod descends to the crank. In fig. 2722 this frame is shown to be square, and fig. 2719 is the side view of both varieties.

2723



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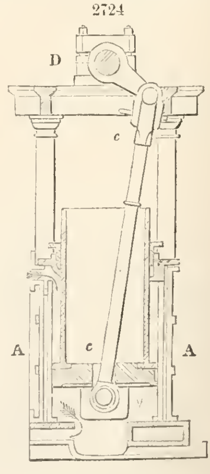


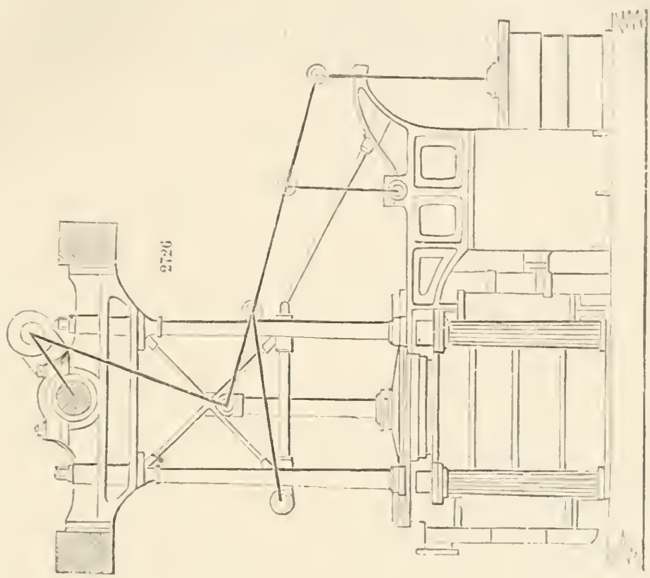
Another method of accomplishing the direct connection without encumbering the deck is called the *trunk engine.* The axis is placed at the height of half the stroke, or more, above the cylinder, and a connecting-rod unites immediately the crank-pin with the centre of the piston. In this way the connecting-rod, passing through the top of the cylinder, would allow the steam to escape but for a large trunk or casing with which it is surrounded, and which, passing through a chasm of large area conceived to be steam-tight, rises and falls with the piston to which it is attached. In fig. 2724, A A is the cylinder; to its piston is attached a trunk B, which works through a stuffing box in the cylinder cover; to the piston the connecting-rod *c c* is attached. Fig. 2723 represents the top of the cylinder A A, with its stuffing-box and the trunk.

These engines were first used for marine purposes with vertical cylinders, and were again introduced into use by Penn, of Greenwich, with horizontal cylinders. The first application of it was to H. M. S. Encounter, a vessel of 360 horse-power. The cylinders are horizontal, and connected at once to the screw-shaft. These engines make between 78 and 80 revolutions per minute, which was sufficient to propel the ship about eleven knots. They were fitted with locomotive slides, and worked with two eccentrics. The air-pumps, like the cylinders, were horizontal; and indeed all the parts of the engines were as low as they possibly could be, for the purpose of bringing the machinery below the water line.

This form of engine was used by the Messrs. Kemble, for the steamers "Pioneer" and "City of Pittsburg." In these the cylinders are again brought back to the original vertical position, and form, notwithstanding, a most compact form of engine.

The Gordon, Fairbairn, and the double-cylinder engines are English varieties of direct-acting engines extensively used abroad, but little used in this country; they deserve a passing notice, as illustrative of the efforts made to reduce the dimensions of marine engines within the least possible limit.

The principle of construction of the *Gorgon engines* will be clearly seen by reference to fig. 2725, which represents a section of one of such engines; and the several parts, for simplicity sake, are represented



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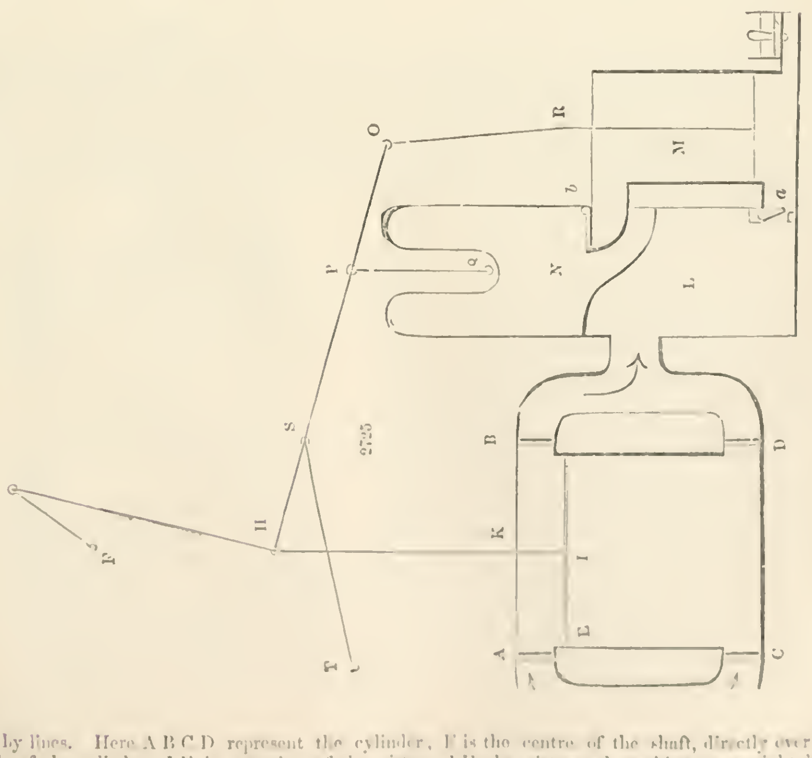
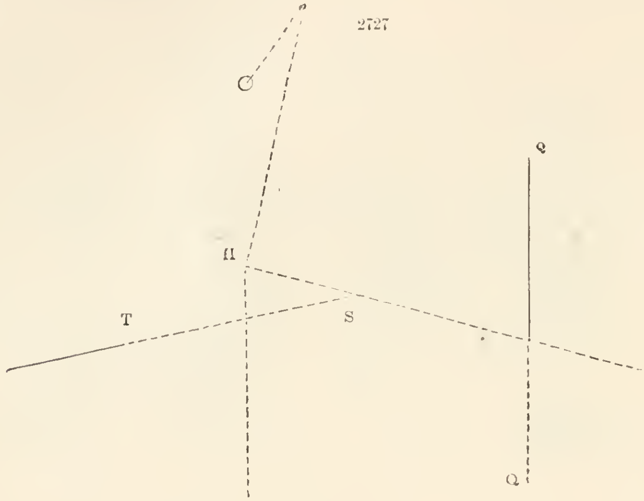


2725

only by lines. Here A B C D represent the cylinder, F is the centre of the shaft, directly over the middle of the cylinder; I E is a section of the piston; I H the piston-rod, working steam-tight in a stuffing-box at K; H G is the connecting-rod, and G F the crank. It is easily seen that as the piston is forced up and down by the steam, the crank will be made to revolve, and consequently cause the paddle-wheel to rotate. The remaining parts of the engine will be readily understood: L is the condenser, M the air-pump, N the hot well, *a* and *b* are the foot-valve and delivery-valves respectively. There are two particulars deserving special notice in this engine, viz.: the slides for admitting the steam and allowing it to escape, and the parallel motion, or the means of keeping the piston-rod in its vertical line. It is observable that there are four slides, viz.: A, B, C, and D, two of which, A and C, are for allowing the ingress of steam, and the other two, B and D, for allowing it to escape to the condenser L. The following is an outline of the parallel motion: H O is a beam called the "rocking-beam," one end of which



2727

is fitted to the upper extremity H, of the piston-rod. P Q is a vertical frame, called the 'rocking-standard;" the lower end of this is connected with some convenient point Q, about which it can move, and the upper end P will therefore describe a small circular arc about Q; but this arc will be so small that it may be practically looked upon as a straight line. T S is a bridle-rod, secured at one end T to the framework of the engine, and at the other to the rocking-beam. If, now, these rods have the proper proportions, the motion of H will be vertical. The rocking-beam is continued along to O, and the air-pump rod is fitted to it by means of the intermediate rod R O. The air-pump rod is kept in a vertical line by means of guides.

Fig. 2726 represents an outline of the Gorgon engine.

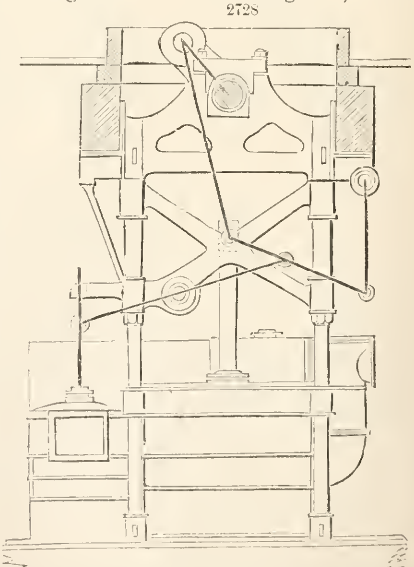
The chief peculiarity of Fairbairn's direct-acting engines is in the parallel motion, which is somewhat similar to that of the Gorgon engines.

The dotted lines, fig. 2727, represent the Gorgon engines. H P O is the rocking-beam; H the point to which the piston-rod and connecting-rod are attached; P the point of attachment of the rocking-standard; then, to construct Fairbairn's parallel motion, let the rocking-standard P Q be inverted, as in the figure, so as to hang down from a point Q′ in the entablature of the engine. In the Gorgon engines, H P is prolonged to O, as before described, and the air-pump is worked from this extremity; but in Fairbairn's engines the radius-gear S T will be produced to some point O′, and O′ T serves as the beam for working the air-pump. The steam is admitted and allowed to escape by means of a slide-valve, worked by an eccentric.

The four main parts of each engine, viz.: the cylinder, slide-valves, condenser, and air-pump, form a square, and thus occupy little space.

Fig. 2728 represents in outline one of the Fairbairn engines.

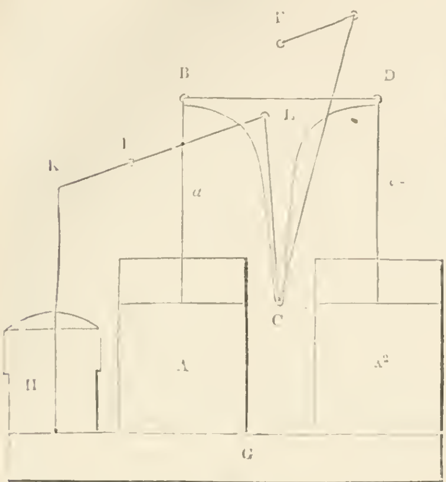
2728



Maudslay's Double-Cylinder Engines. In the foregoing direct engines the connecting-rod is necessarily shorter than it would have been if side-levers had been used; and consequently the force exerted on the crank alters more suddenly as the motion is alternated from the up to the down stroke, and *vice versa*, than would have been the case had the connecting-rod been longer.

Now, in most direct engines a long connecting rod is an impossibility; for the distance from the shaft to the bottom of the vessel being limited, the depth of the cylinder, the radius of the crank, and the length of the connecting-rod, must all be accommodated to it. Messrs. Maudslay and Field proposed to remedy it by adapting two cylinders to each engine, instead of one; the cylinders having one connecting-rod between them. In figs. 2729 and 2730 A and A^2 are the two cylinders of one of the engines; a a^2 the piston-rods; these rods are connected together at their upper extremities by the cross-piece

2729



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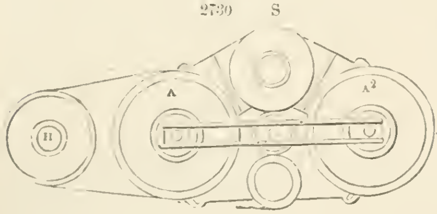
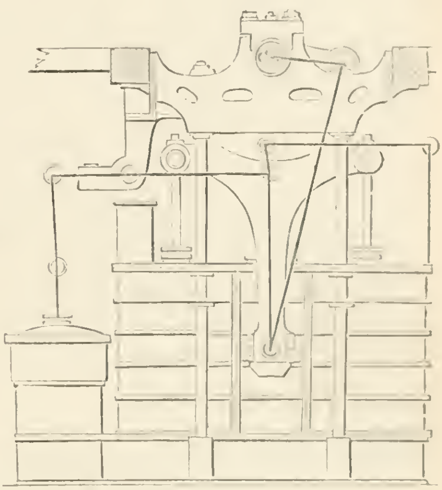


2731



B C D, called (from its form) the T-plate; the lower end C of the T-plate is attached to the connecting-rod C E, which again being connected with the crank E F communicates with the paddle-shaft F. The condenser G is underneath the cylinders. It is clear that if steam be admitted below both pistons at the same time, the pistons, in rising, will force up the T-plate, and with it the connecting-rod, &c.; and conversely these will again descend as the piston is forced down. Hence the working part of the engine can be comprehended. It remains to be shown how the steam is admitted to both cylinders simultaneously. Looking at the plan of the figure, the circle S represents a slide-valve, different in form from the common slide-valve, inasmuch as it is circular instead of being semicircular; it has one upper and lower face in contact with the ports of the cylinder A, and one of each in contact with the cylinder A^2, so that as the valve is raised or depressed, the steam is admitted above or below both pistons at the same instant of time. H is the air-pump, the bucket of which is worked by the beam K L moving round the centre I.

2732

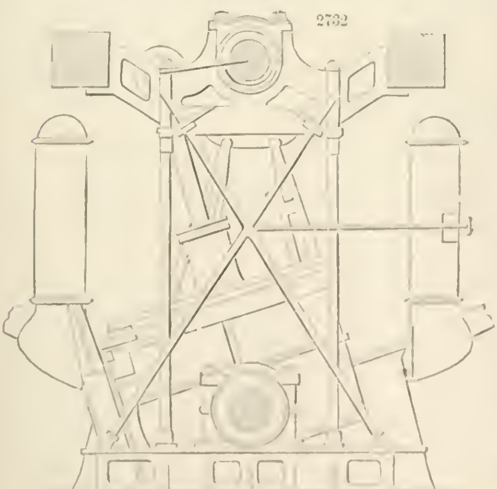


Fig. 2731 is an outline elevation of the double cylinder engine.

In the *oscillating engines* the connecting-rod is altogether dispensed with, the piston-rod being attached directly to the crank; and because the piston-rod from this mode of attachment, must either be bent when motion ensues, or the top of the cylinder must move laterally, this is provided for by allowing the cylinder itself to vibrate in a small arc, effected by casting trunnions on to the cylinder near its middle, as an axis upon which it oscillates.

Fig. 2732 will give an idea of the appearance of the oscillating engine.

Many nautical men, and some engineers, have objected to oscillating engines on account of the movement of the cylinder, which, they imagined, would become a formidable evil in the case of a vessel rolling heavily at sea. These objectors do not seem to have remarked that the rolling of the cylinder is neither dependent upon, nor proportionate to, the rolling of the ship, but is regulated exclusively by the movement of the piston; and it is difficult to see why a mass of matter, in the form of a cylinder, should be more formidable or intractable in its movements than a similar quantity of matter in the form of a side-lever, or in any other shape whatever. It has also been objected against the oscillating engine, that the eduction passages are more tortuous than in common engines, so that the steam gets out of the cylinder less freely. We do not believe such to be the fact, if the comparison be made with the common run of marine engine; and in practice, no diminution of efficacy from this cause is appreciable. All the objections that have been raised to the oscillating engine are hypothetical; they are anticipations of defects *to be* found out in large engines on the oscillating plan, and would probably be plausible enough to carry some weight, were it not the fact that they have been completely controverted by experience. The remark, indeed, is heard sometimes even yet, that the oscillating method may do very well for small engines, but is of doubtful efficacy for large ones. But the definition of large engines has been continually changed, to escape the contradiction experience afforded, and that size is, in every case, decided to be large, which just exceeds the size of the oscillating engine last constructed. The grounds of this skepticism, however, are now being fast contracted; and, indeed, experience has now demolished every objection that theory had raised. Some persons have apprehended that it would be difficult in large oscillating engines to obtain sufficient surface of trunnion to prevent the trunnions from heating; yet we have never been able to learn that any heating of those bearings has been found to occur in practice, and it appears probable that any such disposition would be resisted by the cooling effect of the steam passing through them, which, though hot, is of greatly inferior temperature to that of a hot bearing. It does not appear to us, however, that the trunnions may not be made with any amount of surface that is thought desirable, but we believe the proportion adopted by Messrs. Penn have been found adequate, and are generally adopted in this country.

Rotatory Engines are engines for obtaining a motion round an axis by the direct action of the steam, without involving the necessity of reciprocation. Some of them operate on the principle of reaction of which the engines of Avery and others may be taken as specimens; others operate on the principle of impulse; a third kind trusts to the intervention of some liquid to produce the desired effect, as in the mercury engine of Watt and the wheel of Amonton; while in the fourth class the piston moves in a circle round the axis. It is impossible to give any enumeration even of the numberless schemes for rotatory engines that have at various times been projected; but none of them have been applied with any prospect of success to the purposes of navigation, and in their present state, need scarcely be ranked as marine engines.

MARINE STEAM-ENGINE, *of one hundred and forty-five horse-power.* By CAIRD & Co., Greenock. The following figures illustrate very fully the form and construction of marine engines made by Messrs. Caird & Co. of Greenock, for the steam-packets Actæon and Achilles, and also for the royal mail-packet Urgent, still plying betwixt Liverpool and Dublin. The drawings were made from the engines of the Actæon, since lost on the West-India station; but in order to render them more complete, and therefore more acceptable to the engineer, the expansion-geer subsequently applied to the engines of the Achilles has been embodied. It may also be remarked, that by proportionally reducing the scale of the drawings, they will be found to agree in every respect, beyond a few very slight modifications of a technical kind, with the larger class of engines, since constructed by the same spirited firm for the West-India mail-packets Clyde, Tay, Tweed, and Teviot, of 225 horse-power each engine. The figures may thus be regarded as giving a general representation of the form of marine engines built by a firm to whose engineering skill the profession is indebted for a design of engine equally remarkable for elegance of appearance and compactness of arrangement. In lightness of material it is no doubt surpassed by the recent introduction of malleable-iron framing, and direct-action; but in the class to which it belongs, known as *side-lever engines*, it exhibits a massiveness of appearance and an economy of weight which, in combination with equal strength, has not hitherto been surpassed.

Enumeration of the figures.—Fig. 2714½ exhibits a complete side elevation of the engine, showing the general design and arrangement of the framings, and the relative positions and connections of the working parts; the valve, expansion, and starting geer, parallel motions, and situation of the pumps. In this view the side of the vessel is supposed to be removed and the engine seen *in situ.*

Fig. 2715 is a plan of the sole-plate of the engine with all the parts removed, but showing the position and provision for fixing the steam-cylinder bottom and valve casing, the hot-well, placed on the top of the condenser, the air-pump, and the soles of the main framing.

Fig. 2716 is a general plan of the engine, exhibiting very fully the starting and eccentric geer, the mode of working the pumps, the direction and position of the steam-pipe, and mode of connecting the diagonal framing; also the horizontal relation of the valve and expansion geer.

General description.—Sole-plate and condenser.—The sole-plate, marked A A, with the condenser U, consists of a single casting, double-ribbed on the under side, to give it additional strength and rigidity. For facility of fitting it is provided with fitting-strips on its upper surface; these are faced true to receive the soles of the main frame and cylinder bottom, which are fitted upon it metal to metal, and consequently are likewise provided with corresponding fitting-strips, faced in the same manner. The sole-plate is firmly secured to the keelsons of the vessel by sixteen strong malleable-iron bolts marked *a* in the elevation, and the recesses for which are similarly designated in the plan of the sole-plate. The middle of the plate, falling between the two keelsons, is depressed to allow the condenser and its appendages to stand lower in the vessel than they otherwise would, as shown in the general section.

Framing.—The main framing of the engine consists of four strong fluted columns, cast pair and pair with their soles and entablatures. The soles, as above observed, are fitted upon the sole-plate metal to metal, and are secured to it by bolts and keys, for which snugs are cast on the sole-plate. The entablature is completed by two cross-beams corresponding in form with the sides, into which they are fitted and secured by bolts. The form of their cross-section is shown in the general section of the engine.

The upper or crank framing consists likewise of four columns cast pair and pair with their soles and entablatures; but in this case there are no cross pieces, the two sides being simply braced together by two strong malleable-iron stays marked *c*. One of these passes between two strong lugs cast on the back columns near the top, and the other between the cheeks of the *diagonal framing* marked C. The crank-framing rests on the entablature of the main frame to which it is fitted, and secured by bolts and by two centre keys in each sole, driven on the right and left of a dovetail snug cast on the entablature of the lower frame, and which enters a similarly formed but larger recess in the sole of the upper frame —an arrangement which is clearly shown both in the general elevation and section. This framing is further secured between the ship's beams by the strong stays *b b* cast upon the entablatures. These stays usually abut against cast-iron face-plates, bolted upon the paddle-beams at the points of contact, but they are neither bolted nor otherwise fixed to the facings, but are left free to slide vertically upon them in obedience to any spring which the vessel may have when under way, and which is often considerable, especially in a rough sea. The crank-framing is also braced to the steam-cylinder by the diagonal framing C C, consisting of two strong parallel struts cast upon the inner columns of the crank-framing, from which they spring. These struts terminate in rectangular flanges, answering to similarly formed projections cast on the cylinder on opposite sides of the valve-casing at top; and to these they are carefully fitted metal to metal, and secured by bolts, as partially shown at *d* in the elevation and plan.

The principal use of the crank-framing, and that from which it takes its name, is to support the crank-shaft. This is accomplished in each of the engines by two plummer-blocks, one on each side of the crank, secured by bolts and keys on the entablatures of the frames. The soles of the plummer-blocks are in this, as in all highly finished engines of the same class, likewise faced and fitted metal to metal.

Steam-cylinder.—The steam-cylinder E is cast open, and with broad and strong flanges at both ends. It is placed upon a separate bottom piece, flanged like the cylinder, to allow of their being bolted together. This bottom piece being truly faced, above and below, is secured to the sole-plate of the engine by strong bolts, and rusted. The lower end of the cylinder being truly faced is similarly fitted upon and secured to the upper flange of this bottom piece, so that the whole may be perfectly steam-tight.

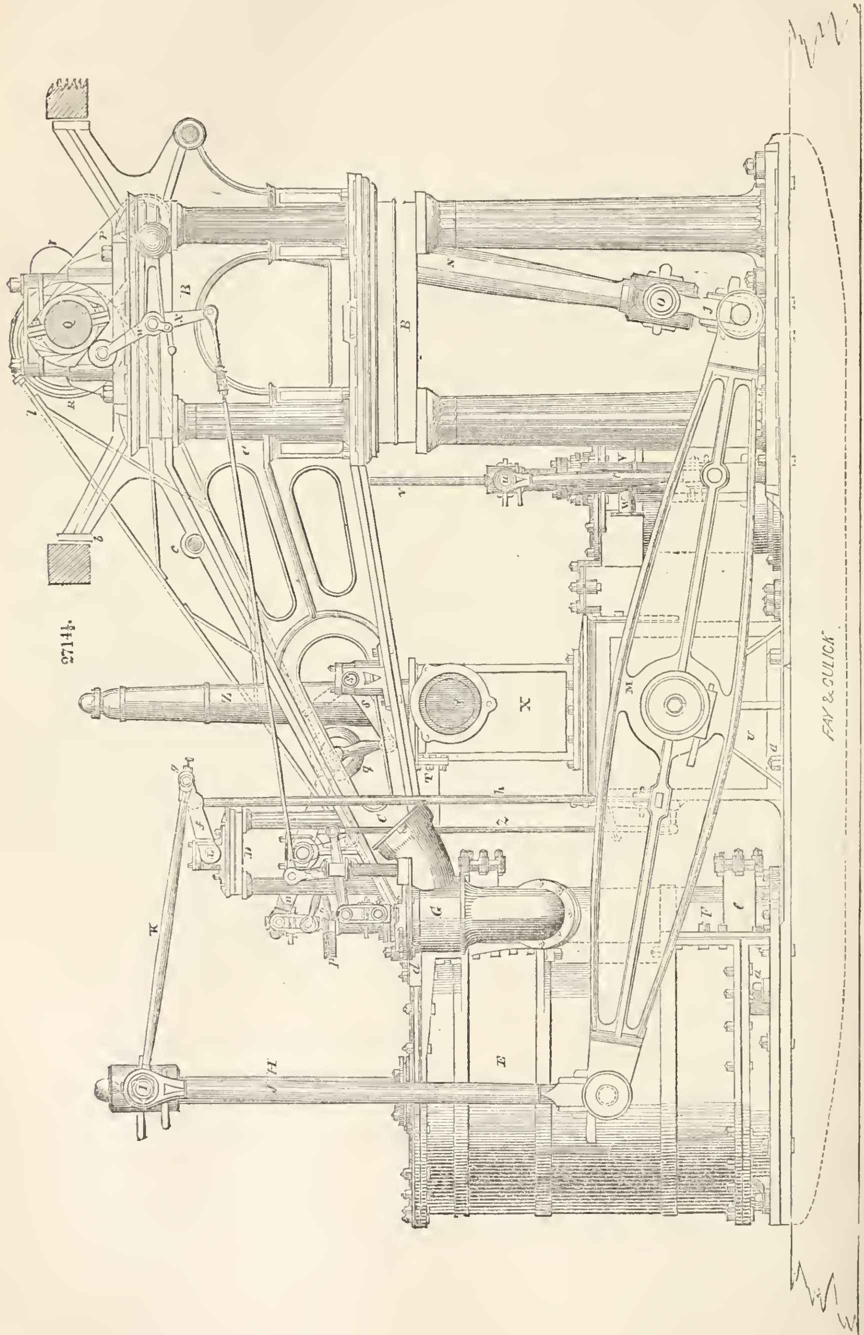
The interior of the cylinder is bored as truly as possible of a uniform inside diameter of sixty-two inches. The cover *d'* which, as will be observed from the section, is cast hollow, is fitted by turning and grinding, into the upper end to nearly the depth of the steam-port. On the inside is a circular recess to receive the heads of the bolts of the junk-ring of the piston; and the exterior plate is expanded by a strong flange to the same diameter as the flange of the cylinder, to which it is secured by bolts. In the centre is formed the stuffing-box through which the piston-rod ascends.

The projecting corner pieces marked *d* are those to which the diagonal framing is attached; they are faced both on their horizontal and vertical surfaces, so that the corresponding flanges, in which the struts of the framing terminate, may be fitted truly upon them. The projecting valve facings are cast of a piece with the cylinder. These are carefully dressed and the whole surface of both exactly reduced to the same plane; and to complete them, a carefully finished facing of brass, but of less breadth, (two inches,) is applied steam-tight round each of the ports, and projects on each side, by runners of a length corresponding to the length of the ledgings of the valves. The outlines of these facings are indicated in the view above referred to, and the transverse form in the general section of the engine.

The piston.—The body of the piston consists of a single hollow casting, strengthened by radiating feathers, with a strong eye in the centre to receive the piston-rod. The under side is a portion of a sphere answering to the curvature of the bottom of the cylinder. The upper side in like manner is convex to its junction with the ring, which is horizontal, and corresponds to a horizontal part round the inside of the cover, within which the cover is a segment of a hollow sphere of the same radius as the top of the piston. By making these parts of a curvilinear section, they are better secured from rupture by changes of temperature; and the piston being symmetrical in its outlines with the cover and bottom, the loss of steam due to the *clearance* is reduced to a minimum.

The under side of the piston only is cast of a diameter equal to that of the cylinder, the deficiency on the upper side being made up by the *junk ring.* This ring is fitted steam-tight, first by turning and subsequently by grinding. Packing rings, consisting of two thicknesses, made up of overlapping segments, are likewise fitted into their place between the junk ring and the flange corresponding on the under side of the piston and are rendered steam-tight by the same means. The whole of these thicknesses, composing the edge of the piston, are simultaneously turned of a uniform diameter, precisely equal to the internal diameter of the cylinder, in which they are intended to work steam-tight; but as this condition would endure only for a short period, however carefully and exactly the fitting might be effected, were no provision made for compensating the wear incident to the continued motion of the piston, and especially under variations of temperature, as in starting, the packing-rings are rendered capable of adjusting their diameter to that of the cylinder, by springs placed behind them. The springs employed in this piston are of a U-form, placed vertically, the strong side bearing upon the piston, and the elastic side against the adjacent ends of two of the segments. The number of springs and segments is thus necessarily equal, and so arranged that every segment is supported at each end by a spring. By this means the piston is made to work in the cylinder steam-tight, and to accommodate itself to any slight variations due to the contraction and expansion of the materials; and likewise to compensate for wear of its own circumference and that of the cylinder.

The junk-ring is secured in its place by bolts and nuts; the nuts are placed in recesses provided for them in the metal of the piston, and the bolts are screwed into them from the outside. The heads thus project on the surface of the ring, and would come into contact, at the end of the up-stroke, with the cylinder cover, but for a circular recess formed in it for their reception, as before noticed.

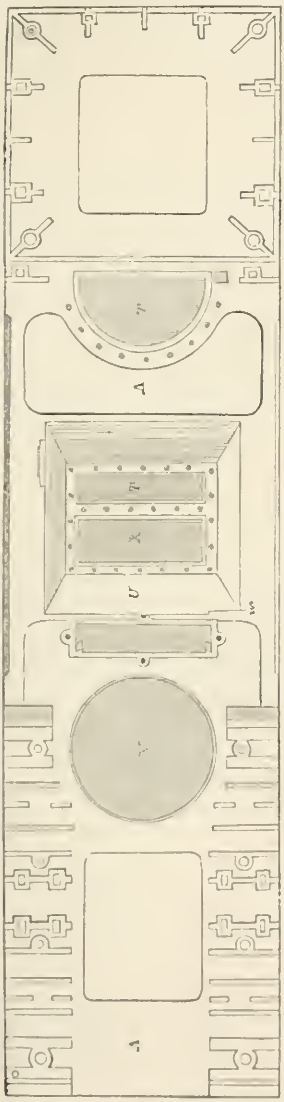


2714½.

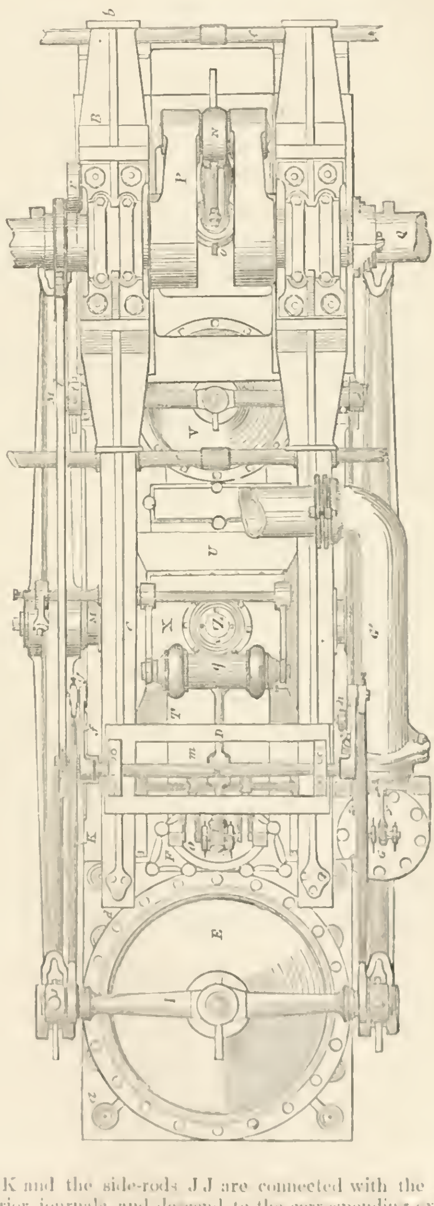
The piston-rod H is inserted into the piston through the eye in the centre, which is bored and tapered from the under side. The rod is of malleable iron, and turned, the body of it truly cylindrical, so that it may work freely in the stuffing-box through which it ascends, and the lower end with the same taper as the eye into which it is fitted, and in which it is secured by a cotter-key traversing the metal of the eye and the thickness of the rod thereby effectually binding the latter to the piston. For convenience of inserting the key a recess is left in the upper plate of the piston, which is afterwards filled, to prevent the steam gaining admission to the hollow interior of the piston.

Piston cross-head and connections.—The piston-rod, ascending through a packed stuffing-box, is inserted into an eye, bored a little smaller than its own diameter in the cross-head I, equidistant from the two extremities; and is then fixed by two gibs and cotter in the usual manner. The cross head has two journals turned on each of its ends, separated from each other by ruffs of an inch

2715.



2716.



breadth. By these journals the radius-bars K K and the side-rods J J are connected with the cross-head. The side rods are fitted upon the exterior journals, and descend to the corresponding extremities of the side levers M M, to which they are also flexibly attached. Their connection at the cross-head, as will be observed from the elevation, is by solid eyes formed in the ends of the rods and bushed, the brasses being retained in their places by the collars of the cross head, with the assistance of a key bearing against the back of the lower brass; but the connection with the side levers is effected differently. Here the brasses are placed within strong malleable iron straps, bent at the middle of their length till their projecting ends fit closely upon the rectangular ends of the side-rods, to which they are secured by a gib and cotter. This species of connection, technically known as the *butt-end and strap,* and universally adopted in like circumstances, provides for any slight wear of the brasses for should these become too large, they can be brought closer together by driving the cotter more tightly, the holes through which the gib and cotter pass being so disposed in the strap and butt that the gib shall only be in contact with the ears of the strap and the cotter with the butt on its under edge. The holes in both strap and butt being thus of greater breadth than the gib and cotter together, the connection admits of adjustment to the extent of the difference, and no further, for then the edges of the holes being in the same plane, the relative positions of the strap and butt will not be altered by any subsequent action upon the cotter.

The side-levers are divided at their extremities at the point of connection with the side-rods J J and the links *j j*, which connect them with the cross-tail. The joints are completed by strong malleable-iron pins which pass through the jaws of the levers, and the bushes of the straps which are placed between them. These centre pins are turned with a little taper on the parts which pass through the levers, and the holes made for their reception are accurately bored to the same diameter and ground. The studs are driven in tightly from the outside, and secured in their places by riveting at the opposite extremity.

Both levers are suspended upon the same axis called the *main centre*, M', which passes through and is fixed in the sides of the condenser. It will be observed that the eye of the lever is fitted with brasses which can be tightened as they wear by a pair of cotter-keys, passing through the boss and bearing against the back of the under brass. Inside, and bearing against the shoulder of the boss, is a ring of malleable iron, of sufficient breadth to cover the margin of the eye to fully an inch beyond the circumference of the brasses, thereby preventing the lever from deviating inwards: and to prevent it from shifting its position outwardly, a plate of the same external diameter is applied by a strong bolt screwed into the end of the main centre.

The side-levers are connected with the connecting-rod N by means of the cross-tail O and links *j j*. The connecting-rod passes through an eye at the middle of its length, and is fixed by two gibs and a cotter, in the same way as the piston-rod is attached to the cross-head, while the links are connected in the same manner as the side-rods, except that the upper ends do not admit of adjustment, being simply riveted in the eyes. The attachment of the connecting-rod with the crank is likewise by a butt-end and strap, the cotter of which is tightened and maintained in its place by a screw and nuts. The crank-shaft Q rests, as before observed, on pedestals fixed upon the entablature of the crank-framing, and is prevented from moving on end by ruffs on the outsides of the pillows, and by the shoulders of the crank-brasses inside.

It may be noticed that the piston-rod, side-rods, cross-head, main centre-shaft, cross-tail and links, connecting-rod, and crank-shaft are all formed of the best malleable iron, and turned and pared to the requisite forms and dimensions.

The parallelism of the piston-rod is maintained when the piston is in motion, by the two radius bars K K, by the radius levers *f f*, fast upon the ends of the shaft L, called the *parallel-motion shaft,* and by the parallel bar *h*. The ends of the radius bars K K, on the cross-head are formed with solid eyes, fitted with brasses, the inner of which are tightened by keys, in the same manner as those of the side-rods which are attached at the same points. The eyes at the opposite ends, which work upon studs in the radius levers *f f*, are formed in the same way, but are smaller, and have the outer brasses adjustable by screwed-pins *g g*. The length of the bar thus admits of slight adjustment between its centres, to compensate for errors of workmanship and wear of the bushes. The parallel bar *h* is also attached by a solid eye and stud to the lever *f*, and admits of still more extensive adjustment at its lower end. This bar, it will be observed, is formed in two pieces, with the contiguous ends screwed right and left, and embraced by a long nut similarly screwed. By turning this nut to the right or left it is obvious that the upper and lower ends will be made to approach or recede, and the distance between the centres be thereby diminished or increased. The upper end of the rod is formed with a solid eye bushed, and the lower with a butt-end and strap in the usual way; it is attached to the exterior side-lever by a malleable-iron stud inserted into a rectangular eye formed in the latter.

The disposition of the flexible points of these connections being such, that in every position of the piston the angles of the parallelogram formed by the part of the side-lever comprehended between the stud of the rod *h* and the junction of the side-rod, opposed to the radius bar K, and by the parallel bar *h* and the side-rod J, shall change proportionally, always preserving the same constant ratio, it follows that the piston-rod cross-head will move constantly in the same place and the parallelism of the piston be thereby maintained.

The parallel-motion shaft L is supported by two plummer-blocks, resting on the entablatures of the small pillar-framing D. This framing, called the *parallel-motion framing*, consists of four columns, cast, like the larger framings, pair and pair, with their soles and entablatures, and with provision on the latter for bolting and keying the pedestals. The soles rest upon oblique flanges cast on the diagonal framing C C, to which they are secured by bolts and keys.

The valves and valve-geer.—The valve casing F is cast of a semi-cylindrical form, corresponding to the form of the valves, which are of that kind designated, in accordance with their outline, short D-slides.

The casing is fitted steam-tight and bolted to the side of the cylinder by projecting flanges cast on both for that purpose; and also to the sole-plate over the recess T', shown in the general elevation The flat side, as will be observed from the general section, occupies only about a third of the whole length equidistant from both ends, and is cast with projecting flanges, which are carefully fitted steam-tight between the ends of the projecting faces of the cylinder. These faces thus project inside, but are concealed by the circular part of the casing, in which, it will be observed, when the cover is applied, there is no communication with the external atmosphere; through the passages T it communicates with the condenser U, and through the steam-ports with the cylinder. The steam-pipe G likewise opens into it, and a communication is thereby effected with the boilers.

The valves, as already noticed, are of the kind known as short D-slides. There are two of these, one to each port of the cylinder. The backs are turned truly circular, and the faces are planed and ground to the brass facings of the ports, so that they may slide upon them steam-tight, and with as little friction as possible. They are kept tight against the faces, and also rendered steam-tight in the casing by hemp packings, introduced through the *packing-ports* cast in the casing. These packings are covered by the packing-rings which are pressed against them by set pins acting in nuts between the packing-rings and the port-covers, as fully shown in the general section. These set pins can be tightened at pleasure by a box key, inserted through holes formed in the covers, and filled with hollow plugs, which can be withdrawn when necessary.

The planes forming the faces of the valves are slightly less than double the breadth of the port, but the circular parts are necessarily much larger. The faces and backs are connected by strong diaphragms, through which pass the ends of the rods which couple the two valves together. These rods are turned to an exact length between the ruffs, against which the contiguous sides of the diaphragms bear, and are kept fast in their places by nuts upon their protruding ends. They are stiffened at the middle of their length by a cross-stay. A strong stud is inserted downwards in the middle of the diaphragm of the upper slide, and is retained in its place by a nut on the end projecting below. The upper end is formed with strong projecting lugs, between which the enlarged square end of the valve-spindle is received, and retained by a strong square pin which passes through the lugs of the stud and the end of the spindle, thereby forming an inflexible joint at the point of connection.

The valve-spindle passing through a packed stuffing-box in the cover of the valve casing, is attached by means of a small cross-head and side links, to the lever *n*. This lever is fast upon the transverse shaft *m*, which has its bearings immediately under those of the parallel-motion shaft in the framing D. On the opposite end of the lever *n*, is fixed a weight *q*, sufficiently heavy to counterpoise the weight of the valves. This weight is connected with the shaft S, called the *starting-shaft*, by two small levers *s s*. These levers are fast upon the shaft S, but are flexibly connected to the axis of the weight *q*, by two short connecting-rods jointed to each. The shaft S is carried on pedestals fixed upon the cheeks of the diagonal framing C C, and has a short lever crank keyed upon the end projecting to the inside of the engine. A long lever is fitted to this fixed piece by a hollow boss which passes upon the tail, but, being required only occasionally, it is not fixed, that it may be removed when not in use, and for that reason it is not shown in the drawings; but supposing it applied, it is plain that by moving it towards the right and carrying the shaft S with it in the same direction, the balance weight *q* will be elevated and the valves depressed. The reverse action will produce the reverse effect by again lowering the weight and raising the valves. Now, observing in the section that the lower steam-port of the cylinder is open to communication with the condenser, and that the upper port communicates only with the interior of the casing, if the weight *q* be raised until the valves descend through a space equal to the breadth of the faces, it is clear that the conditions will be reversed, and that the upper port will be opened to communication with the condenser, through the passage T, and that the lower passage will be shut, and the lower port will communicate with the interior of the casing.

Upon one end of the traverse-shaft *m*, is a crank-arm, upon the pin of which a gab formed in the end of the compound rod *l l*, called the *eccentric rod*, rests. This rod, which consists of two bars of malleable iron stiffened by diagonal braces, is attached at its base to the two opposite lugs of the eccentric ring R, which works freely upon the eccentric embraced by it, and which revolves with the crank-shaft of the engine; consequently, supposing the crank to revolve, the rod *l l* will at the same time receive an alternating rectilineal motion, which being transferred to the crank-lever of the traverse-shaft *m*, will cause the ends of the lever *n* alternately to ascend and descend. But the valve-spindles being attached to this lever, its motion will be transferred to the valves, which will thus be made alternately to ascend and descend in the same manner as when a lever is applied by manual strength to the shaft S. This is the action necessary to maintain the motion of the engine, as will be explained.

As in the case of the piston-rod, the parallelism of the valve-spindle is maintained by means of the links *o o*, arranged as in the common parallel motion of stationary engines. The radius rods are attached to opposite sides of a small framing consisting of two columns, fixed on the cover of the valve casing, and having their entablature *p* of a semicircular form to allow the cotters of the cross-head links to pass when the engine is in action.

The condenser and its appendages.—The condenser U and the lower exhaust passage T′ T′ are cast of a piece with the sole-plate. Two strong eyes are cast in the sides of the condenser to receive the main centre-shaft M′, which passes completely through it. In the top is an opening for the upper exhaust passage T T, the vertical part of which is cast of a piece with the hot well X. This also rests upon the condenser, but is separated from the interior by an inflected partition.

The cold water for effecting the condensation of the steam which passes into the condenser by the exhaust ports, when the engine is in action, is admitted by an injection pipe. This pipe passes through the side of the vessel and communicates with the water without; but in order to regulate the supply a valve is placed in the pipe, close upon the condenser; its position is marked by *r* in the plan of the sole plate. The face upon which the slide works is formed on the side of the condenser at *r*, over which the casing is fixed. The mode of working the valve is by a small brass spindle which rises through a packed stuffing box in the cover of the casing; this is attached to a long lever passing to the opposite side of the engine, and which can be more or less depressed at pleasure, to allow of a larger or smaller supply of injection.

The part of the pipe within the condenser, passes completely across, and is perforated with numerous small holes to diffuse the water more completely in the body of the condenser, and thereby render it more effective. To prevent the water from passing into the lower exhaust passage, a shelf is attached over the opening, which, throwing the water over the edge of the partition into the body of the condenser, prevents it from accumulating in the passage, and at the same time renders the water o more avail than if it had been allowed to strike against the side of the condenser.

The air-pumps and valves.—The condenser communicates at bottom by a valve, called the *foot-valve*, with the air-pump V, the barrel of which is 4½ inches, clear of the sole-plate, thereby leaving space for a body of water to enter it from below. The barrel of the pump is bored and lined with a thin cylinder of brass turned to fit within it. A strong flange is cast round it at 11 inches from its lower end, which is fitted water-tight, and bolted to the margin of a circular opening cast in the upper division of the sole-plate, for the reception of the lower end of the barrel, as shown in the section, and also in the plan of the sole-plate.

The bucket consists of a ring connected to the eye at the centre, into which the rod is fitted by four arms. The under side of the ring has a flange cast upon it of one inch breadth, between which and the projecting ledge of the junk-ring, bolted on the upper side, a packing of hemp is retained. But before applying this packing, both the flange and the junk-ring are turned to work easily in the barrel. The pump-rod is sheathed also with brass, to prevent corrosion by contact with the water. To apply this sheathing, the rod, which consists of malleable iron, is first roughly turned; it is then thoroughly cleaned and taken to the brass foundry, where the covering of brass is cast upon it, of somewhat more than the required thickness. It is again put into the lathe and turned to the requisite diameter. The rod, which thus possesses all the advantages of strength and diminished liability to corrosion, is retained in the tapered eye of the bucket by a cotter, and passes through a packed stuffing-box in the cover of the pump. The bucket-valve is of that kind technically known as the *pot-lid valve*, in contradistinction to the *butter-fly valve*, which consists of two hinged flaps. The pot-lid valve consists of a circular plate, which slides vertically on the pump-rod by means of a bored eye at its centre; the plate is strengthened by ribs radiating from the eye, and terminating in a narrow ring on its circumference, which is faced, and fits water-tight upon the similarly faced edge of a ring projecting round the plane of the bucket.

To understand the action of this valve it is only necessary to conceive the under part of the barrel to be filled with water, and the bucket to be forced to descend in it; it is then obvious that the water passing between the arms will meet the under surface of the valve, and prevent it descending with the bucket; for being inelastic, and also being prevented from returning into the condenser by the foot-valve, it must force a passage at the least resisting point; but the only resistance which the valve offers being its own weight, the water will bear it up and force a passage at its circumference, over the ring of the bucket, and will continue to ascend *relatively* in the barrel so long as the bucket continues to descend; but when the bucket has attained the lowest point of the stroke and begins to return, then the valve, being of greater specific gravity than the water, will shut by its own weight, and will carry whatever water is above it to the height of its own ascent. The water thus carried up is ejected by the valve called the discharge-valve, into the *hot-well* X, so called because the water thus thrown into it by the air-pump, being that employed in condensation, has its temperature proportionally increased.

It may be observed that the bucket and valve are of brass, as are also spindles which form their axes. The box-framings of these valves are formed of cast-iron, faced with brass, and fitted water-tight into their seats, where they are each retained by two long copper keys, one at each side, inserted from above before the covers are put on. The covers are likewise fitted water-tight and bolted down.

The valves are prevented from opening beyond the requisite distance, by projecting bridges situated before them, as shown in the section.

The hot-well.—The hot-well, as already observed, is situated above the condenser. The part marked X, with the vertical part of T, of the upper exhaust passage, is formed of a single casting, fitted water-tight to the top of the condenser. In one side of the well, as shown in the section, is a rectangular recess covered by a door, through which admission can be obtained to the interior; and in the side adjacent to that of the vessel, as shown in the elevation, is a circular opening to which the discharge-pipe Y is bolted. Through this latter the excess of water beyond that required for supplying the boilers, is discharged into the sea. The pipe consists of a single length outside of the condenser, to which it is fitted by an expansion joint, to compensate for the spring of the vessel when at sea; and has also a valve in it capable of opening outwards, but which being shut resists the pressure of the water inwards.

An air-vessel Z is placed over the hot-well and fitted to it air and water tight. The object of this vessel is to create an elastic pressure by means of the air contained within it, to assist in ejecting the water through the discharge-valve should the hot-well from any cause become surcharged. The pressure thus brought into action by continuing to increase with the exigency of the case will, under all ordinary circumstances, prevent accumulation of water in the well to any detrimental extent.

Feed and bilge pumps.—The same cross-head *u* by which the air-pump is worked, serves also to work two other pumps of smaller dimensions. These are the feed-pump, by which water is supplied from the hot-well to the boilers, and the bilge-pump, by which leakage water is withdrawn from the hold of the vessel. These are very nearly identical in construction with the bilge-pump. The barrel is formed of cast-iron, but the plunger, which is made hollow for the sake of lightness, is formed of brass. It is connected to the cross-head by a cotter, a portion of the end being made solid for that purpose.

This pump communicates with the hot-well by a pipe projecting from the side of the barrel, a portion of which is shown in the general elevation, where it is marked W. The feed-box is bolted upon the side of the part of the hot-well formed in the condenser, at the position marked *w'* in the plan of the sole-plate, by square flanges upon the face. In the side of the hot-well are two square holes corresponding to the two openings in the feed-box, and these being made to coincide, the pipe from the feed-pump is attached to the lower of the two circular openings in front of the box corresponding to the lower of the square openings, and the upper communicates by a copper pipe with the boilers. This connection being effected, and a clack-valve, opening towards the pump, being placed in the lower division of the box, and a similar valve, opening reversely, being placed in the upper division, if the plunger be made to ascend in the barrel of the pump, leaving a corresponding space unoccupied, the water will flow from the hot-well, by its own gravity, into the pump; but on the plunger beginning to descend the valve in that division of the feed box will be closed by the pressure of the water tending to return to the hot-well, and consequently will be forced through the upper valve, and along the feed-pipe, to the boilers. But if more water be drawn by the pump than is required for the boilers, it is simply ejected through the valve in the upper division of the box, and thus returned to the well. The pressure of water in the box is maintained by a loaded conical valve placed on the top: this can be adjusted at pleasure to suit the pressure of steam in the boilers.

Instead of being guided by parallel-motion bars, the pump cross-head is restricted in its vertical path by two guide-rods *v v* attached to the flanges of the feed and bilge pumps at their lower ends, and to the diagonal framing above; these pass through bushed eyes in the cross-head which is thus confined at the same time that it slides freely upon the rods in its alternating ascent and descent.

The cross-head is connected to the side-levers by the rods *t t*, which are formed with solid bushed eyes at their upper ends, and with butts and straps at their lower extremities.

Snifting-valve.—The bottom of the air-pump well communicates by a pipe with a small conical valve, which is technically called the *snifting-valve.* This valve is kept shut by a screwed pin passing through a malleable iron bridge made fast upon the mouth of the pipe. To the side of this pipe, above the valve, is cast a small return branch, by which the water passing through the valve is carried off.

The use of this valve is to admit of the escape of the air within the condenser, air-pump, and steam-passages, on starting the engine, and before these have been filled with steam. When about to start, the pin is simply unscrewed by hand, to permit the valve to rise and allow the air and water to escape, and give place to the steam, which now flows onwards from the valve-casing, occupying all the passages and condenser, and finally begins to issue by the valve itself.

Blow-through valve.—This valve is situated at the position marked *u'* in the plan of the sole-plate. It is placed in a chest fixed upon the steam-valve casing at the lower end, and has two openings, one above and the other below the packing port. The valve itself is placed between these two apertures.

This valve is used simultaneously with the snifting-valve, to allow the steam to fill the passages and condenser, when preparing to start the engine, and thereby to displace the air and water which may be lodged in them, through the snifting-valve.

Priming-valves.—These are two small valves, situated in the steam-ports of the cylinder, and are called *priming-valves* from their being intended to discharge any water carried over into the cylinder with the steam, and which is technically termed priming. These valves are kept shut by springs acting against them externally, and of such strength as to resist the ordinary pressure of the steam; but should water lodge in the passages, owing to its non-elastic properties, it will be ejected through the valves by the action of the piston tending to compress it.

Expansion geer.—The expansion geer consists of an apparatus by which the amount of steam admitted during a stroke of the piston can be diminished at pleasure, when it is not required to work the engines to full power. The first part of the apparatus consists of a cam with five faces fixed on the crank shaft, as shown in the elevation and plan of the engine. These faces are of different lengths, giving five different degrees of expansive action. They are so formed that the friction roller on the end of the lever *w*, and bearing against any one of them, is thrown forward through the same space; but the time of action varying as the length of the face, the effect will depend upon the particular face in contact with the roller; and this, according to its distance from the frame, may be made to bear against either one or other of the faces. The position of the roller, and consequently of the lever to which it is attached, is regulated by a screw and nut; the last is formed in the back lever *x*, which is forged of a piece with the weighted lever, and has a long hollow boss working on a stud fixed in the framing. The screw has a handle upon the projecting end, which being turned causes the lever *w* to advance or recede upon the boss of the double lever on which it slides by a sunk key. The roller is kept against the face of the cam by the action of the weighted lever; the weight tending to descend and carry the lever with it, causes the opposite lever to press upwards against the face of the cam.

The lever *x* is connected by a joint with an adjustable rod, carried forward to the lever *y*, which is fast upon a cross-shaft supported by two small columns on the flange of the expansion chest, marked G in the elevation. On the same shaft is keyed the double ended lever *y'*, one end of which is connected, by flexible links, with the spindle of the expansion valve, which is of the kind known by the name of *equilibrium* valves. The opposite end of the lever *y'* communicates by a rod *z* with an arrangement of levers attached to the side of the condenser, by which the apparatus can be thrown into geer and disengaged at pleasure. Thus the end of the crank lever *z'* being moved to the right, the rod *z* will be drawn down, and with it the end of the horizontal lever *y'* to which it is attached; but the lever *y'* being fast upon the same axis as the vertical lever *y*, this lever will be thrown back, and at the same time the lever *x*, with which it communicates; and again the lever *x* being fast upon the same axis as the lever *w*, this last will be projected forward, and the roller thrown out of contact with the cam, and the engine will receive the full supply of steam.

Action of the engine.—To bring the engine into action, the steam is allowed free admission into the valve-casing by the steam pipe G G, leading from the steam chest over the boilers. To prevent the pipe being injured by expansion, arising from the variations of temperature to which it is liable, it is provided with expansion joints which allow the ends to slide upon each other, and thereby maintain the same aggregate length between the two extremities. It has also a valve, called the throttle valve, placed in it to regulate the supply of steam, and to cut off the communication between the boilers and the casing when necessary. The valve is placed close to the junction of the pipe with the casing; it is simply a disk of the same diameter as the inside of the pipe, with a rectangular eye cast in it to receive the spindle upon which it works.

The steam-ports of the cylinder being both shut by the valves, and the blow-through and snifting-valves open, the steam is allowed to pass into the valve-casing by opening the throttle-valve, partially at first, which fills the steam-passages and condenser, driving the air and water before it. When this has been accomplished, and steam alone issues by the snifting-valve, the blow-through valve is closed, and the injection-valve is opened; the cold water now rushing into the condenser effects the condensation of the steam with which it was filled, and creates the desired vacuum. The eccentric-rod *l* being out of geer with the crank upon the traverse-shaft *m*, and a long lever, as before described, being applied to the starting-shaft S, the steam-valves are raised until the under port communicates by the passage with the condenser, and the upper port with the interior of the valve-casing, now full of steam, which, in consequence of this disposition, will flow into the cylinder above the piston and force it to descend. The next operation is to reverse the pressure upon the starting-lever and thereby to reverse the position of the valves, shutting off the communication of the upper port with the casing, and opening it to the condenser, at the same time that the communication of the lower port is cut off from the condenser and opened to the interior of the casing. This being done the steam will flow from the cylinder into the condenser, and encountering there a shower of cold water from the injection-pipe, will be condensed, and a vacuum thereby formed in the cylinder above the piston. By that means the pressure over the piston is removed, and the steam flowing into the cylinder beneath it, forces it to ascend to the top of the cylinder.

But the piston being connected by the cross-head and side-rods, with the side-levers, carries these with it in its ascent and descent, through an arc, whose chord is equal to the length of the stroke of the piston; and the side-levers being connected at their opposite ends by means of the cross-tail and connecting-rod, with the crank, the motion of the piston is thus transferred to the crank-shaft, and through it to the paddles, which are fast upon its extremities.

After two or three strokes of the piston the moving parts will have acquired a certain degree of momentum, and this is taken advantage of to render the engine self-acting. The crank-shaft being in motion, if the eccentric-rod *l* be thrown into geer with the traverse-shaft, exactly the same effect will be produced upon the valves as by the lever applied to the starting-shaft S; for by the alternating thrust and pull of the rod, communicated to it by the eccentric R, the crank of the traverse-shaft will be made to describe a certain portion of a revolution, proportional to the eccentricity of the eccentric, and the valve lever *n* being fast upon that shaft, the valves must consequently ascend and descend regularly with the revolutions of the crank-shaft; and these revolutions are performed uniformly with the alternating ascent and descent of the piston.

The water is drawn out of the condenser by means of the air-pump with the same regularity; for the air-pump cross-head being worked by the side-levers, it will move simultaneously with them; the feed-pump being also attached to the same cross-head, the boilers will be furnished with water in proportion to the speed of the engine, and consequently in proportion to the quantity of steam used.

Literal references.

A, the sole-plate of the engine.
a a a, holding-down bolts by which the sole-plate is fixed to the keelsons.
B, the crank framing.
b b, spring-stays of the crank framing which work between face-plates on the paddle-beams.
C, the diagonal framing.
c c, stay-rods connecting the framings of both engines.
D, the parallel-motion framing.
d d, flanges by which the diagonal framing is bolted to the cylinder.
E, the steam-cylinder.
F, the steam-valve casing.
G, the steam-pipe and expansion-valve chest.
H, the steam-piston rod.
I, the cylinder cross-head.
J J, the cylinder side-rods.
K K, the radius-bars of the piston-rod parallel motion.
f f, the radius levers of the parallel motion.
g g, pinching-screws for adjusting the ends of the radius-bars.
L, the parallel-motion shaft.
h, the parallel-motion side-rod attached to the lever *f*, and to
M M, the great side-levers of the engine.
M′, the main centre.
i i, bosses at the centres of the side-levers, through which pass the keys for tightening the bearings.
N, the connecting-rod.
O, the cross-tail of the connecting-rod.
j, the cross-tail links.
P P, the cranks.
Q Q, the crank or paddle shaft.
R, the eccentric for working the valves.
l, the eccentric-rod.
m, the traverse or valve shaft.
n, the valve-lever.
o, small parallel-motion for the valve-spindle.
p, a small framing to which are attached the ends of the radius-bars of the valve parallel-motion.
q, the back balance or counter weight of the valve.
r, the back balance or counter weight of the eccentric.
s s, levers by which the valve counter weight is attached to
S, the starting-shaft.
T and T′, the upper and lower exhaust passages.
U, the condenser, cast of a piece with the sole-plate.
V, the air-pump cylinder, lined with brass.
t t, the air-pump side-rods.
u, the air-pump cross-head.
v, guides for the air-pump cross-head.
W, the feed-pump.
X, the hot-well.
Y, the discharge-pipe.
Z, the air-vessel.
u′, (in plan of sole-plate) the part of the sole-plate to which the blow-through valve is bolted.
v′, (in plan of sole-plate) a projection on the condenser, to which the expansion-valve casing is bolted

w', (in plan of sole-plate) the part of the hot-well to which the feed-chest is bolted.
w, the movable lever of the expansion-geer.
x, the fixed lever of the expansion-geer.
y y' y', additional levers for working the expansion-valve.

American Marine Steam-Engine.—Section and details of the engine of the United States Mail Steamer Pacific, built at the Allaire Works city of New York, after the design of C. W. Copeland, Esq

Details.

Fig. 2717, longitudinal section of engine.
Fig. 2718 shows a plan of the bed-plate.
Fig. 2719, a longitudinal projection.
Fig. 2720, a transverse section, vertically of the bed-plate and condenser through the centre of the side-lever shaft bearing.
Fig. 2721, transverse section of bed-plate through the centre of the sockets, for the support of the pillow-block columns.
Fig. 2722 shows a vertical elevation of steam cylinder.
Fig. 2723, plan.
Fig. 2724, a vertical elevation of the air-pump.
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Fig. 2727, plan.
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Fig. 2729, sectional plan.
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Fig. 2734, side elevation.
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Fig. 2756, vertical section.
Fig. 2757, plan.
Fig. 2758, vertical elevation of bilge pump.
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Fig. 2765 plan of bilge-pump chest.
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Fig. 2772, side view of centre-bearing for water-wheel shaft.
Fig. 2773, plan.
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Fig. 2776, side view of driven crank.
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Fig. 2779, plan.
Fig. 2780, parallel-motion shaft.
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Fig. 2784, side view and plan of radius rods for parallel motion.
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Fig. 2786, pillow-block columns.
Fig. 2787, side elevation of bush for driven crank.
Fig. 2788, plan.
Fig. 2789, vertical elevation of cross-tail, with side-lever links attached.
Fig. 2790, plan of cross-tail.
Fig. 2791, end view of side-lever links.
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Fig. 2793, vertical projection of cylinder cross-head.
Fig. 2794, plan.
Fig. 2795, piston rod.
Fig. 2796, side view of side-lever shaft, with washers on the ends.
Fig. 2797, end view.
Fig. 2798, side view and plan of main connecting-rod.
Fig. 2799, side view and plan of cylinder side-links.
Fig. 2800, side view and plan of cut-off eccentric-rod.
Fig 2801, side view and plan of steam eccentric-rod.
Fig. 2802, vertical elevation of air pump cross-head
Fig. 2803, plan.

Literal References to Fig. 2717.

A, the bed plate, upon which the engine stands.
B, the cylinder bottom, cast upon the bed plate, in which is the lower steam opening.
C, cylinder.
D, steam piston.
E, piston rod.
F, cylinder cross-head, attached to the piston rod, and also to the side levers, by two side rods.
G, cylinder side rods.
H H, upper and lower steam chests, in which are fitted valves for the induction and eduction of steam to and from the cylinder.

I I, steam-valves.
J J, valve-stems, on which are keyed the steam-valves.
K, parallel-motion shaft and standard.
L, lifting-rods, for lifting steam and exhaust valves, worked from an eccentric on the water-wheel shaft.
M M, steam-toes, keyed to the lifting-rod.
N N, feet for lifting-rod, attached to the rock-shaft.
O, steam and exhaust side-pipes.
P, foot-valves and seats.
Q, condenser, cast upon bed-plate.
R, side-lever shaft, passing through and firmly keyed to condenser.
e e, pillow-block columns, keyed into sockets cast upon the bed-plate.
f, pillow-blocks for water-wheel shafts.
g, cranks.
h, main connecting-rod, connecting cross-tail and crank-pin.
i, cross-tail, attached to the side-levers by two short links, also the main connecting-rod.
j, main-braces from pillow-blocks to cylinder.
k, steam-valve lifters, keyed to the lifting-rods.
l, parallel bar for parallel motion.
m, parallel motion connecting-rod
n, eccentric-rod.
o, guide-rod for air-pump cross-head.
p, brace from pillow-blocks to bed-plate.

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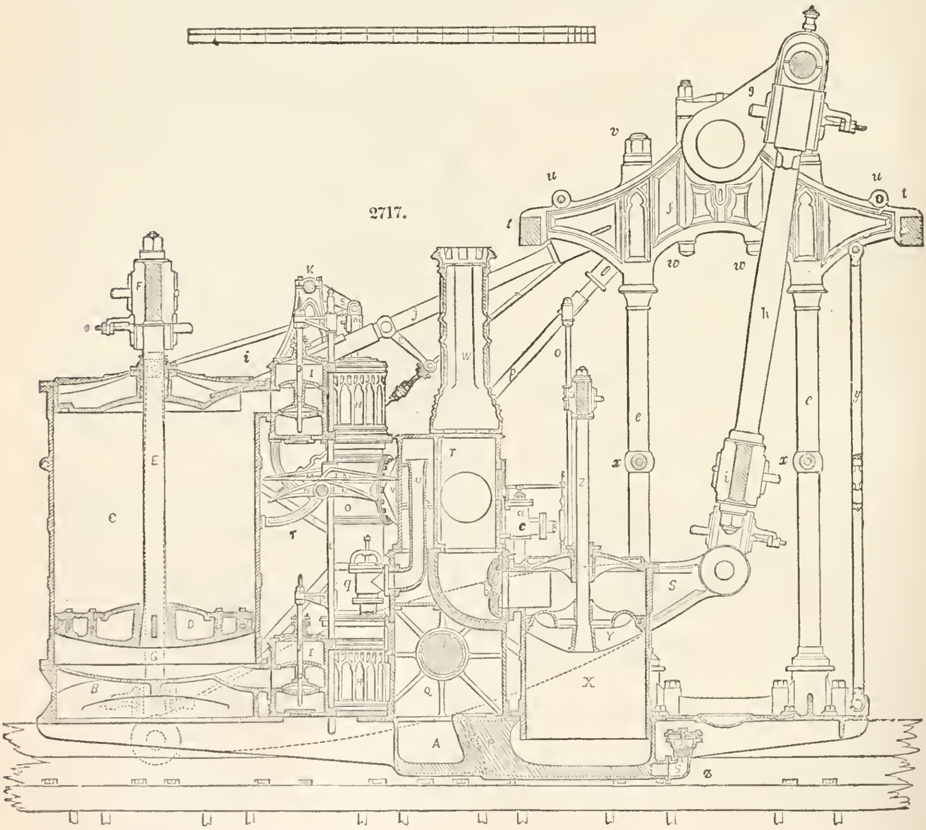
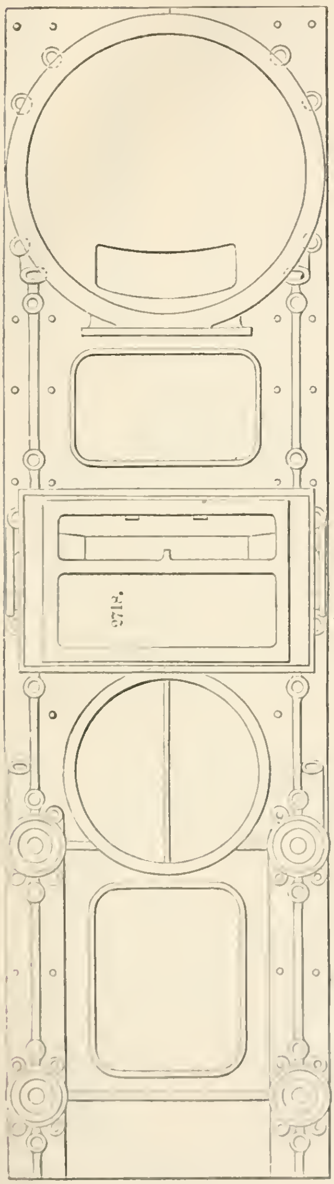


S, side-levers.
T, hot-well.
U, injection-pipe.
V, connection, from exhaust-pipe to condenser.
W, air-column, to receive the air arising from the waste water, thereby facilitating its discharge.
X, air-pump.
Y, air-pump piston.
Z, air-pump rod.
a, air-pump cross-head.
b, delivery valves and seats.
d, force-pump chest.
q, injection-valve.
r, centre-bearing for rock-shaft.
s, brace from cylinder to bed-plate.
t t, cross-beams for pillow-blocks.
u u, studs and transverse braces.
v, nuts for securing pillow-blocks to columns.
w, bolts for holding down pillow-block caps.
x x, studs between columns and bolts, running transversely through each set.
y, braces from pillow-blocks to bed-plates, in the centre of each and between engines.
z, snifting-valve.



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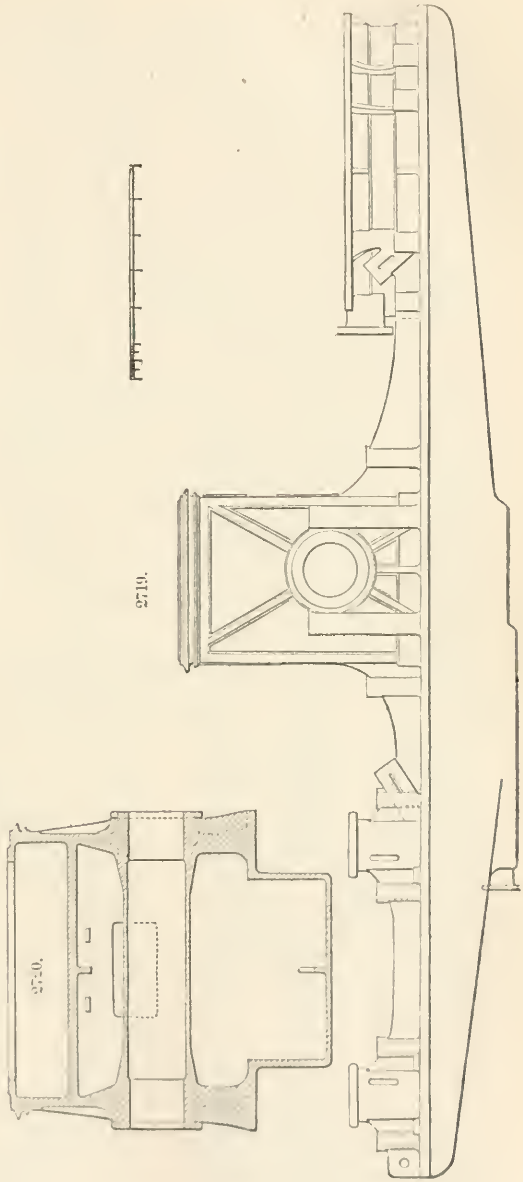

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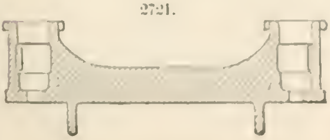

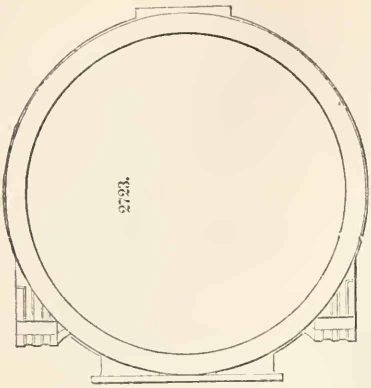

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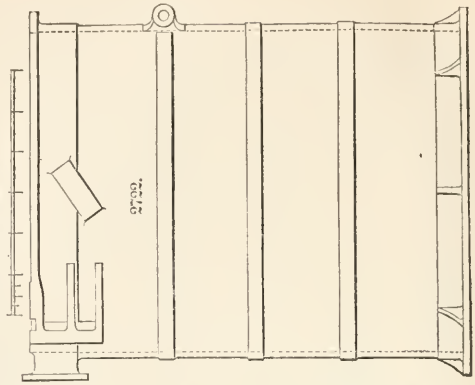

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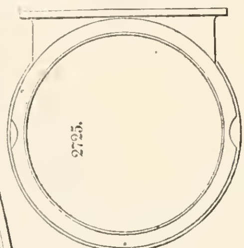

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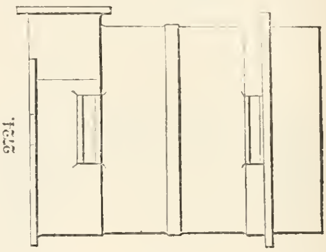

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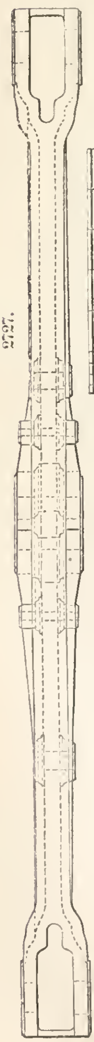

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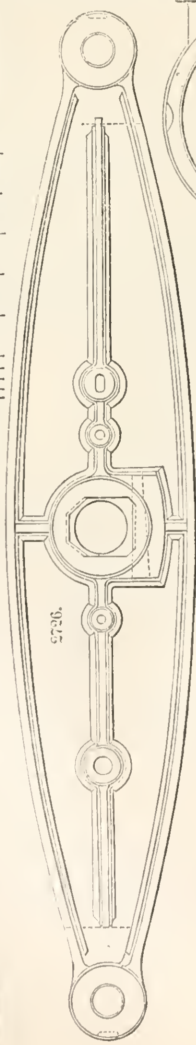

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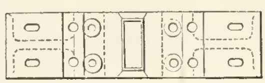

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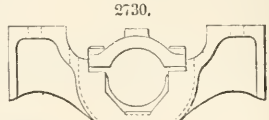

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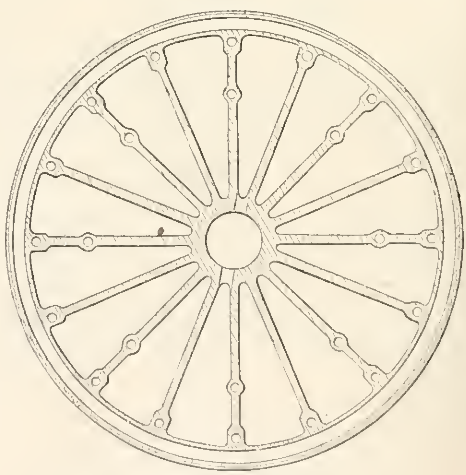

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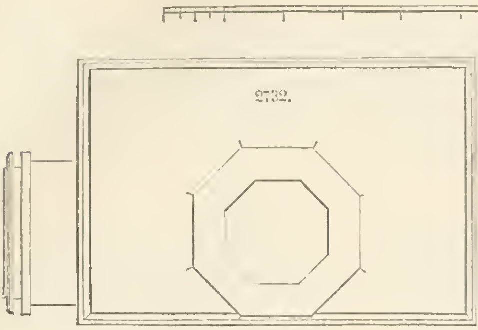
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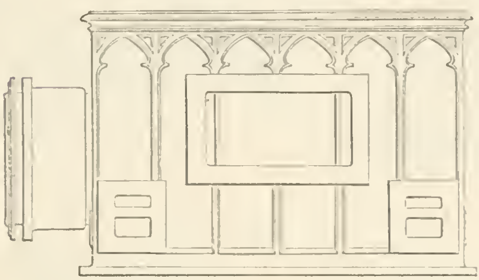

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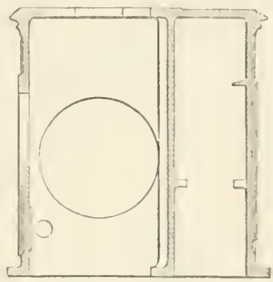

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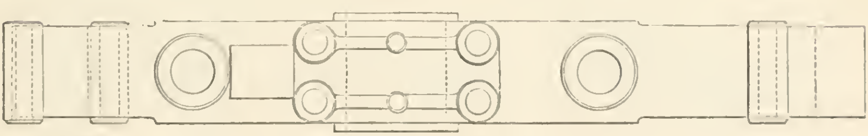

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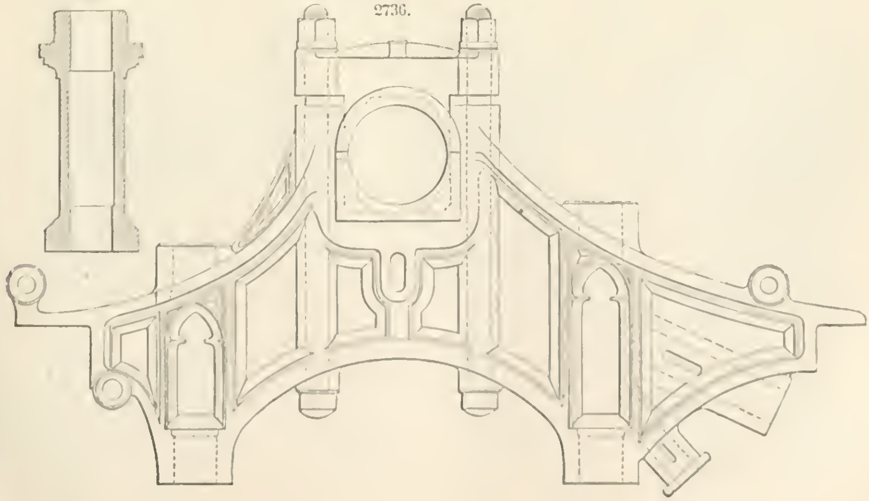

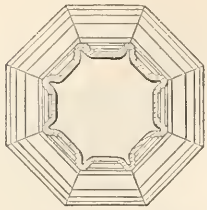

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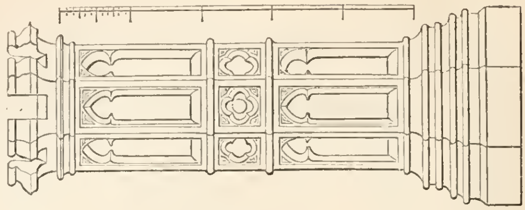

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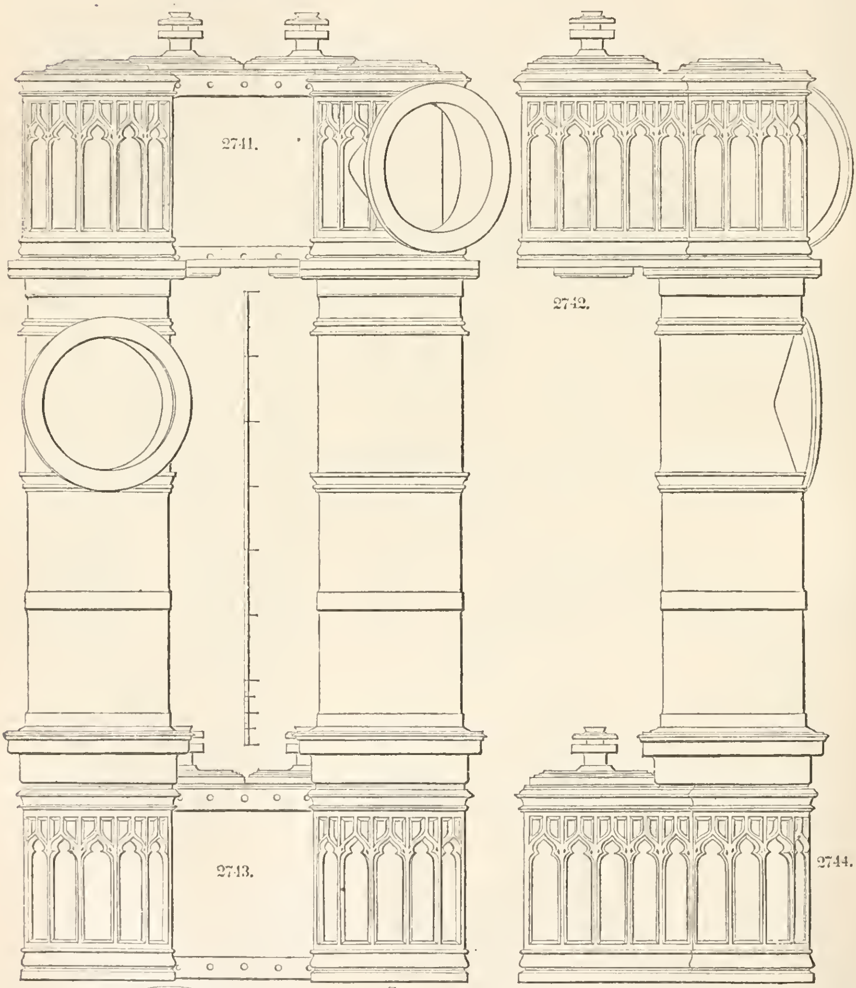

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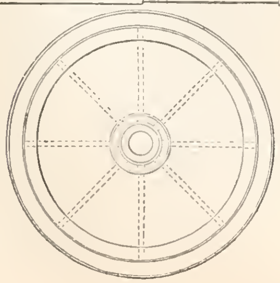

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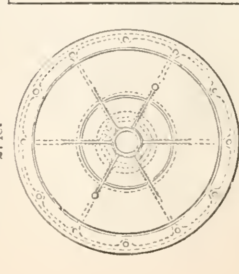

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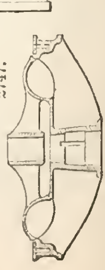

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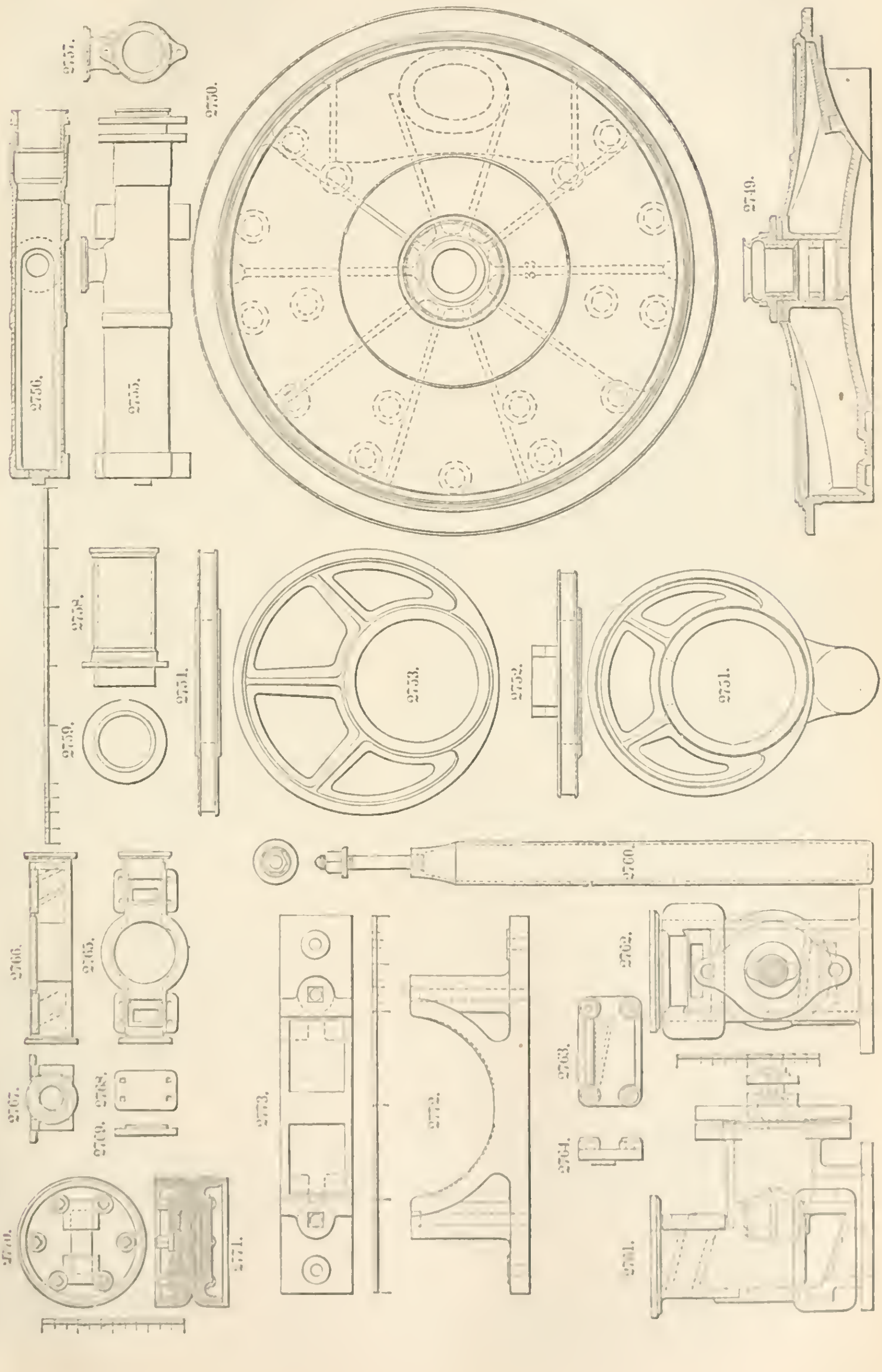
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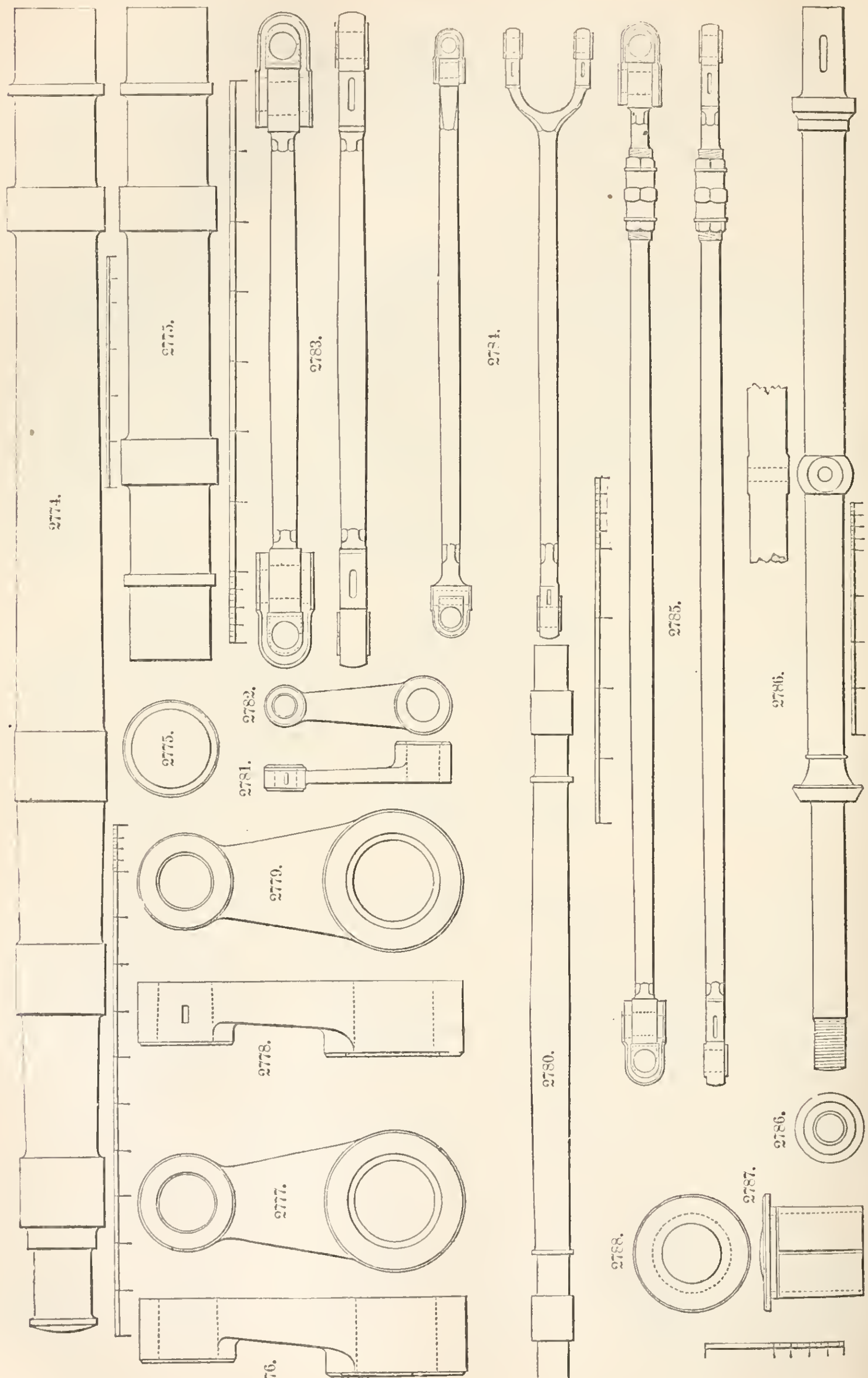
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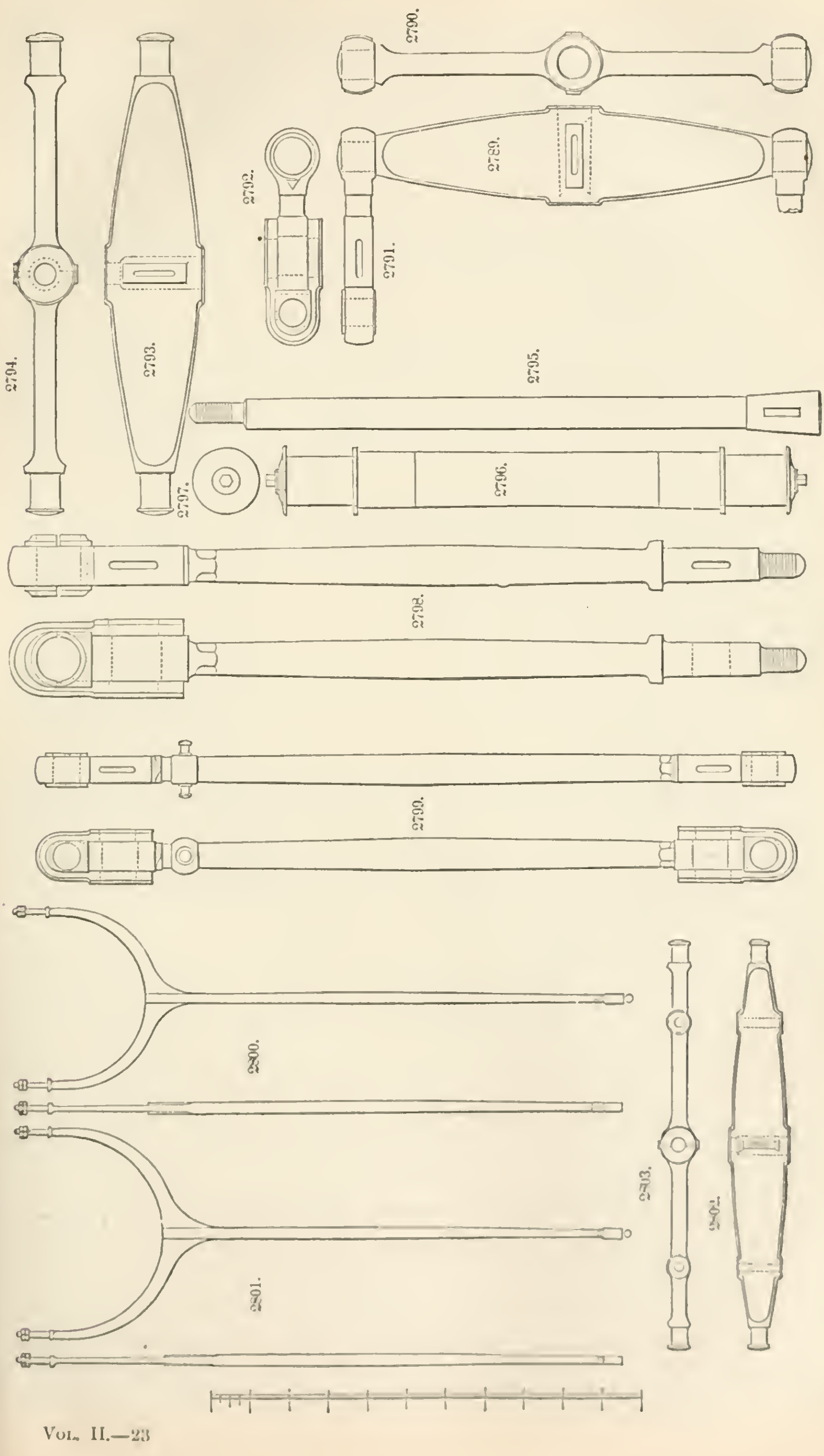
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Engines of the Golden Gate. Plate II. is the front elevation, and Plate III. the side elevation and section through air pumps. *a* main shaft, *b* crank-pin, *c c c c* cylinder; *d* trunnions on which the cylinder oscillates to accommodate itself to the motion of the crank; *e* stuffing box on the cylinder-head. This is made as long as practicable, to give as much bearing as possible for oscillating the cylinder. *f f* belt-passage connecting the trunnion with *g g* side-pipe. *h h* valve-stems, connecting with the balance puppet-valves in *i i i* valve-chests. The lower valve on the right or steam side is concealed by *j j j j*, air-pump; the air-pump bucket is provided with India-rubber valves, and is worked by *k*, crank on the intermediate shaft. *l l l l*, condenser: there are two condensers and two air-pumps; they are located between the cylinders and inclined towards each other, one only being represented.

The passage *f f*, together with the side-pipes, valve-chests, and appurtenances, are fixed to the cylinder, and oscillate with it, the steam being received through one trunnion and allowed to escape to the condenser through the opposite one. *m* is an injection-cock admitting the water upon a scattering plate in the condenser. These are the first oscillating engines to which balance puppet-valves have ever been applied; and the constructors, Messrs. Stillman & Allen, deserve great credit for successfully carrying out so decided an improvement.

The valves are worked by the toes *o o* in the usual manner. The rock-shafts *p p* receive motion partly from the movement of the cylinder, and partly from the eccentric. Levers are permanently attached to the trip-shafts *q q*, the ends of which work in a slotted piece curved to the centre of the trunnion. This piece is guided, as represented in the engraving, by vertical rods sliding in bushes attached to the fixed framing, and is connected by a rod to the starting lever *r*, all the levers for working by hand being so balanced, that the engineer with one hand can work the engine up to the usual speed. The cut-off valve is placed outside the trunnion, and is a balance puppet-valve, worked by the ordinary cam motion, and so arranged as to act either as cut-off or throttle, or both, the levers being placed within reach of the engineer when working the engine.

The Golden Gate has four return tubular boilers—two forward and two aft of the engines. They are placed at the sides of the ship, leaving room for the fire-room in the centre. The furnaces are consequently athwart-ships instead of ranging fore and aft as usual.

The Illinois, plying between this city and Chagres, the John L. Stevens, the Augusta, plying between this city and Savannah, the Republic, the Agnes, a vessel constructed for the Spanish government in 1850, the Arago of the Havre line, the Adriatic of the Collins line, are among the American examples of paddle-wheel steamers fitted with oscillating engines.

The Golden Gate is of the following principal dimensions: Length on deck, 265 feet; beam, 40 feet; depth of hold, 22 feet; tonnage, 2030 tons; diameter of cylinders, 85 inches; stroke, 9 feet; average revolutions, $18\frac{1}{4}$; average pressure in boilers above atmosphere, 12 lbs.; cut-off from commencement, 3 feet; amount of fire surface, 12,052 square feet; tube surface, 8396; grate surface, 367; calorimeter of tubes, $61\frac{3}{4}$ feet; paddle-wheels, diameter 31 feet; length of paddle, 12 feet; depth, 24 inches; number of paddles in each wheel, 30.

Barrows' Double Acting Reversible Rotary Steam Engine.—Arranged for working steam expansively.

Plate IV. is a perspective view of two cylinders or engines fixed on one shaft for the expansive working of the steam. The cylinders are of equal diameter but of unequal length. The steam is first admitted to the smaller: after doing its work in which, the greater part is admitted at a lower pressure to the larger cylinder. In this respect, working the steam through two engines, it somewhat resembles the well-known Woolf engine, but with this difference, that the steam is taken from the first engine at such a point that it exerts no back pressure. This will be understood by examining Plate V., which represents a vertical and horizontal section of the smaller engine only. The larger engine resembles this, except in having but four instead of eight pistons, or leaves, and in having no outlets for the steam at the top and bottom, as in the smaller.

c is a pedestal of cast iron on which the cylinder rests, forming the whole of the frame of the engine; *a* is the cylinder, whose inner periphery is turned perfectly true, and whose ends are closed by heads *d d*, in each of which heads is a groove *h h*, the form of which is best shown in fig. 5 by dotted lines, being that of a circle with segments cut off on opposite sides, leaving only two-fourths of its circumference. On opposite sides of the cylinder are abutments *n n*, cast upon the steam-heads *m m*; on either side of which abutments are quadrangular openings *t t'*, *u u'*, connecting with the double three-way cocks *q q'*. To the inside of the cylinder is fitted the steam-wheel *ee ee e'e'*. The ends of the steam-wheel are formed of two plates *ee*, *ee*, of a diameter equal to the interior of the cylinder, and secured by bolts *ii*, to a ring *c'e'* of less diameter, which forms the bottom of the channel *f*, in which the steam acts. Its axle *j* passes through boxes in the cylinder ends, packed with metallic packing, and lined with anti-friction rollers. The rollers may, no doubt, be omitted in practice, as a refinement of little use, if not positively productive of derangement. The peripheries of the two plates *ee*, *ee*, forming the ends of the steam-wheel, are made to fit steam-tight to the interior of the cylinder, by means of metallic packing-rings let into the interior of their flanges as represented. The abutments *n n* are packed with metallic packing *o* to the bottom, and *p* to the sides of the channel *f*; the packing-pieces *o* and *p* being dovetailed together, so that *p* will slide with *o*, but at the same time slide outwards, independently of it as they wear. The steam acts in the passage *f* upon 8 slides or leaves *g g*, which we will term pistons, which revolve with the steam-wheel, but are capable of sliding to or from the centre through slots in the ring *e'e'*. It will be seen that the sides of the channel *f* are formed by the plates *ee*, before described, so that the channel is, in fact, wholly sunk in the rim of the steam-wheel. The pistons are made a little wider than the channel, and partially supported by shallow radial grooves on the inside of the plates *ee*. The pistons are packed on their edges both to the inner periphery of the cylinder and to the grooves in the sides of the channel *f*. This packing is shown on the right hand of fig. 2, Plate V., in section, the section being taken through the centre of the piston, and exhibiting the end and side packing dovetailed loosely together in the same manner as already described in the packing of the abutments. The slots through which the piston slides are also packed, as represented in fig. 1. All the packing pieces are kept to their work by small helical springs at their backs. From the inner edge of each piston at each side, a square stud b' projects through a radial slot f', in the plates ee, and at the end of each stud is a pivot g', carrying a friction-roller. These friction-rollers travel in the grooves hh, inside the fixed cylinder head, and during the revolution of the wheel cause the pistons to alternately project and withdraw into the wheel. By the form of the groove, it will be seen that each piston will project across the channel f during two fourths of the revolution, while during the remaining two-fourths, it will be wholly or in part withdrawn into the interior of the wheel. At the moment of passing either abutment nn, the outer edge of the piston will coincide with the outer surface of the ring $e'e'$, so that the packing pieces oo of the abutments have presented to them by the revolution of the steam-wheel simply a continuous cylindrical surface.

The steam-heads or cocks mm, through which the steam is admitted to the cylinder, and which supply the place of valves, valve-gear, and reversing-gear in ordinary engines, are of peculiar construction, having six ways or passages in each. There are conical seats in each to receive the plugs qq', in which are passages to correspond with the ways in the steam-heads. The steam-pipe s has two branches leading to the two steam-heads. Of the six ways or passages in each steam-head, two tt' are steam-passages leading from the cock-seats into the channel f, the former above and the latter below the abutment, (see the right-hand side of fig. 1, Plate V.); nn' are exhaust passages leading from the cylinder to the cock-seats, the former from above and the latter from below the abutments (see left-hand side of fig. 1, Plate V.). In addition to the four already described, one r leads from the steam-pipe to the cock-seat, and the remaining one v, fig. 2, Plate V. is a continuation of the cock-seat, provided with a flange at its extremity for connecting to the exhaust-pipe. The vertical section, fig. 1, is taken through the steam-passages on the right side, but through the exhaust-passages on the left. The plugs qq' have each two passages, the first k, fig. 2, being for the purpose of communication between the steam-pipe and either of the passages tt', and admitting steam on either the upper or lower side of its corresponding abutment, the other l, in a hollow part of the plug, being for forming a communication between the exhaust-passage v, and the opposite side of the abutment to that which is in communication with the steam-pipe. The two plugs qq' are furnished with levers (see Plate IV.), by which they are turned to admit the steam on either side of the abutment, and allow the escape of the exhaust from the opposite side, and the levers are connected, so that both are reversed at the same instant. Whatever relation, therefore, exists between the several passages in one steam-head and cock, the opposite relation must exist between the passages in the other. In fig. 1, Plate V., the cock on the right-hand side of the figure is in such position, that steam is admitted through the passage t above the abutment, the passage t being effectually closed, while in the same cock the exhaust passage u', imperfectly represented by dotted lines as being more distant from the eye, is open, and admits the exhaust steam to escape from the lower side of the abutment into the hollow portion of the plug at its further end. In the other steam-head, the lower steam and the upper exhaust are supposed to be open, the dotted steam-passages tt being on this side nearer the eye than the exhaust passages nn', through which this section is taken.

It will be recollected that there is no movement of these cocks, except in reversing, all the passages being full open, and the steam exerting its full force in every possible position of the wheel. The arrows indicate the movements of the steam, and also the direction in which the wheel revolves, every particle of steam expended being effective in driving the wheel, without loss by filling any cavities uselessly, as in the valve passages and clearance of every variety of reciprocating engine.

It now remains to describe the provision for rendering available some portion of the expansive power of the steam. The spaces in the channel f between each piston appear as if filled with steam of full pressure, which is carried along by the revolution of the wheel, and discharged into the exhaust passage of the opposite steam-head. This would be the case but for the passages ww', midway between the steam-heads, through which a large portion of the steam thus confined expands itself into the second or mate engine, which is of similar construction, but containing only four instead of eight pistons. The channel in which the steam works in the second engine may also be deeper, and any desired ratio may subsist between the capacities of the two engines. Suppose the boiler pressure to be 60 lbs. per square inch, and the capacity of the second engine be twice that of the first, steam from the boiler at 60 lbs. above the atmosphere, or 75 lbs. total pressure, is expanded in passing the passage w into three times its original space, two volumes going over into the second engine, while one volume remains in the first. The pressure will thus be reduced, according to the law of Boyle and Marriotte, to about $\frac{75}{3} = 25$ lbs. total, or 10 lbs. above the atmosphere. The additional force, therefore, due to the existence of the second engine will be that of 10 lbs. per inch upon a double area, or one-third that of the first engine $[10 \times 2 = 60 \times \frac{1}{3}]$ If the engines are condensing, and exhaust into a perfect vacuum, the power of the second engine will be two-thirds that of the first $[25 \times 2 = 75 \times \frac{2}{3}]$. If the second engine be only equal in capacity to the first, the pressure on its pistons will be half the boiler pressure, or 37·5 lbs.; and the effect of the second will be one-half the first, when both exhaust into a vacuum, or a little more than one-third when exhausting into the atmosphere $[37{\cdot}5 - 15 = 22{\cdot}5$ lbs. $22{\cdot}5 > 60 \times \frac{1}{3}]$. Any one may readily calculate the effect of any other ratio between the cylinders, or of any other initial pressure than 60 lbs. The inventor prefers a second cylinder of about twice the capacity of the first.

A considerable advantage to be derived under some circumstances from the existence of two engines, is the possibility of using both for a few minutes on any extraordinary occasion, under full pressure, by connecting each directly with the boiler. In Plate IV., a represents the first and b the second engine. Under ordinary circumstances, the stop-valves c and d being open, the steam from the boiler would be admitted through c into a alone, after working through which, a portion would pass over through the stop-valve d into the cylinder b. Should occasion require an extraordinary effort, the valve d may be closed and e opened, thus shutting the communication between the engines, and opening each to the full pressure of steam from the boiler. Both might be thus worked so long as the boiler could generate a sufficient supply of steam.

Engines of the Vaguero, (Plate VI.) The Vaguero may be considered one of the best specimens of a modern auxiliary propeller. The hull was modelled and built by George Steers, Esq.; the engines were designed and constructed at the Faron Iron Works, East River. The vessel is 145 feet keel, 155 feet on deck, 24 feet 4 inches breadth of beam moulded, and 10 feet depth of hold. She draws, with 175 tons of coal and stores on board, 8 feet of water. The engines are remarkable only for the extremely small space occupied, and novel method of obtaining the valve movement. The cylinders are oscillating, with slide-valves and the usual cut-off, and inclined to an angle of 36° when on their centres. They are 26 inches diameter, 28 inches stroke, and geered, by the internal geer represented, in the proportion of $2\frac{3}{8}$ to 1. The view given in the plate is a front elevation, the stout timber-frame being removed on one side to allow a fair section of the cylinder port, behind which appears the after and similar frame. Both frames, and a portion of the dead wood, as also a portion of the flange on the large geer-wheel, are represented as broken through at a lower point, to allow a view of the pinion and shaft of the propeller.

The valve motion is derived principally from the oscillation of the cylinders, the connection being to cranks of about 2 inches throw on the shaft of the hand-wheel in the centre. The latter shaft is in line with the main shaft, and is carried round with it by means of arms and adjusting screws, which meet the extremity of the crank-pin, extended for the purpose. There are two arms on the shaft, making with each other an angle of about 140°, the extra arm coming into play on reversing the engines.

The valve receives its motion immediately from a geered segment on a shaft traversing the valve-chest. The arms on the end of this shaft are in fact one piece, with a curved slot, for the convenient transfer of the connection from one arm to the other. This transfer is effected by means of a small geer-wheel taking into a rack near the side of the slot. The connecting-pin, and consequently the small geer-wheel, is turned by a small hand-wheel on its extremity. This wheel is omitted in the plate.

Behind the port cylinder is dotted the pump-shaft and arm, worked by connection with a crank on the after end of the driving-shaft. From arms on this shaft are worked the air and feed pumps, which are placed horizontally on the starboard side, and secured to the condenser. The condenser and hot well are cast in one piece, the capacity of the former being 20 and the latter 8 cubic feet. The air-pump is 23 inches diameter, and 18 inches stroke, with solid piston. The feed-pump is $4\frac{1}{2}$ inches diameter and 14 inches stroke. The valves of the air-pump are of India rubber, and of the usual construction. The boiler is a single ascending return-flue, $21\frac{1}{2}$ feet long; diameter of shell, 8 feet; width across the front, 9 feet; Two furnaces present each 20 square feet of grate surface; and the whole heating surface of the boiler is 1,000 square feet. The consumption of anthracite is estimated at about five tons per day; number of revolutions under steam alone, from 30 to 35; pressure of steam, about 25 lbs., cutting off at half stroke.

The propeller is of brass, 3 bladed 8 feet in diameter, 16 inches long, and weighs 2,100 lbs. The pitch is 10 feet, expanding to 11. Working-surface, exclusive of hub, 24 square feet. The diameter of the propeller-shaft is $6\frac{1}{2}$ inches—the thrust of the propeller being taken by 6 collars, working in a corresponding box of brass.

The Vaguero is owned by an Havana company, and is designed especially for freighting between that place and the southern ports on the island. A two-way cock is provided for the extinguishment of fires, by turning which a volume of steam from the boiler may be turned into either the coal-bunkers or the hold. On the starboard side of the engine-room, which is also the fire-room, is a small vertical steam-engine, working a double-acting force-pump for extra feed, and an apparatus for hoisting goods or coal. The fire-annihilator, *i. e.* the steam-cock alluded to, is worked from the deck.

Marine Engines, designed by Mr. Joseph Hall of Munich, and fitted in a boat on the Upper Danube. The arrangement is very fully detailed in the engravings. Fig. 2804 is a side elevation of one of the engines, with boiler and paddle-wheel, as fitted in the vessel. Figure 2805 is a corresponding transverse section through the vessel, showing both engines, with various parts in section. The view on the right of the centre line represents sections through the paddle-box, air-pump, feed-pump, crank shaft journals, condenser passage, and the barrel of the boiler—the cylinders not being shown. On the left, the air-pump and paddle-wheel are in elevation, the cylinder being in section through its exhaust passage, as in connection with the blast-pipe. Figure 2806 is a plan of the combined engines, one being in horizontal section. The boiler and the fire-box A B, are constructed just as in a locomotive. At C C, are two parallel frames of double boiler plate, filled in with timber, running along the boiler, and riveted fast to it. D D are two similar frames, standing up from the bottom of the boat; and these four lines of framing carry, at one end, the four inner journals of the paddle-shaft, and at the other the pair of steam cylinders E E. The steam is admitted in the usual way by a regulator in the dome, through the pipe F, to the steam-chest G. The expansion-vale spindle H, has a right and left-hand screw at I I, each screw having a plain cut-off slide, commanding the steam ports J, leading into the second steam-chest K, and fitted with piston-valves worked by the spindle L. The cut-off spindle H, is worked by the outside eccentric M, the rod of which is linked to it direct. The variation in the expansion is effected by the light shaft N, passing alongside the engines to the engineer's hand, and having a bevel pinion O, gearing with a similar pinion P, on the transverse shaft Q, passing across between both engines. In this way the shaft N, commands the valves of both engines through the two pairs of bevel pinions R R—the result of turning the shaft N to the right or left being to expand or approximate the two cut-off slides by the right and left screws, and thus increase or diminish the degree of expansion without affecting the lead. The cylindrical, or piston-valve chest, has three valves S T and U, on the same rod V; and, as represented in the horizontal section, the engine is upon its bottom centre, and steam is entering between the valves U and T; the valve U being on the point of opening to admit steam to the cylinder—the waste steam of the previous stroke having escaped by the opening cast in the middle of the cylinder, and through similar recesses formed in the valve T, into the blast-pipe W. Now it is to be remembered that the valve U must travel downwards until its port leading into the cylinder is full open; and, as the whole three valves are on one rod, as U is opening to admit steam to the cylinder, T is closing the communication between the cylinder and the blast-pipe. So soon as the ports

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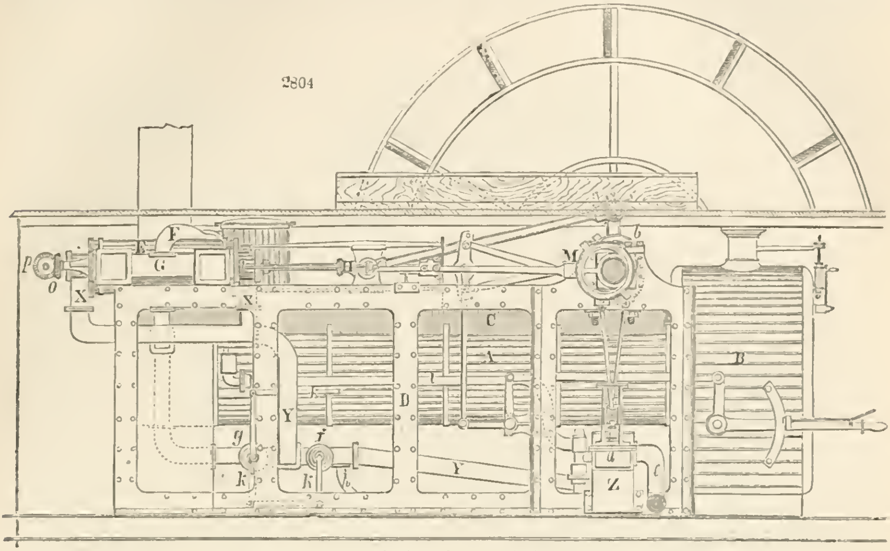

Scale 4 feet to 1 inch.

to the blast-pipe—which are only half the width of the valve—are closed, the other valve S opens, and the remaining vapor escapes through the pipes X, cast on the steam-chest, to the pipe Y, leading to the condenser Z. As the expansion at each stroke commences at the face of the cut-off slides, whatever amount of steam may be in the piston-valve chest at the time is also expanded; therefore, to diminish this amount as much as possible, two additional pistons S′ S′, are fitted upon the valve-rod, for the pur-

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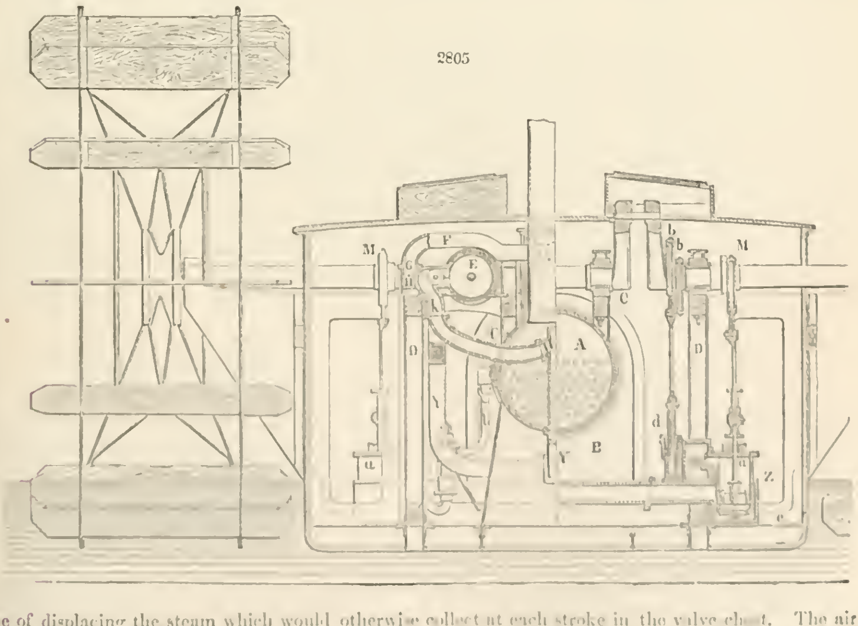
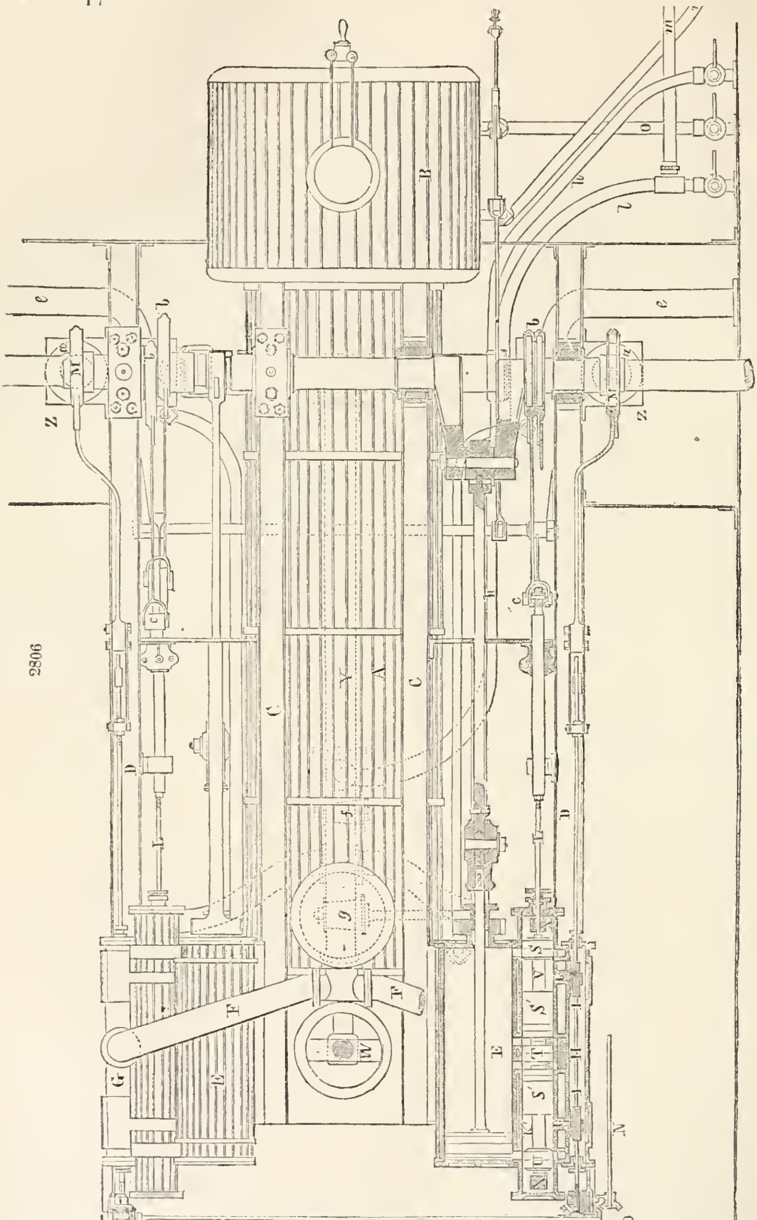


pose of displacing the steam which would otherwise collect at each stroke in the valve chest. The air-pump *a*, is of the ordinary construction: it is bolted on to the condenser, and is worked by the same eccentric which works the expansion valves. The piston steam-slides, S T and U, are worked by the back and forward eccentrics *b b*, through the reversing link *c*. The backward eccentric also works the feed-pump *d*—the feed being taken from the hot well, whilst the remainder runs to waste by the pipe *e*.

The steam is admitted to the cylinder when the piston is on the centre, and is allowed to escape to the eduction-port or blast-pipe when the piston is $1\frac{3}{4}$ths inch from the end of its stroke. The valve S opens to the condenser when the piston has travelled $1\frac{3}{4}$ths inch from the commencement of its stroke —the full length of stroke being 30 inches—so that the cylinder is open to the condenser when the piston has travelled $\frac{1}{17}$th of its stroke.



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At f and g, two cocks are placed upon the pipe Y, leading to the condenser, and these cocks are so arranged that when one is open the other is shut. The injection-pipe h, is placed between the air-pump and the cocks f and g, so that by reversing the latter by means of the rods and levers $k\,k$, the engine will work with the condenser or without it. When working without the condenser, the cylinder is open to the atmosphere throughout the entire stroke, as in the common high-pressure engine, and under such circumstances, the pipe l is open to the feed-pump, for the boiler supply. The pipe m, leads to a small steam pump not seen in the drawing, and the pipe n, conveys the water from the steam pump to the boiler. The pipe o is the blow-off pipe.

MATCHES. The contrivances in which sulphur matches were inflamed by immersion in phosphorus (*phosphorous matches*) were first superseded by the so-called *chemical matches*, which consisted of sulphur matches, with a coating of chlorate of potash. This salt, when brought into contact with concentrated sulphuric acid in the cold, is decomposed with explosion and the production of fire, into bisulphate of potash, perchlorate of potash, and chlorous acid, and by the two latter (one of which is resolved into chlorine and oxygen, and the other into chloride of potassium and oxygen) inflammable matters of all kinds, as sulphur, metallic sulphurets, resin, gum, &c., are inflamed, when within the immediate reach of its action. The sulphur ends of the matches are covered with a composition of chlorate of potash, flowers of sulphur, colophony, gum, and cinnabar, (as a coloring matter:) on dipping this into a bottle containing asbestus, previously moistened with sulphuric acid, it quickly becomes inflamed. These matches are now superseded by the more simple lucifer matches, which inflame without the aid of acid, or any thing of the kind, by mere friction; an invention, the history of which, notwithstanding its novelty, is already lost, partly on account of its simplicity, and from the rapid introduction of similar processes.

Lucifer matches.—These, like the last, are sulphur matches, to which a separate inflammable compound has been added. The primary coating of sulphur cannot be dispensed with, because the inflammable composition burns much too rapidly to set fire to the wood. The flame produced by the combustible mixture is, therefore, first communicated to the sulphur, and from it to the wood. The mixture at first contained chlorate of potash as an essential ingredient, and the production of fire depended upon the power of this substance of inflaming the sulphur, phosphorus, &c., with explosion, the effect being produced even by shaking or friction. Thus phosphorus was mixed with mucilage, at a temperature of 104° F., so as to form an emulsion, to which the chlorate of potash was then added. The phosphorus was sometimes replaced by sulphuret of antimony. The operation of mixing the ingredients in the dry state is at all times dangerous. The unpleasant noise which occurred whenever a match was inflamed, and a certain amount of danger from fire, rendered it desirable to replace the detonating action of the mixture by a slow combustion, and this has been accomplished in the *noiseless lucifer matches.* None of those compositions which inflame *without* explosion contain chlorate of potash, but nitre and phosphorus instead; the latter of which burns at the expense of the oxygen of the former. The general principle concerned in the action of these matches is, that substances (as phosphorus) having a great affinity for oxygen, are mixed with a large amount of it, condensed into a small space, (in the nitre,) so that the slightest cause is sufficient to effect their combination. The peroxides of lead and manganese, which abound in oxygen, are often mixed with the nitre; they act in the same way when they have once attained a red heat.

As the thickness of the match, and the quantity of the composition upon it, must always bear a certain proportion, both because the latter is expensive, and burns with a disagreeable odor, the matches require to be cut by machinery, or planes constructed for the purpose; they are thus obtained thin, sufficiently strong, perfectly uniform, and of an elegant appearance. Moist poplar wood is best suited for this purpose. The round or angular matches are dipped in bundles into melted sulphur, and then coated with the inflammable composition: sixteen parts of gum-arabic, 9 parts of phosphorus, 14 parts of nitre, and 16 of finely divided peroxide of manganese, form a good composition, which must be worked up with water to avoid danger. The mixture then forms a thick paste, into which the matches are separately dipped and then dried. Occasionally, smalt and similar matters are added, to produce certain colors, or to increase the effects of friction. After repeated trials, the inflammability of the composition has been gradually diminished to such an extent, that it only inflames when strongly rubbed against rough surfaces, but not readily by pressure or shaking, especially when the matches are preserved in closed boxes; hence they are much less dangerous than might be anticipated. The slow combustion of the sulphur, with the emission of sulphurous acid, forms a great objection to these matches, as this gas is injurious to respiration. Matches have consequently been introduced into commerce which have been first dipped into fused stearine, instead of sulphur; these, however, frequently miss fire.

According to Ure, the following process answers well:

Phosphorus	4	parts.
Nitre	10	"
Fine glue	6	"
Red ochre, or red lead	5	"
Smalt	2	"

Convert the glue, with a little water, by a gentle heat, into a smooth jelly; put it into a slightly warm porcelain mortar to liquify; run the phosphorus down through this gelatine at a temperature of about 140° or 150° F.; add the nitre, then the red powder, and lastly the smalt, till the whole forms a uniform paste. To make writing-paper matches, which burn with a bright flame, and diffuse an agreeable odor, moisten each side of the paper with tincture of benzoin, dry it, cut it into slips, and smear one of their ends with a little of the above paste by means of a hair pencil. On rubbing the said end after it is dry against a rough surface, the paper will take fire without the intervention of sulphur.

To form lucifer wood matches, that act without sulphur, melt in a flat-bottomed tin pan as much white wax as will stand one tenth of an inch deep; take a bundle of wooden matches free from resin, rub their ends against a red-hot iron plate till the wood be slightly charred; dip them now in the melted wax for a moment, shake them well on taking them out, and finally dip them separately in the above viscid paste. When dry, they will kindle readily by friction.

For the rapid manufacture of the wooden splints for lucifer matches, a patent was granted to Mr. Reuben Partridge, in March, 1842. He employs a perforated metallic plate, having a steel face, strengthened by a bell-metal back. The size of the perforations must depend on that of the desired splints, but they must be as close together as possible, that there may be a very small blank space between them, otherwise the plate would afford too great resistance to the passage of the wood. By this construction, the whole area of the block of wood may be compressed laterally into the countersunk openings, and forced through the holes, which are slightly countersunk to favor the entrance and separation of the wooden fibres. A convenient size of plate is three inches broad, six inches long, and one thick. The mode of pressing is by fixing the back of the plate against a firm resisting block or bearing, having an aperture equal to the area of the perforations in the plate, and then placing the end of the piece or pieces of wood in the direction of the grain against the face of the plate within the area of the perforated portion. A plunger or lever, or other suitable mechanical agent, being then applied to the back or reverse end of the piece of wood, it may be forced through the perforations in the plate, being first split as it advances by the cutting edges of th holes, and afterwards compressed and driven through the perforations in the plate, coming out on the opposite side or back of the plate in the form of a multitude of distinct splints, agreeably to the shapes and dimensions of the perforations.

MATERIALS, *properties of, used in the mechanic arts.* The following tables show, in a condensed form, the characteristics of materials.

Experiments on the direct Cohesive Powers of various Materials.

Names of Materials.	Cohesive powers reduced to a sq. inch rod.	Experimenters.	Quoted from.
WOODS.	lbs.		
Oak	17,300	Muschenbroek.	Introd. ad Phil. Nat.
do.	13,950	Rondelet.	L'Art de Batir, iv.
do. dry English from	12,000 8,000	Barlow.	Essay on the Strength of Timber.
Beech	17,709	Muschenbroek.	Introd. ad Phil. Nat.
do.	11,500	Barlow.	Essay on the Strength of Timber.
Alder	14,186	Muschenbroek.	Introd. ad Phil. Nat.
Chestnut, Spanish	13,300	Rondelet.	L'Art de Batir, iv.
Ash, very dry, from	17,850 15,784	Barlow.	Essay on the Strength of Timber.
do.	12,000	Muschenbroek.	Introd. ad Phil. Nat.
Elm	13,489	do.	do.
Acacia	20,582	do.	do.
Mahogany	8,000	Barlow.	Essay on the Strength of Timber.
Walnut	8,130	Muschenbroek.	Introd. ad Phil. Nat.
Teak	15,000	Barlow.	Essay on the Strength of Timber.
Poplar from to	6,641 4,596	Muschenbroek.	Introd. ad Phil. Nat.
Fir from to	13,448 11,000	Barlow.	Essay on the Strength of Timber.
do.	8,506	Muschenbroek.	Introd. ad Phil. Nat. i.
Scotch Pine	7,818	do.	do.
Norway Pine	7,287	Rondelet.	L'Art de Batir, iv.
Larch	10,224	do.	do.
Cedar	4,973	Muschenbroek.	Introd. ad Phil. Nat. i
METALS.			
STEEL.			
Cast-steel previously tilted	134,256	Rennie.	Phil. Trans. for 1813.
Cast-steel not tilted	68,110	Brown.	Barlow's Essays, &c.
Blistered steel reduced per hammer	133,152	Rennie.	Phil. Trans. for 1818.
Sheer steel reduced per hammer..	127,632	do.	do.
IRON WIRE.			
Iron wire	113,077	Sickengen.	Ann. de Chimie, vol. 25.
do. 1-10th inch diameter	93,964	Telford.	Barlow's Essay, p. 245, 2d ed.
do.	85,797	Buffon.	Œuvres de Gauthey, ii. p. 153.
MALLEABLE IRON IN BARS.			
German bar, mark B R, highest results	93,069	Muschenbroek.	Introd. ad Phil. Nat. i. 426.
Swedish bar, highest result	88,972	do.	do.
German bar, mark L, highest result	85,900	do.	do.
Liege bar, highest result	82,839	do.	do.
Spanish bar	81,901	do.	do.
Oosement bar, highest result	76,697	do.	do.
Swedish bar reduced per hammer.	72,064	Rennie.	Phil. Trans. 1818.

Names of Materials.	Cohesive powers reduced to a sq. inch rod.	Experimenters.	Quoted from.
	lbs.		
Common round iron	66,309	Telford.	Barlow's Essay, p. 230.
German bar, marked L	69,530	Muschenbroek.	Introd. ad Phil. Nat. i. 426
Common Staffordshire bar	64,580	Telford.	Barlow's Essay, p. 230.
Common German bar	69,133	Muschenbroek.	Introd. ad Phil. Nat. i. 426.
Swedish bar	68,728	do.	do.
Oosement bar	68,728	do.	do.
Welsh bar	62,079	Telford.	Barlow's Essay, p. 230.
Bar of the best quality	66,000	Rumford.	Phil. Mag. x. p. 51.
A bar of Welsh, one of Swedish, and one faggoted scrap iron, each gave a result of	60,413	Telford.	Barlow's Essay, p. 229.
The Swedish iron broke at a flaw.			
Liege bar	62,369	Muschenbroek.	Introd. ad Phil. Nat. i. 426.
Staffordshire bar	57,288	Telford.	Barlow's Essay, p. 229.
German bar, marked B R	61,361	Muschenbroek.	Introd. ad Phil. Nat. i. 426.
Bar (mean of 33 experiments)	61,041	Perronnet.	Œuvres de Gauthey, ii. 154.
Russian old sable, mark C C N	64,230	Brown.	Barlow's Essay, p. 233.
English bar reduced per hammer.	55,872 ?	Rennie.	Phil. Trans. for 1818.
Welsh bar (3 experiments)	60,238	Brown.	Barlow's Essay, p. 233.
Bar of good quality	55,000	Rumford.	Phil. Mag. vol. x. p. 51.
Swedish bar (3 experiments)	57,503	Brown.	Barlow's Essay, p. 232.
CAST-IRON.			
Bar, specific gravity 7·807	68,295 ?	Muschenbroek.	Introd. ad Phil. Nat. i. 417.
do. cast vertically	19,488	Rennie.	Phil. Trans. for 1818.
do. cast horizontally	18,656	do.	do.
do. Welsh pig	17,565	Brown.	Barlow's Essay, p. 235.
COPPER.			
Wire	61,228	Sickingen.	Ann. de Chimie, xxv. 9.
Wrought copper reduced by the hammer	33,792	Rennie.	Phil. Trans. for 1818.
Cast, Barbary, spec. grav. 8·182	22,570	Muschenbroek.	Introd. ad Phil. Nat. i. 417.
do. Japan, do. do. 8·726	20,272	do.	do.
do.	19,072	Rennie.	Phil. Trans. for 1818.
PLATINUM.			
Platinum wire, spec. grav. 20·847.	56,473	Morveau.	Ann. de Chimie, xxv. 8.
do. do.	52,987	Sickingen.	do. p. 9.
SILVER.			
Silver wire	38,257	do.	do.
Silver cast, spec. grav. 11·091	40,902	Muschenbroek.	Introd. ad. Phil. Nat. 417.
GOLD.			
Gold wire	30,888	Sickingen.	Ann. de Chimie, xxv. 9.
Gold cast, spec. grav. 19·238	20,150	Muschenbroek.	Introd. ad Phil. Nat. i. 417.
ZINC.			
Zinc wire	22,551	Morveau.	Ann. de Chimie, lxxi. 194.
do. sheet	16,600	Tredgold.	Phil. Mag. vol. i. p. 422.
do. cast	2,689	Muschenbroek.	Introd. ad Phil. Nat. i. 407.
TIN.			
Tin wire	7,129	Morveau.	Ann. de Chimie, lxxi. 194.
English block, cast	6,650	Muschenbroek.	Introd. ad Phil. Nat. i. 417.
English, spec. grav. 7·295	5,322	do.	do.
Cast	4,736	Rennie.	Phil. Trans. for 1818.
Banca tin cast, spec. grav. 7·2165.	3,679	Muschenbroek.	Introd. ad Phil. Nat. i. 417.
Malacca tin cast, do. 6·1256.	3,211	do.	do.
LEAD.			
Milled sheet, spec. grav. 11·407	3,328	Tredgold.	Phil. Mag. vol. i. p. 422.
Wire	3,116	Muschenbroek.	Introd. ad Phil. Nat. i. 452.
do. spec. grav. 11·282	2,581	do.	do.
do.	2,517	Morveau.	Ann. de Chimie, lxxi. 194.
Cast lead	1,824	Rennie.	Phil. Trans. for 1818.
Cast, English, spec. grav. 11·479	885	Muschenbroek.	Introd. ad Phil. Nat. i. 452.

Names of Materials.	Cohesive powers reduced to a sq. inch rod.	Experimenters.	Quoted from.
BISMUTH.	lbs.		
Bismuth cast, spec. grav. 9·810....	3,250	Muschenbroek.	Introd. ad Phil. Nat. i. 452.
do. spec. grav. 9·926	3,008	do.	do.
ANTIMONY.			
Antimony cast, spec. grav. 4·500...	1,006	do.	do.
ALLOYS.			
Copper 10 tin 1, sp. gr. 8·351......	32,093	Muschenbroek.	Introd. ad Phil. Nat.
do. 8 do. 1, do. 8·392......	36,088	do.	do.
do. 6 do. 1, do. 8·707......	44,071	do.	do.
do. 4 do. 1, do. 8·723......	35,739	do.	do.
do. 2 do. 1	1,017	do.	do.
Gun metal, hard	36,368	Rennie.	Phil. Trans. for 1818.
Brass, fine yellow.....................	17,968	do.	do.
Tin, English, 10 lead 1.............	6,904	Muschenbroek.	do.
do. 8 do. 1.............	7,922	do.	do.
do. 6 do. 1.............	7,997	do.	do.
do. 4 do. 1.............	10,607	do.	do.
do. 2 do. 1.............	7,470	do.	do.
do. 1 do. 1.............	7,074	do.	do.
sp. gr.			
Tin, Banca, 10 Antimony 1, 7·359	11,181	do.	do.
do. 8 do. 1, 7·276	9,881	do.	do.
do. 6 do. 1, 7·228	12,632	do.	do.
do. 4 do. 1, 7·192	13,480	do.	do.
do. 2 do. 1, 7·105	12,029	do.	do.
do. 1 do. 1, 7·060	3,184	do.	do.
do. 10 bismuth 1, 7·576	12,688	do.	do.
do. 4 do. 1, 7·613	16,692	do.	do.
do. 2 do. 1, 8·076	14,017	do.	do.
do. 1 do. 1, 8·146	12,020	do.	do.
do. 1 do. 2, 8·580	10,013	do.	do.
do. 1 do. 4, 9·009	7,875	do.	do.
do. 10 zinc, Ind'n, 1, 7·288	12,914	do.	do.
do. 2 do. 1, 7·000	15,025	do.	do.
do. 1 do. 1, 7·321	15,844	do.	do.
do. 1 do. 2, 7·100	16,023	do.	do.
do. 1 do. 10, 7·130	5,671	do.	do.
Tin, English, 8 do. Goslar, 1,	10,607	do.	do.
do. 4 do. 1,	10,258	do.	do.
do. 2 do. 1,	10,964	do.	do.
do. 1 do. 1,	9,024	do.	do.
do. 1 antimony 1, 7·000	1,450	do.	do.
do. 3 do. 2,	3,184	do.	do.
do. 4 do. 1,	11,343	do.	do.
Lead, Scotch, 1 bismuth 1, 10·931	7,319	do.	do.
do. 2 do. 1, 11·090	5,840	do.	do.
do. 10 do. 1, 10·827	2,826	do.	do.

Experiments on the Resistance of different Metals to Pressure.

Size of prism.		Name of Metal.	Crushing weight.	Remarks.
Size of base.	Height.			
inch.	inch.		lbs.	
1-4th.	1-4th.	Cast copper.	7,318	Crumbled by pressure.
do.	do.	Brass.	10,304	Fine yellow brass reduced one-tenth by 3213 lbs., and one-half with 10,304 lbs.
do.	do.	Wrought copper.	6,440	Reduced one-sixteenth with 3427 lbs., one-eighth with 6440 lbs.
do.	do.	Cast tin.	966	Reduced one-sixteenth with 552 lbs., one-third with 960 lbs.
do.	do.	Cast lead.	483	Reduced one-half with 483 lbs.

Experiments on the Resistance of Cast-iron to Pressure.

Size of prism.		Specific gravity.	Crushing weight.	Mean from each set.	Remarks.
Size of base.	Height.				
inch.	inch.		lbs.	lbs.	
1-8th.	1-8th.	7033	1,454		These specimens were from one block.
do.	do.	do.	1,416	1,440	
do.	do.	do.	1,449		
do.	2-8ths.	6977	1,922	2,116	Iron from a block.
do.	do.	do.	2,310		
do.	3-8ths.	do.	2,363		
do.	4-8ths.	do.	2,005		
do.	5-8ths.	do.	1,407		
do.	6-8ths.	do.	1,743	1,758	These specimens were from the same block.
do.	7-8ths.	do.	1,594		
do.	8-8ths.	do.	1,439		
1-4th.	1-4th.	do.	10,561		
do.	do.	do.	9,596		
do.	do.	do.	9,917	9,773	These specimens were from the same block as the above.
do.	do.	do.	9,020		
do.	do.	7013	12,665		
do.	do.	do.	10,720		
do.	do.	do.	10,605	10,114	These specimens were from horizontal castings.
do.	do.	do.	8,699		
do.	do.	7074	12,665		
do.	do.	do.	10,950		
do.	do.	do.	11,088	11,136	These specimens were vertical castings.
do.	do.	do.	9,844		
do.	do.	do.	11,096		
do.	1-2d.	7113	9,455	9,414	Horizontal casting.
do.	do.		9,374		
do.	do.	7074	9,938	9,982	Vertical casting.
do.	do.		10,027		
do.	3-8ths.	7113	9,006		
do.	5-8ths.	do.	8,845		
do.	6-8ths.	do.	8,362	....	Horizontal castings.
do.	7-8ths.	do.	6,430		
do.	8-8ths.	do.	6,321		
do.	3-8ths.	7074	9,328		
do.	5-8ths.	do.	8,385		
do.	6-8ths.	do.	7,896	....	Vertical castings.
do.	7-8ths.	do.	7,018		
do.	8-8ths.	do.	6,430		

The Experimental Strength of various species of Timber opposed to a Transverse Strain.

Kinds of Wood.	Specific Gravity.	Length in feet.	Breadth in inches.	Depth in inches.	Deflection at the time of fracture.	Breaking weight in lbs.	Value of constant strength.	Authorities.
Oak, English, young tree.......	·863	2·	1	1	1·87	482	2892	Tredgold.
Do. old ship timber	·872	2·5	1	1	1·5	261	1980	do.
Do. from old tree	·625	2·	1	1	1·38	218	1308	do.
Do. medium quality.............	·748	2·5	1	1		284	2130	Ebbels.
Do. green	·763	2·5	1	1		219	1741	do.
Do. do......	1·063	11·75	8 5	8·5	3·2	24812	1785	Buffon.
Beech, medium quality	·690	2 5	1	1		271	2031	Ebbels.
Alder........................	·555	2·5	1	1		212	1590	do.
Plane tree..........................	·618	2·5	1	1		243	1821	do.
Sycamore	·590	2·5	1	1		214	1605	do.
Chestnut tree	·875	2·5	1	1		180	1350	do.
Ash, from young tree...........	·811	2·5	1	1	2·5	324	2430	Tredgold.
Do. medium quality............	·690	2·5	1	1		254	1905	Ebbels.
Ash	·753	2·5	1	1	2·38	314	2355	Tredgold.
Elm, common	·544	2·5	1	1		216	1620	Ebbels.
Do. weych, green	·763	2·5	1	1		192	1440	do.
Acacia, green	·820	2·5	1	1		219	1866	do.
Mahogany, Spanish, seasoned.	·852	2·5	1	1		170	1275	Tredgold.
Do. Honduras, seasoned.........	·256	2 5	1	1		255	1911	do.

Exhibiting the Experimental Strength of various Species of Timber, etc.—Continued.

Kinds of Wood.	Specific Gravity.	Length in feet.	Breadth in inches.	Depth in inches.	Deflection at the time of fracture.	Breaking weight in lbs.	Value of constant strength.	Authorities.
Walnut, green	·925	2·5	1	1		195	1461	Ebbels.
Poplar, Lombardy	·375	2·5	1	1		131	981	do.
Do. Abele	·511	2·5	1	1	1·5	228	1710	Tredgold.
Teak	·744	7	2	2	4·00	820	2151	Barlow.
Willow	·405	2·5	1	1	3	146	1095	Tredgold.
Birch	·720	2·5	1	1		207	1551	Ebbels.
Cedar of Libanus, dry	·586	2·5	1	1	2·75	165	1236	Tredgold.
Riga fir	·480	2·5	1	1	1·3	212	1590	do.
Memel fir	·553	2·5	1	1	1·15	218	1635	do.
Norway fir from Longsound	·639	2	1	1	1·125	396	2376	do.
Mar forest fir	·715	7	2	2	5·5	360	945	Barlow.
Scotch fir, English growth	·529	2·5	1	1	1·75	233	1746	Tredgold.
Do. do.	·460	2·5	1	1		157	1176	Ebbels.
Christiana white deal	·512	2	1	1	·937	343	2058	Tredgold.
American white spruce	·465	2	1	1	1·362	285	1710	do.
Spruce fir, British growth	·555	2·5	1	1		186	1395	Ebbels.
American pine	·460	2·0	1	1	1·125	329	1974	Tredgold.
Larch, choice specimen	·640	2·5	1	1	3·0	253	1896	do.
Do. medium quality	·622	2·5	1	1		223	1671	do.
Do. very young wood	·396	2·5	1	1	1·78	129	966	do.
English oak	·934	7	2	2	8·1	637	1672	Barlow.
Canadian do.	·872	7	2	2	6·0	673	1766	do.
Dantzic do.	·756	7	2	2	4·86	560	1457	do.
Adriatic do.	·993	7	2	2	5·73	526	1383	do.
Ash	·760	7	2	2	8·92	772	2026	do.
Beech	·696	7	2	2	5·73	593	1556	do.
Pitch pine	·660	7	2	2	6·00	622	1632	do.
Red pine	·657	7	2	2	5·83	511	1341	do.
New England pine	·553	7	2	2	4·66	420	1102	do.

Of Experiments on the Stiffness of different Woods.

Kinds of Wood.	Specific Gravity.	Length in feet.	Breadth in inches.	Depth in inches.	Deflection.	Weight which produced deflection.	Value of a from $a = \frac{40\, bd^3\, \delta}{l_3\, W}$	Authorities.
Ash, young tree, white colored	·811	2·5	1	1	0·5	141	·009	Tredgold.
Do. old tree, red colored	·753	2·5	1	1	0·5	113	·0113	do.
Do. medium quality	·690	2·5	1	1	0·5	78·5	·0163	Ebbels.
Ash	·760	7	2	2	1·27	225	·0105	Barlow.
Beech	·688	7	2	2	1·025	150	·01277	do.
Teak	·744	7	2	2	1·276	300	·0076	do.
Elm	·540	2·5	2	2	1·42	125	·0212	do.
Elm	·544	2·5	1	1	0·5	99·5	·0128	Ebbels.
Cedar of Libanus	·486	2·5	1	1	0·5	36	·0355	Tredgold.
Maple, common	·625	2·5	1	1	0·5	65	·0197	do.
Abele	·511	2·5	1	1	0·5	84	·0152	do.
Willow	·405	2·5	1	1	0·5	41	·031	do.
Horse chestnut	·483	2·5	1	1	0·5	79	·0162	do.
Lime tree	·483	2·5	1	1	0·5	84	·0152	do.
Walnut, green	·920	2·5	1	1	0·5	62	·020	Ebbels.
Chestnut, Spanish	·895	2·5	1	1	0·5	68·5	·0187	do.
Acacia	·820	2·5	1	1	0·5	125	·0102	do.
Plane, dry	·648	2·5	1	1	0·5	99·5	·0128	do.
Alder, do.	·555	2·5	1	1	0·5	80·5	·0159	do.
Birch, do.	·720	2·5	1	1	0·5	90·5	·0141	do.
Wych elm, green	·763	2·5	1	1	0·5	92	·014	do.
Lombardy poplar, dry	·374	2·5	1	1	0·5	56·5	·0224	do.
Mahogany, Honduras	·560	2·5	1	1	0·5	118	·0109	Tredgold.
Do. Spanish	·853	2·5	1	1	0·5	93	·0137	do.
Sycamore	·590	2·5	1	1	0·5	76	·0168	Ebbels.
Pear, green	·792	2·5	1	1	0·5	59·5	·0215	do.
Cherry, do.	·690	2·5	1	1	0·5	92·5	·0138	do.
Beech, dry	·696	2·5	1	1	0·5	97·5	·0131	do.

Of Experiments on the Stiffness of Fir.

Kinds of Fir.	Specific Gravity.	Length in feet.	Breadth in inches.	Depth in inches.	Deflection in inches.	Weight producing the deflection in lbs.	Value of e from $\frac{40\,bd^3\,\delta}{l^3\,W}$	Authorities.
Fir, Riga, yellow medium		1·8	2	7	0·25	103	·0015	Tredgold.
Do. Norway	.6398	2	1	1	0·5	261	·00957	Do.
Do. Riga, yellow	·480	2·5	1	1	0·5	123	·0102	Do.
	·464	2·5	1	1	0·5	116	·0110	Ebbels.
Do. Memel medium	·553	2·5	1	1	0·5	143	·0089	Tredgold.
	·544	2·5	1	1	0·5	145	·0088	
American pine	·460	2	1	1	0·5	237	·0105	Do.
	·407	3	1	1	0·5	69	·0112	
White spruce, Christiana	·512	2	1	1	0·5	261	·00957	Do.
Do. Quebec	·465	2	1	1	0·5	180	·0130	Do.
Pitch pine	·712	7	2	2	1·33	150	·0166	Barlow.
Fir, New England	·560	7	2	2	·970	150	·0121	Do.
Riga fir	·765	7	2	2	·912	150	·01137	Do.
Mar forest, Scotland	·715	7	2	2	1·560	125	·0233	Do.
Larch, Blair, Scotland, dry	·622	2·5	1	1	0·5	93	·0137	Tredgold.
Do. seasoned medium	·644	2·5	1	1	0·5	101	·0126	Do.
	·554	2·5	1	1	0·5	112	·0111	Ebbels.
Do. very young wood	·396	2·5	1	1	0·5	45	·0284	Tredgold.
Scots fir	·529	2·5	1	1	0·5	89	·01437	Do.
Spruce, British	·555	2·5	1	1	0·5	93	·0124	Ebbels.
Fir, (bois-disbrin)		21·3	10·48	10·48	1·02	4·389	·0115	Girard.
Do. do.		10·65	10·58	10·48	0·2245	4·122	·0220	Do.

Experiments on the Resistance of various Materials to a Crushing Force.

Names of Materials.	Specific Gravity.	Crushing weight.
		lbs.
1. Elm, cube of 1 inch		1284
2. American pine, do.		1606
3. White deal, do.		1928
4. English oak, do.		3860
5. Portland stone, 2 inches long		805
6. Statuary marble, 1 inch		3216
7. Craigleith, do.		8688
8. Chalk, cube of 1½ inch		1127
9. Brick, pale red, do	2085	1265
10. Roe-stone, Gloucestershire, do		1449
11. Red brick, do.	2168	1817
12. Do. Hammersmith pavior's do.		2254
13. Burnt do.		3243
14. Fire brick, do.		3864
15. Derby grit, do.	2316	7070
16. Do. another specimen, do.	2428	9776
17. Killaly white freestone, do.	2423	10264
18. Portland do.	2428	10284
19. Craigleith white freestone, do.	2452	12346
20. Yorkshire paving with the strata, do.	2507	12856
21. Do. do. against strata, do.		12856
22. White statuary marble, do.	2760	13632
23. Bramley Fall sandstone, do.	2506	13632
24. Do. against strata, do.		13632
25. Cornish granite, do.	2662	14302
26. Dundee sandstone, do.	2530	14918
27. Portland, a two inch cube	2423	14918
28. Craigleith, with the strata, 1½ inch cube	2452	15560
29. Devonshire red marble		16732
30. Compact limestone	2584	17354
31. Granite Peterhead		18636
32. Black compact limestone	2598	19924
33. Purbeck	2599	20610
34. Freestone, very hard	2528	21254
35. Black Brabant marble	2697	20742
36. White Italian marble	2726	21783
37. Granite, Aberdeen, Blue kind	2625	24556

Of Experiments on the Stiffness of Oak.

Kinds of Oak.	Specific Gravity.	Length in feet.	Breadth in inches.	Depth in inches.	Deflection in inches.	Weight producing the deflection in lbs.	Values of a from $\frac{40 bd^3 \delta}{l^3 W}$	Authorities.
Old ship timber	·872	2·5	1	1	0·5	127	·00998	Tredgold.
Oak from young tree, King's Langley, Herts	·863	2·	1	1	0·5	237	·0105	Do.
Oak from Beaulieu, Hants	·616	2·5	1	1	0·5	78	·0164	Do.
Do., another specimen	·736	2·5	1	1	0·5	65	·0197	Do.
Oak from old tree	·625	2	1	1	0·5	103	·0240	Do.
Oak, Riga	·688	2	1	1	0·5	233	·0107	Do.
Do. English.......................	·960	7	2	2	1·275	270	·0119	Barlow.
Do. Canada........................	·867	7	2	2	1·07	225	·009	Do.
Do. Dantzic........................	·787	7	2	2	1·26	208	·0105	Do.
Do. Adriatic	·948	7	2	2	1·55	150	·0193	Do.
Do. green...........................	·763	2·5	1	1	0·5	96	·0133	Ebbels.
Do. Dantzic seasoned	·755	2·5	1	1	0·5	148	·0087	Tredgold.
Do. do.		12·8	3·19	3·19	1·06	268	·008	Aubry.
					4·25	803	·0105	
Do. green...........................		6·87	5·3	5·3	·433	7587	·005	Buffon.
Do. do.		23·58	5·3	5·3	2·7	706	·0095	Do.
Do.		8·52	5·06	6·22	0·709	4146	·0013	Girard.
Do. (bois-disbrin)		16·06	10·66	11·73	0·67	4559	·0213	Do.
Oak....................................		2	1	1	0·35	149	·0117	Tredgold.
Do.		2	1	1	0·35	167	·0104	Do.

Experiments on the Resistance of Seasoned Oak Beams to Forces pressing in the direction of their lengths.

Kind of Wood.	Length in feet.	Breadth in inch.	Depth in inches.	Deflection in inch.	Weight producing the deflection in lbs.	Proportional elasticity.	Duration of the experiments in hours.	Weight that broke the pieces.	Authority.
Oak seasoned	2.125	2·126	2·126	·0787	7,856	·0006	4	15·631	Lamande.
				·03937	13,525	·00033	6	21·296	
				·1181	14.119	·00032	18	19·993	
				·03937	11,750	·00042	8	21·060	
Do.....................	4·25	2·126	2·126	·0787	6,298	·0002	21	11·844	Do.
				·1574	6,298		27	12·225	
				·1574	6,298			13·565	
				·1574	6,298		6	12·458	
Do.....................	6·375	2·126	2·126	·1574	3,277	·00015	6	7·244	Do.
				·1574	2,860	·00018		7·484	
				·2361	2.750	·00019	5	8·492	
				·1574	2,750			7·878	
Do.....................	2·125	3·18	3·18	·0787	34,599	·0007	27	50·958	Do.
				·03937	45.168	·0005	24	50·958	
Do.....................	4·25	3·18	3·18	·1574	20.317	·0003	29	43·639	Do.
				·1574	18,647	·00031	5	36·865	
				·19685	20.578	·0003	9	36·205	
				·27559	21,819	·00026	17	28·182	
Do.....................	6·375	3·18	3·18	·1574	9,121	·00028	7	26·939	Do.
				·19685	9.713	·00027	19	28·987	
				·0787	11,000	·00023	4	23·929	
				·2361	10.142	·00025	18	33·048	
				·1574	12.746	·0002	6	36·902	
Do.....................	2.125	4·25	4·25	·0787	61,883	·00118	11	95·262	Do.
				·03937	56,691	·00129	8	66·112	
				·03937	56,693		23	105·826	
				·0787	67.467	·00107	28	94·476	
				·03937	57,780	·00125	30	88·442	
Do.....................	4·25	4·25	4·25	·03937	63.066	·00027	8	100·755	Do.
				·0787	29.695	·0006	5	85·998	
				·0787	50.525	·00035	19	73·238	
				·03937	45.201	·0004	19	96·368	
Do.....................	6·375	4·25	4·25	·1574	21,589	·00038	7	64·090	Do.
				·2361	17,331	·00047	5	59·373	
				·1574	18.517	·00044	22	54·062	
				·2361	27.599	·0003	22	65·608	

On the Elasticity of various Woods, as computed by Mr. Tredgold.

Kinds of Wood.	Elasticity = e.	Kinds of Wood.	Elasticity = e.
English oak	0·0015	Mahogany, Honduras	0·00161
Beech	0·00195	Teak	0·00118
Alder	0·0023	Cedar, Lebanon	0·0053
Chestnut, green	0·00267	Riga fir	0·00152
Ash	0·00168	Memel fir	0·00153
Elm	0·00184	Norway spruce	0·00142
Acacia	0·00152	Weymouth pine	0·00157
Mahogany, Spanish	0·00205	Larch	0·0019

MEAN. A middle state between two extremes; thus we say, arithmetical mean is half the sum of any two quantities: as $\frac{a+b}{2}$ = arithmetical mean between a and b.

Geometrical mean is the square root of the product of any two quantities; that is, $\sqrt{ab}$ is the geometrical mean between a and b.

MEASURE. Measure denotes any certain quantity with which other homogeneous quantities are compared.—See WEIGHTS AND MEASURES.

MECHANICAL POWERS. Power is a compound of *weight*, multiplied by its *velocity*; it cannot be increased by mechanical means.

The weight is the resistance to be overcome, the power is the requisite force to overcome that resistance. When they are equal, no motion can take place.

The powers are THREE *in number, viz.*, LEVER, INCLINED PLANE, *and* PULLEY.

Note.—The wheel and axle is a *continual* or *revolving* lever, the wedge is a *double* inclined plane, and the screw is a *revolving* inclined plane.

LEVER.—*When the fulcrum (or support) of the lever is between the weight and the power.*

Rule.—Divide the weight to be raised by the power, and the quotient is the difference of leverage, or the distance from the fulcrum at which the power supports the weight.

Or, multiply the weight by its distance from the fulcrum, and the power by its distance from the same point, and the weight and power will be to each other as their products.

Example.—A weight of 1600 lbs. is to be raised by a force of 80 lbs.; required the length of the longest arm of the lever, the shortest being 1 foot.

$$\frac{1600 \times 1}{80} = 20 \text{ feet, } Ans.$$

Proof, by second rule.

$$1600 \times 1 = 1600.$$
$$80 \times 20 = 1600.$$

Example.—A weight of 2160 lbs. is to be raised with a lever 7 feet long and 300 lbs.; at what part of the lever must the fulcrum be placed?

$\frac{2160}{300} = 8·2$; that is, the weight is to the power as 8·2 to 1; therefore the whole length $\frac{7 \times 12}{8·2 + 1} = \frac{84}{9·2} =$ 9·13 inches, the distance of the fulcrum from the weight.

Example.—A weight of 400 lbs. is placed 15 inches from the fulcrum of a lever; what force will raise it, the length of the other arm being 10 feet?

$$\frac{400 \times 15}{120} = 50 \text{ lbs., } Ans.$$

Note.—Pressure upon fulcrum equal the sum of weight and power.

When the fulcrum is at one extremity of the lever, and the power, or the weight, at the other.

Rule.—As the distance between the power or *weight* and fulcrum, is to the distance between the weight or *power* and fulcrum, so is the effect to the power, or the *power* to the *effect*.

Example.—What power will raise 1500 lbs., the weight being 5 feet from it, and 2 feet from the fulcrum?

$$5 + 2 = 7 : 2 :: 1500 : 428·5714 + Ans.$$

Example.—What is the weight on each support of a beam that is 30 feet long, supported at both ends, and bearing a weight of 6000 lbs. 10 feet from one end?

30 : 20 : : 6000 : 4000 lbs. at the end nearest the weight; and
30 : 10 : : 6000 : 2000 lbs. at the end farthest from the weight.

Note.—Pressure upon fulcrum is the difference of the weight and the power.

The GENERAL RULE, therefore, for ascertaining the relation of POWER to WEIGHT in a lever, whether it be straight or curved, is, the power multiplied by its distance from the fulcrum, is equal to the weight multiplied by its distance from the fulcrum.

Let P be called the power, W the weight, p the distance of P from the fulcrum, and w the distance of W from the fulcrum; then

$$P : W : : w : p, \text{ or } P \times p = W \times w;$$

and

$$\frac{W \times w}{p} = P. \qquad \frac{P \times p}{w} = W.$$

$$\frac{W \times w}{P} = p. \qquad \frac{P \times p}{W} = w.$$

If several weights or powers act upon one or both ends of the lever, the condition of equilibrium is

$$P \times p + P' \times p' + P'' \times p'', \text{ \&c.,} = W \times w + W' \times w', \text{ \&c.}$$

In a system of levers, either of similar, compound, or mixed kinds, the condition is

$$\frac{P \times p \times p' \times p''}{w \times w' \times w''} = W.$$

Let $P = 1$ lb., p and p' each 10 feet, p'' 1 foot; and if w and w' be each 1 foot, and w'' 1 inch, then $\frac{1 \times 120 \times 120 \times 12}{12 \times 12 \times 1} = \frac{172800}{144} = 1200$; that is, 1 lb. will balance 1200 lbs. with levers of the lengths above given.

Note.—The weights of the levers in the above formulæ are not considered, the centre of gravity being assumed to be over the fulcrums.

If the arms of the lever be equally bent or curved, the distances from the fulcrum must be measured upon perpendiculars, drawn from the lines of direction of the weight and power, to a line running horizontally through the fulcrum; and if unequally curved, measure the distances from the fulcrum upon a line running horizontally through it till it meets perpendiculars falling from the ends of the lever.

Wheel and Axle.—The power multiplied by the radius of the wheel is equal to the weight multiplied by the radius of the axle.

As the radius of the wheel is to the radius of the axle, so is the effect to the power.

When a series of wheels and axles act upon each other, either by belts or teeth, the weight or velocity will be to the power or unity as the product of the radii, or circumferences of the wheels, to the product of the radii, or circumferences of the axles.

Example.—If the radii of a series of wheels are 9, 6, 9, 10, and 12, and their pinions have each a radius of 6 inches, and the weight applied be 10 lbs., what weight will it raise?

$$\frac{10 \times 9 \times 6 \times 9 \times 10 \times 12}{6 \times 6 \times 6 \times 6 \times 6} = 75 \text{ lbs. weight.}$$

Or, if the 1st wheel make 10 revolutions, the last will make 75 in the same time.

To find the power of cranes, &c.

Rule.—Divide the product of the driven teeth by the product of the drivers, and the quotient is the relative velocity, which, multiplied by the length of the winch and the force in lbs. and divided by the radius of the barrel, will give the weight that can be raised.

Example.—A force of 18 lbs. is applied to the winch of a crane, the length being 8 inches; the pinion having 6, the wheel 72 teeth, and the barrel 6 inches diameter.

$$\frac{6}{72} = 12 \times 8 \times 18 = 1728 \div 3 = 576 \text{ lbs. weight.}$$

Let w represent length of winch,
r " radius of barrel,
P " force applied,
v " velocity,
W " weight raised.

$$\frac{v\,w\,P}{r} = W.$$

$$W\,r = v\,w\,P.$$

$$\frac{W\,r}{v\,w} = P.$$

Example.—A weight of 94 tons is to be raised 360 feet in 15 minutes, by a force the velocity of which is 220 feet per minute; what is the power required?

$$\frac{360}{15} = 24 \text{ feet per minute.}$$

$$\frac{24 \times 94}{220} = 10{\cdot}2542 \text{ tons.}$$

In a wheel and axle, where the axle has two diameters, the condition of equilibrium is

$$W : P : : R : \tfrac{1}{2}(r - r');$$

$$\text{or, } P \times R = W \times \tfrac{1}{2}(r - r');$$

that is, the weight is to the power as the lever by which the power works, is to half the difference of the radii of the axle;

R representing radius of wheel,
r " radius of large axle,
r' " radius of less axle.

Inclined Plane.—*Rule.*—As the length of the plane is to its height, so is the weight to the power.

Example.—Required the power necessary to raise 1000 lbs. up an inclined plane 6 feet long and 4 feet high.

As 6 : 4 : : 1000 : 666·66 *Ans.*

Let W represent weight,
h " height of plane,
l " length of plane,
P " power,
b " base of plane,
p' " pressure on plane.

$$\frac{W \times h}{l} = P.$$

$$\frac{P \times l}{h} = W.$$

$$\frac{W \times b}{l} = p'.$$

To find the length of the base, height, or length of the plane, when any two of them are given.

Rule.—For the length of the base, subtract the square of the height from the square of the length of the plane, and the square root of the remainder will be the length of the base.

For the length of the plane, add the squares of the two other dimensions together, and the square root of their sum will be the length required.

For the height, subtract the square of the base from the square of the length of the plane, and the square root of the remainder is the height required.

Example.—The height of an inclined plane is 20 feet, and its length 100; what is its base, and the pressure of 1000 lbs. upon the plane?

$$\sqrt{20^2 - 100^2} = 9600 = 97{\cdot}98 \text{ the base.}$$

As 100 : 20 : : 1000 : 200 lbs. necessary power to raise the 1000 lbs., and $\frac{1000 \times 97{\cdot}98}{100} = 979{\cdot}8$ the pressure upon the plane.

If two bodies on two inclined planes sustain each other by the aid of a cord over a pulley, their weights are directly as the lengths of the planes.

Example.—If a body of 50 lbs. weight, upon an inclined plane of 10 feet rise in 100, be sustained by another weight on an opposite plane of 10 feet rise to 90 of an inclination, what is the weight of the latter?

As 100 : 90 : : 50 : 45, the answer.

When a body is supported by two planes, and if the weight be represented by the sine of the angle between the two planes. The pressures upon them are reciprocally as the sines of the inclinations of those planes to the horizon, viz.:

The weight,	are as	Sine of the angle between the planes.
The pressure upon one plane,		Sine of the angle of one plane.
The pressure upon the other plane,		Sine of the angle of the other plane.

Thus, if the angle between the planes was 90°, of one plane 60°, and the other 30°—since the natural sines of 90°, 60°, and 30° are 1, ·866, and ·500—if the body weighed 100 lbs., the pressure upon the plane of 30° would be 86·6 lbs., and upon the plane of 60°, 50 lbs., = the centre of gravity being in the centre of the body.

When the power does not act parallel to the plane, draw a line perpendicular to the direction of the power's action from the end of the base line, (at the back of the plane,) and the intersection of this line on the length will determine the length and height of the plane.

Note.—When the line of direction of the power is parallel to the plane, the power is least.

The space which a body describes upon an inclined plane, when descending on the plane by the force of gravity, is to the space it would freely fall in the same time, as the height is to the length of the plane; and the spaces being the same, the times will be inversely in this proportion.

Example.—If a body be placed upon an inclined plane 300 feet long and 25 feet high, what space will it roll down in one second by the force of gravity alone?

As 300 : 25 : : *16·08 : 1·33 feet, *Ans.*

If a body be *projected down an inclined plane* with a given velocity, then the distance which the body will be from the point of projection in a given time will be $t \times v + \frac{h}{l} \times 16{\cdot}08t^2$; but if the body be *projected upward,* then the distance of the body from the point of projection will be $t \times v - \frac{h}{l} \times 16{\cdot}08t^2$.

The force which accelerates a body down an inclined plane is that fractional part of the force of gravity which is represented by the height of the plane divided by its length.

Let h represent the height of the plane, l its length, t the time in seconds, s the space which a body will move through in a given time, v the velocity, and i the angle of inclination $\left(\text{sin. } i = \frac{h}{l}\right)$.

$$s = \frac{16{\cdot}08\,h\,t^2}{l}, \text{ or } \frac{t\,v}{2}, \text{ or } \frac{l\,v^2}{64{\cdot}3\,h}, \text{ or } \frac{v^2}{64{\cdot}3 \text{ sin. } i}, \text{ or sin. } i \times 16{\cdot}08\,t^2.$$

$$v = \frac{2\,s}{t}, \text{ or } \frac{32{\cdot}16\,h\,t}{l}, \text{ or } \sqrt{\frac{64{\cdot}3\,h\,s}{l}}, \text{ or sin. } i \times 32{\cdot}16\,t, \text{ or } \sqrt{\text{sin. } i \times 64{\cdot}3\,s}.$$

* The distance a body will freely fall in one second by the force of gravity.

$$t = \frac{2s}{v}, \text{ or } \frac{lv}{32{\cdot}16\,h}, \text{ or } \sqrt{\frac{ls}{16{\cdot}08\,h}}, \text{ or } \frac{v}{32{\cdot}16 \sin. i}, \text{ or } \sqrt{\frac{s}{16{\cdot}08 \sin. i}}.$$

$$\frac{h}{l}, \text{ or } \sin. i = \frac{v}{32{\cdot}16\,t}, \text{ or } \frac{s}{16{\cdot}08\,t^2}, \text{ or } \frac{v^2}{64{\cdot}3\,s}.$$

The accelerating force on the plane is to the accelerating force of gravity as v^2 is to $64{\cdot}3 \times s$.

If $\sin. i = \frac{1}{2}$, it shows that the length of the plane is twice its height, or $\frac{1}{2} = 30°$.

If the proportion which the length of the plane bears to the height be given, substitute these proportions for the length and height in the above rules, and the conclusions will be equally true.

WEDGE.—*When two bodies are forced from one another, in a direction parallel to the back of the wedge.*

Rule.—As the length of the wedge is to half its back, so is the resistance to the force.

Example.—The length of the back of a double wedge is 6 inches, and the length of it through the middle 10 inches; what is the power necessary to separate a substance having a resistance of 150 lbs.?

As 10 : 3 : : 150 : 45 lbs., *Ans.*

When only one of the bodies is movable.

Rule.—As the length of the wedge is to its back, so is the resistance to the power.

Example.—What power, applied to the back of a wedge, will raise a weight of 15,000 lbs., the wedge being 6 inches deep, and 100 long on its base?

As 100 : 6 : : 15000 : 900 lbs.,* *Ans.*

Note.—As the power of the wedge in practice depends upon the split or rift in the wood to be cleft, or in the body to be raised, the above rules are only theoretical where a rift exists.

SCREW.—As the screw is an inclined plane wound round a cylinder, the length of the plane is found by adding the square of the circumference of the screw to the square of the distance between the threads, and taking the square root of the sum, and the height is the distance between the consecutive threads.

Rule.—As the length of the inclined plane is to the pitch or height of it, so is the weight to the power.

When a wheel or capstan is applied to turn the screw, the length of the lever is the radius of the circle described by the handle of the wheel or capstan bar.

Let P represent power,
R " length of lever,
W " weight,
l " length of the inclined plane,
p " pitch of screw or height of plane,
x " effect of power at circumference of screw,
r " radius of screw.

Then, by the above rules,

As $l : p :: W : P$,	$P : W :: p : l$,
$l : W :: p : P$,	$r : R :: P : x$,
$W : l :: P : p$,	$P : x :: r : R$,
$p : l :: P : W$,	$R : r :: x : P$.

Example.—What is the power requisite to raise a weight of 8000 lbs. by a screw of 12 inches circumference and 1 inch pitch?

$12^2 + 1^2 = 145$, and $\sqrt{145} = 12{\cdot}04159$.

Then, 12·0416 : 1 : : 8000 : 664·36 lbs., *Ans.*

And if a lever of 30 inches length was added to the screw,

$12 \div 3{\cdot}1416 = 3{\cdot}819 \div 2 + 30 = 31{\cdot}9095$, length of lever.

Then, as $31{\cdot}9095 \times 2 \times 3{\cdot}1416 : 12{\cdot}0416 :: 664{\cdot}36 : 39{\cdot}9$ lbs., *Ans.*

Or, let C represent the circumference described by the power, and we have

$P : W :: p : C$,
$C : p :: W : P$,
$P \times C = W \times p$;

When a hollow screw revolves upon one of less diameter and pitch, (or the differential screw,) the effect is the same as that of a single screw, in which the distance between the threads is equal to the difference of the distances between the threads of the two screws.

If one screw has 20 threads in an inch pitch, and the other 21, the power is to the weight as the difference between $\frac{1}{20}$ and $\frac{1}{21}$, or $\frac{1}{420} = 1$ to 420.

In a complex machine, composed of the screw, and wheel, and axle, the relation between the weight and power is thus:

Let x represent the effect of the power on the wheel,
R " the radius of the wheel,
p " the pitch of the screw,
r " the radius of the axle,
C " the circumference described by the power.

* This is exclusive of friction, which in this machine is very great.

Then, by the properties of the screw,

$$P \times C = x \times p;$$

and of the wheel and axle,

$$x \times R = W \times r.$$

Hence we have

$$P \times C \times x \times R = x \times p \times W \times r.$$

Omitting the common multiplier, x,

$$P \times C \times R = W \times p \times r;$$

$$\text{or} \quad P : W :: p \times r : C \times R,$$

$$\text{and } p \times r : C \times R :: P : W.$$

Example.—What weight can be raised with a power of 10 lbs. applied to a crank 32 inches long, turning an endless screw of $3\frac{1}{2}$ inches diameter and one inch pitch, applied to a wheel and axle of 20 and 5 inches in diameter respectively?

Circumference of 64 = 201.

$$1 : 201 :: 10 : 2010.$$

Radii of wheel and axle, 10 and 2·5.

$$2{\cdot}5 : 10 :: 2010 : 8040 \text{ lbs., } \textit{Ans.}$$

$$\text{or } 2{\cdot}5 \times 1 : 201 \times 10 :: 10 : 8040.$$

And when a series of wheels and axles act upon each other, the weight will be to the power as the continued product of the radii of the wheels to the continued product of the radii of the axles;

$$\text{thus, } W : P :: R^3 : r^3;$$

$$\text{or, } r^3 : R^3 :: P : W,$$

there being three wheels and axles of the same proportion to each other.

Example.—If an endless screw, with a pitch of half an inch, and a handle of 20 inches radius, be turned with a power of 150 lbs., and geered to a toothed wheel, the pinion of which turns another wheel, and the pinion on the second wheel turns a third wheel, to the pinion or barrel of which is hung a weight, it is required to know what weight can be sustained in that position, the diameter of the wheels being 18, and the pinions 2 inches?

$$p \times r^3 : C \times R^3 :: P : W;$$

$$\text{or } {\cdot}5 \times 1^3 : 125{\cdot}6 \times 9^3 :: 150;$$

which, when extended, gives

$${\cdot}5 : 91562{\cdot}4 :: 150 : 27468720 \text{ lbs., } \textit{Ans.}$$

Note.—The diameter of a screw is not a necessary element in determining the weight it will support, when the point at which the power is applied is given.

PULLEY.—*When only one cord or rope is used.*

Rule.—Divide the weight to be raised by the number of parts of the rope engaged in supporting the lower or movable block.

Example.—What power is required to raise 600 lbs., when the lower block contains six sheaves and the end of the rope is fastened to the upper block, and what power when fastened to the lower block?

$$\frac{600}{6 \times 2} = 50 \text{ lbs., 1st } \textit{Ans.}$$

$$\frac{600}{6 \times 2 + 1} = 46{\cdot}15 \text{ lbs., 2d } \textit{Ans.}$$

$$\text{or } W = n \times P,$$

n signifying the number of parts of the rope which sustain the lower block.

When more than one rope is used.

In a *Spanish burton*, where there are two ropes, two movable pulleys, and one fixed and one stationary pulley, with the ends of one rope fastened to the support and upper movable pulley, and the ends of the other fastened to the lower block and the power, the weight is to the power as 5 to 1.

And in one where the ends of one rope are fastened to the support and the power, and the ends of the other to the lower and upper blocks, the weight is to the power as 4 to 1.

In a system of pulleys, with any number of ropes, the ends being fastened to the support,

$$W = 2^n \times P,$$

n expressing the number of ropes.

Example.—What weight will a power of 1 lb. sustain in a system of 4 movable pulleys and 4 ropes?

$$1 \times 2 \times 2 \times 2 \times 2 = 16 \text{ lbs., } \textit{Ans.}$$

When fixed pulleys are used in the place of hooks, to attach the ends of the rope to the support,

$$W = 3^n \times P.$$

Example.—What weight will a power of 5 lbs. sustain with 4 movable and 4 fixed pulleys, and 4 ropes?

$$5 \times 3 \times 3 \times 3 \times 3 = 405 \text{ lbs., } \textit{Ans.}$$

When the ends of the rope, or the fixed pulleys, are fastened to the weight,

$$W = (2^n - 1) \times P,$$

$$\text{and } W = (3^n - 1) \times P,$$

which would give, in the above examples,

$$1 \times 2 \times 2 \times 2 \times 2 = 16 - 1 = 15 \text{ lbs.,}$$

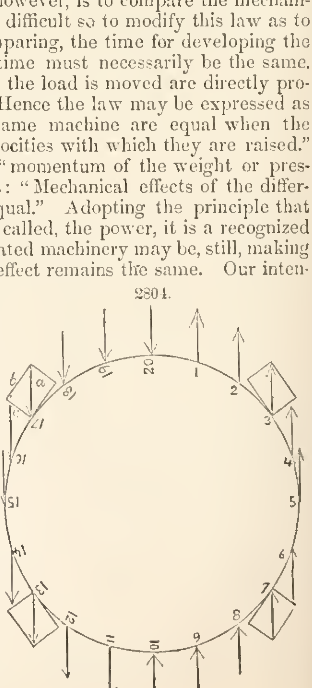
$$5 \times 3 \times 3 \times 3 \times 3 = 405 - 1 = 404 \text{ lbs.}$$

MECHANICAL POWER OF STEAM. Under the head of CRANK, in the first volume of this Dictionary, reference is made to this article for an elucidation of the theory of its movement, as also for an explanation of the mechanical laws of steam. These last should be sought under their proper head "Steam," while the theory of the crank will be explained in this place, as reference has been made to it under this head.

If we consider the rotatory engine with revolving piston apart from the practical objections against its application, it is a perfect engine, and is capable of giving out all the effect of the steam. An impression has, however, widely prevailed that this is not the case with the common reciprocating engine with its connecting-rod and crank. Several scientific writers on the steam-engine have pointed out the error of this conviction, so that all the better-informed class of engineers are well aware that the crank, like all other pieces of machinery, fully transmits the power which is communicated to it. There are others, however, who cannot understand this: they cannot set out from the great fundamental principle of virtual velocities, and satisfy themselves with asserting the truth as a simple and inevitable deduction from it. They are continually asking the question, "How is it that, in the common crank, we are able to show that, at two given points in its revolution, the position is such that an infinite power would produce no effect at all; that there are only two positions in which the force and effect are equal; and that, at every other position, the effective pressure given out by the connecting-rod to the crank is less than the original pressure of the steam on the piston—the remainder of the pressure of the steam producing only a useless pressure on the cranks—how then can the crank be conceived to transmit the whole mechanical effect of the steam?" In the present remarks we intend to give an answer to this question. We intend to examine, at considerable length, the action of the crank, and to show that the great fact upon which the whole science of mechanics has rested ever since the time of Galileo, still obtains in all its generality in this particular case. For the purpose of clearly elucidating the subject we intend to consider it at first in a very simple and practical manner, and then to examine it in a more theoretical point of view.

Before proceeding further it is necessary to have a clear conception of the meaning of the term "power." It is obvious that it must be different from the term "force" or "pressure;" for, if its meaning were the same, it would be absurd to say that the crank always transmits the whole "power," since in some positions it does not transmit any of the pressure of the steam at all. The term "power," as generally used by writers on the steam-engine, means the mechanical power of the steam, or its mechanical effect. In estimating the mechanical effect we have to consider two things: 1st, the load or force raised, and 2d, the distance through which it is raised; and the mechanical effects are considered to be equal when the product of these two are equal. For example, suppose two different machines constructed in such a manner that in the one 1 lb. of steam is made to raise 10 tons through 8 feet, and that in the other 1 lb. of steam is made to raise 15 tons through 6 feet; we say that the mechanical effect of the steam is the same in these two machines, because $10 \times 8 = 15 \times 6$. This principle may be expressed in the form of a rule:—"Mechanical effects are equal when the weights raised are inversely proportional to the distances through which they are raised." This law is useful for comparing the mechanical effects of different machines; our purpose, at present, however, is to compare the mechanical effects of different parts of the same machine. It will not be difficult so to modify this law as to suit our purposes. When it is different machines that we are comparing, the time for developing the mechanical effects may be different, but in the same machine the time must necessarily be the same. From this equality of time we infer that the spaces through which the load is moved are directly proportional to the uniform velocity with which they are described. Hence the law may be expressed as follows: "The mechanical effects of the different parts of the same machine are equal when the weights or pressures raised are inversely proportional to the velocities with which they are raised." The product of a weight or pressure into its velocity is called the "momentum of the weight or pressure." After this definition, our rule may be expressed as follows: "Mechanical effects of the different parts of the same machine are equal when the momenta are equal." Adopting the principle that the momentum measures the mechanical effect, or, as it is usually called, the power, it is a recognized principle, proved by all writers on mechanics, that however complicated machinery may be, still, making allowance for the resistances arising from friction, the mechanical effect remains the same. Our intention at present is only to show that it obtains in the particular case of the crank. The crank-pin moves through a greater space than the piston; and when the piston is moving very slowly the crank-pin is moving very quickly, so that the ultimate effect is the same at every moment. By multiplying the pressure into the velocity, it will be found that the same quantity of steam produces the same amount of power at every part of the stroke.

2804.



Suppose the velocity of the piston to be uniform, then the motion of the extremity of the connecting-rod will be uniform also. The extremity of the crank always moves irregularly, but as it moves over a greater space than the extremity of the connecting-rod, its mean velocity must be greater. The proportion is obviously as follows:

Velocity of piston : mean velocity of extremity of crank : : twice the length of stroke : circumference which the extremity of the crank describes.

Let l denote the length of stroke, and π the ratio of the circumference of a circle to its diameter; then we have the proportion,

Velocity of piston : mean velocity of extremity of crank : : $2\,l : \pi\,l : : 2 : \pi$, and, therefore, mean velocity of extremity of crank $= \pi \times$ velocity of piston $\div 2$. Since the mean velocity of the crank is greater than that of the piston, then, according to our law, in order to produce the same mechanical effect, the mean effective pressure must be less, and that in the same proportion. We may approximate to the mean effective pressure by calculating it for a great many equidistant positions, and taking the average. Thus let Fig. 2804 represent the circle which the extremity of the crank describes. Divide it into 20 equal parts. Suppose the connecting-rod to remain always in a parallel direction, and the constant pressure in it to be 100. The effective pressure at any point P will be 100 sin. POE. From this we have the following table:

Points in the Figure.		Pressure in the Direction of Revolution.
At 0 and at	20	100 × sin. 0° = 0·00
1	19	100 × sin. 18° = 30·90
2	18	100 × sin. 36° = 58·78
3	17	100 × sin. 54° = 80·90
4	16	100 × sin. 72° = 95·11
5	15	100 × sin. 90° = 100·00
6	14	100 × sin. 108° = 95·11
7	13	100 × sin. 126° = 80·90
8	12	100 × sin. 144° = 58·78
9	11	100 × sin. 162° = 30·90
10	10	100 × sin. 180° = 0·00
		Mean pressure 63·11

From this we learn that the mean effective pressure is to the pressure at piston in the proportion of about 63 to 100. This is very nearly the same proportion as 2 to π; for $110 \div 63 = 1·6$ nearly, and $\pi \div 2 = 1·7$. Hence we have the proportion, pressure at piston : mean effective pressure at extremity of crank : : mean velocity of extremity of crank : velocity of piston. This shows, according to our law, that the mechanical effect of the pressure at the piston is wholly transmitted to the crank.

We have said not only that the mechanical effect is the same ultimately, but that it is the same momentarily; that is to say, that the product of the effective force at any point, and the velocity at that point, is constantly equal to the product of the pressure at the piston, and its velocity at the corresponding position. It is more difficult to illustrate this in the same manner, on account of the difficulty of calculating the relative velocity of the crank and piston. It is very easy to show, however, that at what is called the "position of the centres" no loss of power can really take place. This happens for this very plain reason, that there is no power exerted at that time. It ought to be remembered that at that time the communication which supplies the steam from the boiler is cut off. The steam on one side having done its work, only waits to be released from its chamber, and escapes at the opening of the eduction valve, and at the same instant is in the act of being permitted to enter on the opposite side for reversing the motion. Hence at these points all application of force has ceased, and arrangements are making for reversing the motion; besides which, when the engine is on the centre, the piston has not any motion.

With regard to the remaining points of the circle, at which it is said power is lost, the velocity imparted to the crank is always an exact equivalent for the force which is apparently lost. At present we wish only to illustrate this fact, for its rigid demonstration requires rather abstract considerations. The following table presents the results of the calculations of the power and velocity. The numbers 1, 2, &c., refer to Fig. 2804.

Position of Crank.		Pressure in Direction of Revolution.	Velocity of Crank divided by Velocity of Piston.
At 0 and at	20	0·00	Infinite
1	19	30·90	3·236
2	18	58·78	1·701
3	17	80·90	1·236
4	16	95·11	1·051
5	15	100·00	1·000
6	14	95·11	1·051
7	13	80·90	1·236
8	12	58·78	1·701
9	11	30·90	3·236
10	10	0·00	Infinite

These are obtained on the supposition that the force on the piston and its velocity are constant, and also that the connecting rod keeps always in a parallel direction. Neither of these suppositions is exactly true in practice. The same law holds, although the pressure on the piston is variable, and also its velocity, and although the connecting-rod takes different inclinations. It will be observed from our table that the smaller the effective pressure in the direction of the revolution, the greater the relative velocity.

The rigid demonstration of these facts requires for their proper exhibition the differential calculus which in this work would be out of place.

MEERSCHAUM. This form of silicate of magnesia is employed in manufacturing the celebrated tobacco-pipes known under this name, and its composition is as follows, differing but little from steatite or soapstone; but, unlike the latter, may be artificially produced:

	Levant.	Madrid.	Natolia.
Silica	60·87	53·80	42·00
Magnesia	27·80	23·80	30·50
Lime	27·80	23·80	2·30
Alumina	} ·009	1·20	} 2·00
Oxide of iron		1·20	
Water	11·29	20·00	23·00
	100·05	98·80	99·30

It is found in the native state on the shores of the inland seas of Europe. That found in Morocco contains, in addition to the above ingredients, ·52 of potash. It is light and soft, and is employed in the Turkish dominions as fuller's earth. In Germany it is extensively used in the manufacture of tobacco-pipes, which are prepared for sale by being soaked first in tallow, then in wax, and finally by being polished with shave-grass. Imitation meerschaum pipes are sold in large quantities, and the greatest caution is necessary to guard against deception. To the connoisseur, the best criterion is the beautiful brown color which the genuine meerschaum assumes after being smoked some time.

MENSURATION—Of Surfaces. *To find the area of a four-sided figure.*—Rule.—Multiply the length by the breadth or *perpendicular* height; the product will be the area.

To find the area of a triangle.—Rule.—Multiply the length of one of the sides, by a perpendicular falling upon it from the opposite angle; half the product will be the area.

To find the length of one side of a right-angled triangle, when the lengths of the other two sides are given.—Rule 1.—*To find the hypothenuse*, add together the squares of the two legs, and extract the square root of that sum.

Rule 2.—*To find one of the legs*, subtract the square of the leg, of which the length is known, from the square of the hypothenuse, and the square root of the difference will be the answer.

To find the area of a regular polygon.—Rule.—Multiply the length of a perpendicular, drawn from the centre to one of the sides, (or the radius of its inscribed circle,) by the length of one side, and this product again by the number of sides; and half the product will be the area of the polygon.

To find the area of a trapezium.—Rule 1.—Draw a diagonal line to divide the trapezium into two triangles; find the areas of these triangles separately, and add them together.

Rule 2.—Divide the trapezium into two triangles, by a diagonal, and let two perpendiculars fall on the diagonal from the opposite angles; then, the sum of these perpendiculars multiplied by the diagonal, and divided by 2, will be the area of the trapezium.

To find the area of a trapezoid.—Rule 1.—Multiply the sum of the two parallel sides by the perpendicular distance between them, and half the product will be the area.

Rule 2.—Draw a diagonal, to divide the trapezoid into two triangles; find the areas of those triangles separately, and add them together.

To find the area of an irregular polygon.—Rule.—Draw diagonals, to divide the figure into trapeziums and triangles; find the area of each separately, by either of the rules before given for that purpose; and the sum of the whole will be the area of the figure.

To find the area of a long irregular figure.—Rule.—Take the breadths in several places, and at equal distances from each other; add all the breadths together, and divide the sum by this number, for the mean breadth; then multiply the mean breadth by the length of the figure, and the product will be the area.

To find the circumference of a circle when the diameter is given; or the diameter when the circumference is given.—Rule 1.—Multiply the diameter by 3·1416, and the product will be the circumference; or divide the circumference by 3·1416, and the quotient will be the diameter.

Rule 2.—As 7 is to 22, so is the diameter to the circumference;
As 22 is to 7, so is the circumference to the diameter.

Rule 3.—As 113 is to 355, so is the diameter to the circumference;
As 355 is to 113, so is the circumference to the diameter.

To find the area of a circle.—Rule 1.—Multiply the square of the diameter by ·7854; or the square of the circumference by ·07958; the product, in either case, will be the area.

Rule 2.—Multiply the circumference by the diameter, and divide the product by 4.

Rule 3.—As 14 is to 11, so is the square of the diameter to the area;
Or as 88 is to 7, so is the square of the circumference to the area.

To find the length of any arc of a circle.—Rule 1.—From 8 times the chord of half the arc, subtract the chord of the whole arc; one-third of the remainder will be the length of the arc, nearly.

Rule 2.—As 180 is to the number of degrees in the arc;
So is 3·1416 times the radius to its length.
Or, as 3 is to the number of degrees in the arc;
So is ·05236 times the radius to its length.

To find the area of a sector of a circle.—Rule 1.—Multiply the length of the arc by half the length of the radius; the product will be the area.

Rule 2.—As 360 degrees is to the number of degrees in the arc of the sector; so is the area of the circle to the area of the sector.

To find the area of a segment of a circle.—Rule 1.—To the chord of the whole arc, add the chord of half the arc and one-third of it more. Then multiply the sum by the versed sine, or height of the segment, and four-tenths of the product will be the area of the segment.

RULE 2.—Divide the height, or versed sine, by the diameter of the circle, and find the quotient in the column of versed sines, in the table of areas of segments.

Then take out the corresponding area in the next column on the right-hand, and multiply it by the square of the diameter, for the answer.

To find the area of a circular zone.—RULE 1.—*When the zone is less than a semicircle,* to the area of the trapezoid, formed by connecting the extremities of the zone by straight lines, add the area of the circular segments beyond those lines; the sum is the area of the zone.

RULE 2.—*When the zone is greater than a semicircle,* to the area of the parallelogram, formed in like manner as above, add the area of the circular segments, at its extremities; the sum is the area of the zone.

To find the area of a circular ring, or space, included between two concentric circles.—RULE.—Find the areas of the two circles separately; then the difference between them will be the area of the ring.

To find the circumference of an ellipse.—RULE.—Square the two axes, and multiply the square root of half that sum by 3·1416; the product will be the circumference, nearly.

To find the area of an ellipse.—RULE.—Multiply the transverse diameter by the conjugate, and the product by ·7854.

To find the area of an elliptic segment.—RULE.—Divide the height of the segment by the axis of which it is a part, and find, in the table of segments of circles, a circular segment having the same versed sine as this quotient. Then, multiply the segment thus found and the two axes of the ellipse continually together, and the product will give the area required.

When the transverse, the conjugate, and the abscissæ are given, to find the ordinate.—RULE.—Multiply the abscissæ into each other, and extract the square root of the product; this will give the *mean* between them. Then, as the transverse diameter is to the conjugate diameter, so is the *mean* to the ordinate required.

When the transverse, the conjugate, and the ordinate are given, to find the abscissæ.—RULE.—From the square of half the conjugate, take the square of the ordinate, and extract the square root of the remainder.

Then, as the conjugate diameter is to the transverse, so is that square root to half the difference of the two abscissæ.

Add this half difference to half the transverse, for the greater abscissa; and subtract it for the less.

When the transverse, the ordinate, and the two abscissæ are given, to find the conjugate.—RULE.—As the square root of the product of the two abscissæ is to the ordinate, so is the transverse diameter to the conjugate.

Note.—In the same manner the transverse diameter may be found from the conjugate, using the two abscissæ of the conjugate, and their ordinate perpendicular to the conjugate.

When the conjugate, the ordinate, and the abscissæ are given, to find the transverse diameter.—RULE.—From the square of half the conjugate subtract the square of the ordinate, and extract the root of the remainder. Add this root to the half conjugate if the less abscissa be given; but subtract it when the greater abscissa is given.

Then, as the square of the ordinate is to the rectangle of the abscissa and conjugate, so is the reserved sum, or difference, to the transverse diameter.

To find the area of a parabola.—RULE.—Multiply the base by the height, and two-thirds of the product will be the area.

To find the area of a frustum of a parabola.—RULE.—Multiply the difference of the cubes of the two ends of the frustum by twice its altitude, and divide the product by thrice the difference of their squares.

To find the abscissa or ordinate of the parabola.—RULE.—The abscissæ are to each other as the squares of their ordinates; that is, as any abscissa is to the square of its ordinate, so is any other abscissa to the square of its ordinate.

Or, as the square root of any abscissa is to its ordinate, so is the square root of another abscissa to its ordinate.

To find the length of a parabolic curve, cut off by a double ordinate.—RULE.—To the square root of the ordinate, add four-thirds of the square of the abscissa; the square root of that sum, multiplied by 2, will give the length of the curve, nearly.

To find the area of a hyperbola.—RULE.—To five-sevenths of the abscissa, add the transverse diameter; multiply the sum by the abscissa, and extract the square root of the product. Then, multiply the transverse diameter by the abscissa, and extract the square root of that product.

Then, to 21 times the first root add 4 times the second root; multiply the sum by double the product of the conjugate and abscissa, and divide by 75 times the transverse; this will give the area, nearly.

To find the length of a hyperbolic curve.—RULE.—To 21 times the square of the conjugate add 9 times the square of the transverse; also, to 21 times the square of the conjugate add 19 times the square of the transverse, and multiply each of these sums by the abscissa.

To each of the two products add 15 times the product of the transverse and square of the conjugate.

Then, as the less sum is to the greater, so is the ordinate to the length of the curve, nearly.

When the transverse, the conjugate, and the abscissæ are given, to find the ordinate.—RULE.—As the transverse diameter is to the conjugate, so is the square root of the product of the two abscissæ to the ordinate required.

Note.—In the hyperbola, the less abscissa added to the axis gives the greater: and the greater abscissa subtracted from the axis, gives the less.

When the transverse and conjugate diameters, and the ordinate, are given, to find the abscissæ.—RULE.—To the square of half the conjugate add the square of the ordinate, and extract the square root of that sum.

Then, as the conjugate diameter is to the transverse, so is the square root to half the sum of the abscissæ.

To this half sum add half the transverse diameter for the greater abscissa, and subtract it for the less.

When the transverse diameter, ordinate, and abscissæ, are given, to find the conjugate.—Rule.—As the square root of the product of the two abscissæ is to the ordinate, so is the transverse diameter to the conjugate.

When the conjugate diameter, the ordinate, and the two abscissæ, are given, to find the transverse diameter.—Rule.—To the square of half the conjugate add the square of the ordinate, and extract the square root of that sum.

To this root add the half conjugate when the less abscissa is used; and subtract it when the greater abscissa is used; reserving the sum or difference.

Then, as the square of the ordinate is to the product of the abscissæ and conjugate, so is the reserved sum, or difference, to the transverse.

Mensuration of Solids.—*To find the solidity of a cube.*—Rule.—Multiply the side of the cube by itself, and that product again by the side; the last product will be the solidity of the given cube.

To find the solidity of a parallelopipedon.—Rule.—Multiply the length, breadth, and depth or altitude, continually together, or, in other words, multiply the length by the breadth, and that product by the depth or altitude, and this will give the required solidity.

To find the solidity of cylinders and prisms.—Rule.—Multiply the area of the base by the height of the cylinder or prism, and the product will give the solid content.

To find the convex surface of a cylinder.—Rule.—Multiply the circumference by the length of the cylinder; the product will be the convex surface required.

To find the convex surface of a right cone, or pyramid.—Rule.—Multiply the perimeter, or circumference of the base, by the slant height, or length of the side of the cone, and half the product will be the surface.

To find the convex surface of a frustum of a right cone, or pyramid.—Rule.—Multiply the sum of the perimeters of the two ends by the slant height or side of the frustum, and half the product will be the surface required.

To find the solidity of a cone, or pyramid.—Rule.—Multiply the area of the base by the perpendicular height, and one-third of the product will be the content.

To find the solidity of the frustum of a cone.—Rule.—Divide the difference of the cubes of the diameters of the two ends by the difference of the diameters; this quotient multiplied by ·7854 and again by one-third of the height, will give the solidity.

To find the solidity of the frustum of a pyramid.—Rule.—Add to the areas of the two ends of the frustum the square root of their product, and this sum, multiplied by one-third of the height, will give the solidity.

To find the solidity of a wedge.—Rule.—To the length of the edge of the wedge add twice the length of the back; multiply this sum by the height of the wedge, and then by the breadth of the back; one-sixth of the product will be the solid content.

To find the solidity of a prismoid.—Rule.—Add into one sum the areas of the two ends and four times the middle section, parallel to them; then, this sum multiplied by one-sixth of the height, will give the content.

Note.—The length of the middle section is equal to half the sum of the lengths of the two ends; and its breadth is equal to half the sum of the breadths of the two ends.

To find the convex surface of a sphere, or globe.—Rule.—Multiply the diameter of the sphere by its circumference.

Or, multiply 3·1416 by the square of the diameter; the product will be the convex surface required.

Note.—The convex surface of any zone or segment may be found, in like manner, by multiplying its height by the whole circumference of the sphere.

To find the solidity of a sphere or globe.—Rule.—Multiply the cube of the axis by ·5236; the product will be the solidity.

To find the solidity of a spherical segment.—Rule.—To three times the square of the radius of its base add the square of its height; then, multiply the sum by the height, and the product by ·5236.

To find the solidity of a spherical zone or frustum.—Rule.—To the sum of the squares of the radius of each end, add one-third of the square of the height of the zone; this sum, multiplied by the said height, and the product by 1·5708, will give the solidity.

To find the solidity of a spheroid.—Rule.—Multiply the square of the revolving axis by the fixed or shorter axis; the product, multiplied by ·5236, will give the content.

To find the solidity of a segment of a spheroid.—Rule 1.—*When the base is circular or parallel to the revolving axis,* multiply the fixed axis by 3, the height of the segment by 2, and subtract the one product from the other; then multiply the remainder by the square of the height of the segment, and the product by ·5236.

Then, as the square of the fixed axis is to the square of the revolving axis, so is the last product to the content of the segment.

Rule 2.—*When the base is perpendicular to the revolving axis,* multiply the revolving axis by 3, and the height of the segment by 2, and subtract the one from the other; then, multiply the remainder by the square of the height of the segment, and the product by ·5236.

Then, as the revolving axis is to the fixed axis, so is the last product to the content.

To find the solidity of the middle frustum of a spheroid.—Rule 1.—*When the ends are circular, or parallel to the revolving axis,* to twice the square of the revolving axis, add the square of the diameter of either end; then, multiply this sum by the length of the frustum, and the product again by ·2618; this will give the solidity.

Rule 2.—*When the ends are elliptical, or perpendicular to the revolving axis,* to twice the product of the transverse and conjugate diameters of the middle section, add the product of the transverse and conjugate of either end; multiply this sum by the length of the frustum, and the product by ·2618; this will give the solidity.

To find the surface of a circular spindle.—RULE.—Multiply the length of the spindle by the radius of the revolving arc. Multiply also the said arc by the central distance, or distance between the centre of the spindle and centre of the revolving arc. Subtract this last product from the former; double the remainder; multiply it by 3·1416, and the product will give the surface of the spindle.

Note.—The same rule will serve for any segment, or zone, cut off perpendicularly to the chord of the revolving arc; but, in this case, the particular length of the part, and the part of the arc which describes it, must be used, instead of the whole length and whole arc.

To find the solidity of a circular spindle.—RULE.—Multiply the central distance, as above, by half the area of the revolving segment. Subtract the product from one-third of the cube of half the length of the spindle. Then, multiply the remainder by 12·5664, or 4 times 3·1416, and the product will be the solidity required.

To find the solidity of the frustum, or zone, of a circular spindle.—RULE.—From the square of half the length of the whole spindle, take one-third of the square of half the length of the frustum, and multiply the remainder by the said half-length of the frustum. Multiply the central distance by the revolving area, which generates the frustum. Subtract the last product from the former; and the remainder, multiplied by 6·2832, or twice 3·1416, will give the content.

To find the solidity of an elliptic spindle.—RULE.—To the square of the greatest diameter, add the square of twice the diameter at one-fourth of its length; multiply the sum by the length, and the product by ·1309, and it will give the solidity, very nearly.

To find the solidity of a frustum or segment of an elliptic spindle.—RULE.—Proceed, as in the last rule, for this, or any other solid, formed by the revolution of a conic section about an axis, namely:

Add together the squares of the greatest and least diameters, and the square of double the diameter in the middle between the two; multiply the sum by the length, and the product by ·1309, and it will give the solidity.

Note.—For all such solids this rule is exact when the body is formed by the conic section, or a part of it, revolving about the axis of the section; and it will always be very near the truth, when the figure revolves about another line.

To find the solidity of a parabolic conoid.—RULE.—Multiply the square of the diameter of the base by the altitude, and the product by ·3927.

To find the solidity of a frustum of a paraboloid.—RULE.—Multiply the sum of the squares of the diameters of the two ends by the height of the frustum, and the product by ·3927.

To find the solidity of a parabolic spindle.—RULE.—Multiply the square of the middle diameter by the length of the spindle, and the product by ·41888, (which is eight-fifteenths of ·7854,) and it will give the content.

To find the solidity of the middle frustum of a parabolic spindle.—RULE.—Add together 8 times the square of the greatest diameter, 3 times the square of the least diameter, and 4 times the product of these two diameters; multiply the sum by the length, and the product by ·05236, (which is $\frac{1}{60}$ of 3·1416;) this will give the solidity.

To find the convex surface of a cylindrical ring.—RULE.—To the thickness of the ring add the inner diameter; multiply this sum by the thickness, and the product by 9·8696, (which is the square of 3·14159,) and it will give the superficies required.

To find the solidity of a cylindrical ring.—RULE.—To the thickness of the ring add the inner diameter; then multiply the sum by the square of the thickness, and the product by 2·4674, (which is one fourth of the square of 3·1416,) and it will give the solidity.

To find the superficies or solidity of any regular body.—RULE 1.—Multiply the tabular *surface* by the square of the linear edge, and the product will be the superficies.

RULE 2.—Multiply the tabular *solidity* by the cube of the linear edge, and the product will be the solidity.

Table of the Surfaces and Solidities of the Regular Bodies when the linear edge is 1.

No. of Sides.	Names.	Surfaces.	Solidities.
4	Tetrahedron	1·73205	0·11785
6	Hexahedron	6·00000	1·00000
8	Octahedron	3·46410	0·47140
12	Dodecahedron	20·64573	7·66312
20	Icosahedron	8·66025	2·18169

METALS AND ALLOYS, *employed in the mechanical and useful arts.* Metals are elementary bodies, being all capable of combining with oxygen, and many of them, during this combination, exhibit the phenomena of combustion. Formerly only seven metals were known, but modern discoveries have added to the number greatly. Metals are distinguished by their great specific gravity, considerable tenacity and hardness, opacity, and property of reflecting the greater part of the light which falls on their surface, giving rise to what is denominated the metallic lustre or brilliancy. Opacity is another leading property of metals; even when beat to the greatest possible thinness, they transmit scarcely any light; from the union of the two qualities density and opacity, arises that of lustre. By their opacity and the denseness of their texture, they reflect the greatest part of the light that falls on their surface. From their density they are susceptible of a fine polish, by which their lustre is increased.

Tenacity distinguishes a number of the metals, and is not possessed in any great degree by other bodies; hence arises their malleability and ductility. Some of the metals are neither malleable nor ductile. Both these qualities are greater in combinations of the metals than in the individual metals. Metals are the best conductors of caloric; their expansibilities are various, and are probably nearly in the order of their fusibilities. Mercury melts at so low a temperature, that it can be obtained in the solid state only at a very low temperature; others, as platina, can scarcely be melted by the most intense heat which we can excite. Metals may be volatilized; at the degree of 600 quicksilver may be volatilized, and zinc and arsenic at a temperature not very remote from this. Metals are the best conductors of electricity.

Table of the Properties of the Metals.

Name.	When discovered.	By whom.	Color.	Specific gravity.	Fusing point, Fahr.	Scale of ductility.	Scale of malleability.	Tenacity.	Ratio of hardness.
Gold	Known from the earliest ages.	....	Pure yellow.	19·257	5237	1	1	68·216	8
Silver		....	White.	10·474	3677	2	2	85·062	6
Iron		....	Blue-gray.	7·788	17977	4	8	269·659	3
Copper		....	Red.	8·895	4587	5	3	157·399	5
Mercury		....	White.	13·568	39	..	..	....	None.
Lead		....	Blue.	11·352	594	8	6	....	14
Tin		....	White.	7·291	442	7	4	24·200	12
Zinc	1541	Paracelsus.	Bluish-white.	6·661	700	6	7	12·720	9
Bismuth	1520	Agricola.	Yellowish-white.	9·822	476	..	..	....	7
Antimony	XVth cent.	B. Valent.	Bluish-white.	6·702	932	..	..	....	10
Arsenic	1723	Brandt.	Gray.	8·308	....	..	..	....	13
Cobalt	....	do.	Gray-white.	8·538	16677	..	..	....	11
Platinum	1741	Wood.	Bluish-white.	21·500	G. B. P.	3	5	124·000	4
Nickel	1751	Cronstedt.	White.	8·279	21877	9	9	....	....
Manganese	1774	Scheele.	Gray-white.	5·850	do.	..	..	....	2
Tungsten	1781	D'Elhuyart.	....	7·600	G. B. P.	..	..	....	1
Tellurium	1782	Muller.	....	6·115	....	..	..	....	....
Molybdenum	do.	Hjelm.	Gray.	7·400	G. B. P.	..	..	....	....
Titanium	1781	Gregor.	Red.	....	do.	..	..	....	....
Uranium	1789	Klaproth.	Gray.	9·000	do.	..	..	....	....
Chromium	1797	Vauquelin.	....	....	do.	..	..	....	....
Columbium	1802	Hatchett.	....	....	do.	..	..	....	....
Palladium	1803	Wollaston.	Bluish-white.	11·300	....	10	10	....	1
Rhodium	do.	do.	Grayish-white	....	G. B. P.	..	..	....	....
Iridium	do.	Descotils.	....	....	....	..	..	....	....
Osmium	do.	Tenant.	Bluish-black.	....	do.	..	..	....	....
Cerium	1804	Berzelius.	Gray-white.	....	do.	..	..	....	....
Potassium	1807	Davy.	do.	0·865	136	..	..	....	100
Sodium			do.	0·972	194	..	..	....	100
Barium			....	....	....	..	..	....	....
Strontium			....	....	....	..	..	....	....
Calcium			....	....	....	..	..	....	....
Cadmium	1818	Stromeyer.	White.	8·604	....	11	11	....	....
Lithium	do.	Arfvedson.	....	....	....	..	..	....	....
Silicium	1824	Berzelius.	....	....	....	..	..	....	....
Zinconium	....	do.	....	....	....	..	..	....	....
Aluminum	1828	Wohler.	....	....	....	..	..	....	....
Glucinum	....	do.	....	....	....	..	..	....	....
Yttrium	....	do.	....	....	....	..	..	....	....
Thonium	1829	Berzelius.	....	....	....	..	..	....	....
Magnesium	do.	Bussy.	....	....	....	..	..	....	....
Varadium	1830	Seftstrom.	....	....	....	..	..	....	....
Lantanium	1840	Mosander.	....	....	....	..	..	....	....

*Antimony** is of a silvery white color, brittle and crystalline in its ordinary texture. It fuses at about 800°, or at a dull-red heat, and is volatile at a white heat. Its specific gravity is 6·712. (*Hatchett, Phil. Trans.* 1803. *Brande*, 849.)

Antimony expands on cooling; it is scarcely used alone, except in combination with similar bars of other metals for producing thermo-electricity: but antimony, which in the metallic state is frequently called "regulus," is generally combined with a large portion of lead, and sometimes with tin, and other metals. See *Lead* and *Tin*.

"Antimony and tin, mixed in equal proportions, form a moderately hard, brittle, and very brilliant alloy, capable of receiving an exquisite polish, and not easily tarnished by exposure to the air; it has been occasionally manufactured into speculums for telescopes. Its sp. gr., according to *Gellert*, is less than the mean of its constituent parts."—*Aikin's Dictionary.*

Bismuth is a brittle white metal, with a slight tint of red; its specific gravity is 9·822. (*Hatchett, Phil. Trans.* 1803.) It fuses at 476°, (*Crichton*,) 507°, (*Rudberg*,) and always crystallizes on cooling. According to Chaudet, pure bismuth is somewhat flexible. A cast bar of the metal (see *Rennie*) one-tenth of an inch in diameter, supports, according to Muschenbroek, a weight of 48 pounds. Bismuth is volatile at a high heat, and may be distilled in close vessels. It transmits heat more slowly than most other metals, perhaps in consequence of its texture. (*Brande*, 861.)

* The alloys are in general arranged under those metals which constitute respectively their largest proportional parts, but in some few instances under those from which they derive their peculiar characters.

Bismuth is scarcely used alone, but it is employed for imparting fusibility to alloys, thus:

8 bismuth, 5 lead, 3 tin, constitute Newton's fusible alloy, which melts at 212° F.

2 bismuth, 1 lead, 1 tin, Rose's fusible alloy, which melts at 201° F.

5 bismuth, 3 lead, 2 tin, when combined melt at 199°.

8 bismuth, 5 lead, 4 tin, 1 type-metal, constitute the fusible alloy used on the Continent for producing the beautiful casts of the French medals, by the *clichée* process. The metals should be repeatedly melted and poured into drops until they are well mixed. Mr. Charles V. Walker substituted antimony for the type-metal, and strongly recommends this latter in preference to the first-named fusible alloy *Electrotype Manipulation*, Part II. p. 9–11, where the *clichée* process is described.

1 bismuth and 2 tin make the alloy Mr. Cowper found to be the most suitable for rose-engine and eccentric-turned patterns, to be printed from after the manner of letter-press. He recommends the thin plates to be cast upon a cold surface of metal or stone, upon which a piece of smooth paper is placed, and then a metal ring; the alloy should neither burr nor crumble; if proper, it turns soft and silky; when too crystalline, more tin should be added.

2 bismuth, 4 lead, 3 tin, }
1 bismuth, 1 lead, 2 tin, } constitute pewterer's soft solders.

All these alloys must be cooled quickly to avoid the separation of the bismuth; they are rendered more fusible by a small addition of mercury.

Copper, with the exception of titanium, is the only metal which has a red color; it has much lustre, is very malleable and ductile, and exhales a peculiar smell when warmed or rubbed. It melts at a bright-red or dull-white heat; or, according to Daniell, at a temperature intermediate between the fusing points of silver and gold = 1996° Fahr. Its specific gravity varies from 8·86 to 8·89; the former being the least density of cast copper, the latter the greatest of rolled or hammered copper. (*Brande*, 812.)

Copper is used alone for many important purposes, and very extensively for the following: namely, sheathing and bolts for ships, brewing, distilling, and culinary vessels. Some of the fire-boxes for locomotive engines, boilers for marine engines, rollers for calico-printing and paper-making, plates for the use of engravers, &c.

Copper is used in alloying gold and silver, for coin, plate, &c., and it enters with zinc and nickel into the composition of German silver. Copper alloyed with one-tenth of its weight of arsenic is so similar in appearance to silver, as to have been substituted for it.

The alloys of copper, which are very numerous and important, are principally included under the general name *Brass*. In the more common acceptation, brass means the yellow alloy of copper, with about half its weight of zinc; this is often called by engineers "yellow brass."

Copper alloyed with about one-ninth its weight of tin, is the metal of brass ordnance, which is very generally called gun-metal; similar alloys used for the *brasses* or bearings of machinery, are called by engineers *hard* brass, and also gun-metal; and such alloys, when employed for statues and medals, are called bronze. The further addition of tin leads to bell-metal, and speculum-metal, which are named after their respective uses; and when the proportion of copper is exceedingly small, the alloy constitutes one kind of pewter.

Copper, when alloyed with nearly half its weight of lead, forms an inferior alloy, resembling gun metal in color, but very much softer and cheaper, lead being only about one-fourth the value of tin, and used in much larger proportion. This inferior alloy is called pot-metal, and also cock-metal, because it is used for large vessels and measures, for the large taps or cocks for brewers, dyers, and distillers, and those of smaller kinds for household use.

Generally the copper is only alloyed with one of the metals, zinc, tin, or lead; occasionally with two, and sometimes with the three in various proportions. In many cases the new metals are carefully weighed according to the qualities desired in the alloy, but random mixtures more frequently occur, from the ordinary practice of filling the crucible in great part with various pieces of old metal, of unknown proportions, and adding a certain quantity of new metal to bring it up to the color and hardness required. This is not done solely from motives of economy, but also from an impression which appears to be very generally entertained, that such mixtures are more homogeneous than those composed entirely of new metals, fused together for the first time.

The remarks we have to offer on these copper alloys will be arranged in the tabular form, in four groups; and, to make them as practical as possible, they will be stated in the terms commonly used in the brass foundry. Thus, when the founder is asked the usual proportions of yellow brass, he will say, 6 to 8 oz. of zinc, (to every pound of copper being implied.) In speaking of gun metal, he would not say, it had one ninth, or 11 per cent. of tin, but simply that it was 1½, 2, or 2¼ oz. (of tin,) as the case might be; so that the quantity and kind of the alloy, or the *addition* to the pound of copper, is usually alone named.

Alloys of copper and zinc only.—The marginal numbers denote the ounces of zinc added to every pound of copper.

⅛ to ½ oz. Castings are seldom made of pure copper, as under ordinary circumstances it does not cast soundly: about half an ounce of zinc is usually added, frequently in the shape of 4 oz. of brass to every pound of copper; and by others 4 oz. of brass are added to every two or three pounds of copper.

1 to 1¼ oz. Gilding metal, for common jewelry: it is made by mixing 4 parts of copper with 1 of calamine brass; or sometimes 1 lb. of copper with 6 oz. of brass. The sheet gilding metal will be found to match pretty well in color with the cast gun metal, which latter does not admit of being rolled; they may be therefore used together when required.

3 oz. Red sheet brass, made at Hegermuhl, or 5½ parts copper, 1 zinc. (*Ure.*)

3 to 4 oz. Bath metal, pinchbeck, Mannheim gold, similor, and alloys bearing various names, and resembling inferior jeweller's gold greatly alloyed with copper, are of about this proportion: some of them contain a little tin; now, however, they are scarcely used.

6 oz. Brass, that bears soldering well.

6 oz. Bristol brass is said to be of this proportion.

8 oz. Ordinary brass, the general proportion; less fit for soldering than 6 oz., it being more fusible.

8 oz. Emerson's patent brass was of this proportion, and so is generally the ingot brass, made by simple fusion of the two metals.

9 oz. This proportion is the one extreme of Muntz's patent sheathing. See 10⅔.

10⅔ oz. Muntz's metal, or 40 zinc and 60 copper. "Any proportions," says the patentee, "between the extremes 50 zinc and 50 copper, and 37 zinc 63 copper, will roll and work at the red-heat;" but the first-named proportion, or 40 zinc to 60 copper, is preferred.

The metal is cast into ingots, heated to a red-heat, and rolled and worked at that heat into ships' bolts and other fastenings and sheathing.

12 oz. Spelter-solder for copper and iron is sometimes made in this proportion; for brass work the metals are generally mixed in equal parts. See 16 oz.

12 oz. Pale-yellow metal, fit for dipping in acids, is often made in this proportion.

16 oz. Soft spelter-solder, suitable for ordinary brass-work, is made of equal parts of copper and zinc. About 14 lbs. of each are melted together and poured into an ingot-mould with cross-ribs, which indents it into little squares of about 2 lbs. weight; much of the zinc is lost. These lumps are afterwards heated nearly to redness upon a charcoal fire, and are broken up, one at a time, with great rapidity on an anvil, or in an iron pestle and mortar. The heat is a critical point; if too great, the solder is beaten into a cake or coarse lumps and becomes tarnished; when the heat is proper, it is nicely granulated, and remains of a bright-yellow color; it is afterwards passed through a sieve. Of course, the ultimate proportion is less than 16 oz. of zinc.

16 oz. Equal parts is the one extreme of Muntz's patent sheathing. See 10⅔.

16½ oz. Hamilton and Parker's patent mosaic gold, which is dark-colored when first cast, but on dipping assumes a beautiful golden tint. When cooled and broken, say the patentees, "all yellowness must cease, and the tinge vary from reddish-fawn or salmon color to a light purple or lilac, and from that to whiteness." The proportions are stated as from 52 to 58 zinc to 50 of copper, or 16¼ to 17 oz. to the pound.

32 oz., or 2 zinc to 1 copper, a bluish-white brittle alloy, very brilliant, and so crystalline that it may be pounded cold in a pestle and mortar.

128 oz., or 2 oz. of copper to every pound of zinc; a hard crystalline metal, differing but little from zinc, but more tenacious; it has been used for laps or polishing disks.

Remarks on the alloys of copper and zinc.—These metals seem to mix in all proportions.

The addition of zinc continually increases the fusibility, but from the extremely volatile nature of zinc, these alloys cannot be arrived at with very strict regard to proportion.

The red color of copper slides into that of yellow brass at about 4 or 5 oz. to the pound, and remains little altered unto about 8 or 10 oz.; after this it becomes whiter, and when 32 oz. of zinc are added to 16 of copper, the mixture has the brilliant silvery color of speculum metal, but with a bluish tint.

These alloys, from about 8 to 16 oz. to the pound of copper, are extensively used for dipping, as in an enormous variety of furniture work; in all cases the metal is annealed before the application of the scouring or cleaning processes, and of the acids, bronzes, and lackers subsequently used.

The alloys with zinc retain their malleability and ductility well, unto about 8 or 10 oz. to the pound; after this the crystalline character slowly begins to prevail. The alloy of 2 zinc and 1 copper, before named, may be crumbled in a mortar when cold.

The ordinary range of good yellow brass, that files and turns well, is from about 4½ to 9 oz. to the pound. With additional zinc, it is harder and more crystalline; with less, more tenacious, and it hangs to the file like copper; the range is wide, and small differences are not perceived.

Alloys of copper and tin only.—The marginal numbers denote the ounces of *tin* added to every pound of copper.

Ancient Copper and Tin Alloys.

¾ oz. Ancient bronze nails flexible, or 20 copper, 1 tin. (*Ure.*)

1¾ oz. Soft bronze, or 9 to 1.
2 oz. Medium bronze, or 8 to 1.
2¼ oz. Hard bronze, or 7 to 1.

{ According to Pliny, as quoted by Wilkinson. Ancient weapons and tools, by various analyses, or 8 to 15 per cent. tin; medals from 8 to 12 per cent. tin, with 2 parts zinc added to each 100, for improving the bronze color. (*Ure.*)

6 to 8 oz. Ancient mirrors.

Modern Copper and Tin Alloys.

1 oz. Soft gun-metal, that bears drifting, or stretching from a perforation.

1⅓ oz. A little harder alloy, fit for mathematical instruments; or 12 copper and one very pure grain tin

1½ oz. Still harder, fit for wheels to be cut with teeth.

1½ to 2 oz. Brass ordnance, or 8 to 12 per cent. tin; but the general proportion is one-ninth part of tin

2 oz. Hard bearings for machinery.

2½ oz. Very hard bearings for machinery. By Muschenbroek's tables it appears that the proportion 1 tin and 6 copper is the most tenacious alloy; it is too brittle for general use, and contains 2⅔ oz. to the pound of copper.

For some other alloys used in machinery, see alloys of copper, zinc, tin, and lead, p. 354

3 oz. Soft musical bells.

3½ oz. Chinese gongs and cymbals, or 20 per cent. tin.

4 oz. House bells.

4½ oz. Large bells.
5 oz. Largest bells.
7¼ to 8¼ oz. Speculum metal. Sometimes one ounce of brass is added to every pound as the means of introducing a trifling quantity of zinc; at other times small proportions of silver are added; the employment of arsenic was strongly advocated by the Rev. John Edwards. Lord Oxmantown, now the Earl of Rosse, says, "tin and copper, the materials employed by Newton in the first reflecting telescope, are preferable to any other with which I am acquainted; the best proportions being 4 atoms of copper to 1 of tin, (Turner's numbers;) in fact, 126·1 parts of copper to 58·9 of tin."—*Trans. Royal Soc.* 1840, p. 504.

The object agreed upon by all experimentalists appears to be the exact saturation of the copper with the tin, and the proportionate quantities *differ very materially* (*in this and all other alloys*) *according to the respective degrees of purity* of the metals: for the most perfect alloys of this group, Swedish copper and grain tin should be used.

Mr. Ross says: "When the alloy is perfect, it should be white, glassy, and flaky. When the copper is in excess, it imparts a red tint easily detected; when the tin is in excess, the fracture is granulated, and also less white." His practice is to pour the melted tin into the fluid copper when it is at the lowest temperature that a mixture by stirring can be effected; then to pour the mixture into an ingot, and to complete the combination by remelting in the most gradual manner, by putting the metal into the furnace as soon almost as the fire is lighted. Trial is made of a little piece taken from the pot immediately prior to pouring.

32 oz. of tin to 1 lb. of copper make the alloy called by the pewterers "temper," which is added in small quantities to tin for some kinds of pewter, called "tin and temper," in which the copper is frequently much less than 1 per cent.

Remarks on the alloys of copper and tin only.—These metals seem to mix in all proportions.

The addition of tin continually increases the fusibility, although when it is added cold it is apt to make the copper pasty, or even to set it in a solid lump in the crucible.

The red color of the copper is not greatly impaired in those proportions used by the engineer, namely up to about 2½ oz. to the pound; it becomes grayish white at 6, the limit suitable for bells, and quite white at about 8, the speculum metal; after this, the alloy becomes of a bluish cast.

The tin alloy is scarcely malleable at 2 oz., and soon becomes very hard, brittle, and sonorous; and when it has ceased to serve for producing sound, it is employed for reflecting light.

The tough, tenacious character of copper under the tools rapidly gives way; alloys of 1½ cut easily 2½ assume about the maximum hardness without being crystalline; after this they yield to the file by crumbling in fragments rather than by ordinary abrasion in shreds, until the tin very greatly predominates, as in the pewters: when the alloys become the more flexible, soft, malleable, and ductile, the less copper they contain.

Alloys of copper and lead only.—The marginal numbers denote the ounces of lead added to every pound of copper.

2 oz. A red-colored and ductile alloy.
4 oz. Less red and ductile; neither of these is so much used as the following, as the object is to employ as much lead as possible.
6 oz. Ordinary pot-metal, called dry pot-metal, as this quantity of lead will be taken up without separating on cooling; this is brittle when warmed.
7 oz. This alloy is rather short, or disposed to break.
8 oz. Inferior pot-metal, called wet pot-metal, as the lead partly oozes out in cooling, especially when the new metals are mixed; it is therefore always usual to fill the crucible in part with old metal, and to add new for the remainder. This alloy is very brittle when slightly warmed. More lead can scarcely be used, as it separates on cooling.

Remarks on the alloys of copper and lead only.—These metals mix in all proportions until the lead amounts to nearly half; after this they separate in cooling.

The addition of lead greatly increases the fusibility.

The red color of the copper is soon deadened by the lead; at about 4 oz. to the pound the work has a bluish leaden hue when first turned, but changes in an hour or so to that of a dull gun-metal character.

When the lead does not exceed about 4 oz. the mixture is tolerably malleable, but with more lead it soon becomes very brittle and rotten; the alloy is greatly inferior to gun metal, and is principally used on account of the cheapness of the mixture, and the facility with which it is turned and filed.

Alloys of copper, zinc, tin, and lead, &c.—This group refers principally to gun metal alloys, to which more or less zinc is added by many engineers; the quantity of tin in every pound of the alloy, which is expressed by the marginal numbers, principally determines the hardness.

Keller's statues at Versailles are found as the mean of four analyses, to consist of

Copper	91·40,	or about	14⅝	ounces.
Zinc	5·53	"	1	"
Tin	1·70	"	⅜	"
Lead	1·37	"	¼	"
	In 100 parts	or the	16	ounces.

1½ to 2½ oz. tin to 1 lb. copper used for bronze medals, or 8 to 15 per cent. tin, with the addition of 2 parts in each 100 of zinc, to improve the color.

The modern so-called bronze medals of our mint are of pure copper, and are afterwards bronzed superficially.

1½ oz. tin ½ zinc to 16 oz copper. Pumps and works requiring great tenacity.

$1\frac{1}{2}$	oz. tin	2	oz. brass	16	"	For wheels to be cut into teeth.
$1\frac{3}{4}$	"	2	"	16	"	(For wheels to be cut into teeth.)
2	"	$1\frac{1}{2}$	"	16	"	For turning-work.
$2\frac{1}{4}$	"	$1\frac{1}{2}$	"	16	"	For nuts of coarse threads, and bearings.

The engineer who uses these five alloys recommends melting the copper alone: the smal. quantity of brass is then melted in another crucible, and the tin in a ladle; the two latter are added to the copper when it has been removed from the furnace; the whole are stirred together and poured into the moulds without being run into ingots. The real quantity of tin to every pound of copper is about one-eighth ounce less than the numbers stated, owing to the addition of the brass, which increases the proportion of copper.

$1\frac{7}{8}$ oz. tin, $1\frac{7}{8}$ oz. zinc, to 1 lb. of copper. This alloy, which is a tough, yellow, brassy gun-metal, is used for general purposes by a celebrated engineer; it is made by mixing $1\frac{1}{2}$ lb. tin, $1\frac{1}{2}$ lb. zinc, and 10 lbs. of copper: the alloy is first run into ingots.

$2\frac{1}{2}$ oz. tin, $\frac{1}{2}$ oz. zinc, to 1 lb. of copper, used for bearings to sustain great weights.

$2\frac{1}{2}$ oz. tin, $2\frac{1}{2}$ oz. zinc, to 1 lb. copper, were mixed by the late Sir F. Chantry, and a razor was made from the alloy; it proved nearly as hard as tempered steel, and exceedingly destructive to new files, and none others would touch it.

1 oz. tin, 2 oz. zinc, 16 oz. brass. Best hard white metal for buttons.

$\frac{1}{2}$ oz. tin, $1\frac{1}{2}$ oz. zinc, 16 oz. brass. Common ditto. (*Phillips's Dictionary.*)

30 lbs. tin, 6 lbs. copper, 4 lbs. brass, constitute white solder. The copper and brass are first melted together, the tin is added, and the whole stirred and poured through birch twigs into water to granulate it; it is afterwards dried and pulverized cold in an iron pestle and mortar. This white solder was introduced as a substitute for silver solder in making gilt buttons. Another button solder consists of 10 parts copper, 8 of brass, and 12 of spelter or zinc.

Remarks on alloys of copper, zinc, tin, lead, &c.—*Ordinary yellow brass*, (copper and zinc,) is rendered very sensibly harder, so as not to require to be hammered, by a small addition of tin, say $\frac{1}{4}$ or $\frac{1}{2}$ oz. to the lb. On the other hand, by the addition of $\frac{1}{4}$ to $\frac{1}{2}$ oz. of lead, it becomes more malleable and casts more sharply. Brass becomes a little whiter for the tin, and redder for the lead. The addition of nickel to copper and zinc constitutes the so-called German silver.

Gun-metal (copper and tin) very commonly receives a small addition of zinc; this makes the alloy mix better, and to lean to the character of brass by increasing the malleability without materially reducing the hardness. The standard measures for the Exchequer were made of a tough alloy of this kind. The zinc, which is sometimes added in the form of brass, also improves the color of the alloy, both in the recent and bronzed states. Lead, in small quantity, improves the ductility of gun-metal, but at the expense of its hardness and color; it is seldom added. Nickel has been proposed as an addition to gun-metal by Mr. Donkin, and antimony by Dr. Ure.

Pot-metal (copper and lead) is improved by the addition of tin, and the three metals will mix in almost any proportions: when the tin predominates, the alloy so much the more nearly approaches the condition of gun-metal. Zinc may be added to pot-metal in very small quantity, but when the zinc becomes a considerable amount, the copper takes up the zinc, forming a kind of brass, and leaves the lead at liberty, and which, in great measure, separates in cooling. Zinc and lead are also very indisposed to mix alone, although a little arsenic assists their union by "killing" the lead as in shot-metal. Antimony also facilitates the combination of pot-metal; 7 lead, 1 antimony, and 16 copper mixed perfectly well the first fusion, and the alloy was decidedly harder than 4 lead and 16 copper; and apparently a better metal. "Lead and antimony, though in small quantity, have a remarkable effect in diminishing the elasticity and sonorousness of the copper alloys."

Gold is of a deep and peculiar yellow color. It melts at a bright-red heat, equivalent, according to Daniell, to 2016° of Fahrenheit's scale, and when in fusion appears of a brilliant greenish color. Its specific gravity is 19·3. It is so malleable that it may be extended into leaves which do not exceed the one two hundred and eighty-two thousandth of an inch in thickness, or a single grain may be extended over 56 square inches of surface. This extensibility of the metal is well illustrated by gilt buttons, 144 of which are gilt by 5 grains of gold, and less than even half that quantity is adequate by giving them a very thin coating. It is also so ductile that a grain may be drawn out into 500 feet of wire. The pure acids have no action upon gold. (*Brande*, 972.)

Gold, in the pure or fine state, is not employed in bulk for many purposes in the arts, as it is then too soft to be durable. The gold foil used by dentists for stopping decayed teeth is perhaps as nearly pure as the metal can be obtained: it contains about six grains of alloy in the pound troy, or the one-thousandth part. Every superficial inch of this gold foil or leaf weighs $\frac{4}{5}$ of a grain, and is 42 times as thick as the leaf used for gilding.

The wire for gold lace prepared by the refiners for gold-lace manufacturers, requires equally fine gold, as when alloyed it does not so well retain its brilliancy. The gold, in the proportion of about 100 grains to the pound troy of silver, or of 140 grains for double-gilt wire, is beaten into sheets as thin as paper; it is then burnished upon a stout red-hot silver bar, the surface of which has been scraped perfectly clean. When extended by drawing, the gold still bearing the same relation as to quantity, namely, the 57th part of the weight, becomes of only one-third the thickness of ordinary gold-leaf used for gilding. In water-gilding, fine gold is amalgamated with mercury, and washed over the gilding metal, (copper and tin;) the mercury attaches itself to the metal, and when evaporated by heat, it leaves the gold behind in the dead or frosted state: it is brightened with the burnisher. (See *Technological Repository*, vol. ii., p. 361: 1828.) By the electrotype process, a still thinner covering of pure gold may be deposited on silver, steel, and other metals. Mr. Dent has introduced this method of protecting the steel pendulum-springs of marine chronometers and other time-pieces from rust.

Fine gold is also used for soldering chemical vessels made of platinum.

Gold alloys.—Gold-leaf, for gilding, contains from 3 to 12 grains of alloy to the oz., but generally 6 grains. The gold used by respectable dentists, for plates, is nearly pure, but necessarily contains about 6 grains of copper in the oz. troy, or one-eightieth part; others use gold containing upwards of one-third of alloy: the copper is then very injurious.

With *copper*, gold forms a ductile alloy of a deeper color, harder and more fusible than pure gold: this alloy, in the proportion of 11 of gold to 1 of copper, constitutes *standard gold;* its density is 17·157, being a little below the mean, so that the metals slightly expand on combining. One troy pound of this alloy is coined into 46$\frac{29}{40}$ sovereigns, or 20 troy pounds into 934 sovereigns and a half. The pound was formerly coined into 44 guineas and a half. The standard gold of France consists of 9 parts of gold and 1 of copper. (*Brande*, 979.)

For *Gold Plate* the French have three different standards: 92 parts gold, 8 copper; also 84 gold, 16 copper; and 75 gold, 25 copper.

In England, the purity of gold is expressed by the terms 22, 18, 16 carats, &c. The pound troy is supposed to be divided into 24 parts, and the gold, if it could be obtained perfectly pure, might be called 24 carats fine.

The "Old Standard Gold," or that of the present currency, is called fine, there being 22 parts of pure gold to 2 of copper.

The "New Standard," for watch-cases, &c., is 18 carats of fine gold, and 6 of alloy. No gold of inferior quality to 18 carats, or the "New Standard," can receive the Hall mark; and gold of lower quality is generally described by its commercial value, as 60 or 40 shilling gold, &c.

The alloy may be entirely silver, which will give a green color, or entirely copper for a red color; but the copper and silver are more usually mixed in the one alloy according to the taste and judgment of the jeweller.

The following alloys of gold are transcribed from the memoranda of the proportions employed by a practical jeweller of considerable experience.*

First group.—Different kinds of gold that are finished by polishing, burnishing, &c., without necessarily requiring to be colored:

The gold of 22 carats fine, or the "Old Standard," is so little used, on account of its expense and greater softness, that it has been purposely omitted.

18 carats, or New Standard gold, of yellow tint:*

15 dwt. 0 grs.	gold.
2 dwt. 18 grs.	silver.
2 dwt. 6 grs.	copper.
20 dwt. 0 grs.	

18 carats, or New Standard gold, of red tint:*

15 dwt. 0 grs.	gold.
1 dwt. 18 grs.	silver.
3 dwt. 6 grs.	copper.
20 dwt. 0 grs.	

16 carats, or Spring gold: this, when drawn or rolled very hard, makes springs little inferior to those of steel:

1 oz. 16 dwt.	gold.	or 1·12
6 dwt.	silver.	— ·4
12 dwt.	copper.	— ·12
2 oz. 11 dwt.		2 ·8

60*s.* gold of yellow tint, or the fine gold of the jewellers; 16 carats nearly:

1 oz. 0 dwt.	gold.
7 dwt.	silver.
5 dwt.	copper.
1 oz. 12 dwt.	

60*s.* gold of red tint, or 16 carats:

1 oz. 0 dwt.	gold.
2 dwt.	silver.
8 dwt.	copper.
1 oz. 10 dwt.	

40*s.* gold, or the old-fashioned jewellers' gold, about 11 carats fine; no longer used:

1 oz. 0 dwt.	gold.
12 dwt.	silver.
12 dwt.	copper.
2 oz. 4 dwt.	

Second group.—Colored golds; these all require to be submitted to the process of wet-coloring, which will be explained: they are used in much smaller quantities, and require to be very exactly proportioned.

Full red gold:

5 dwt.	gold.
5 dwt.	copper.
10 dwt.	

Red gold:

10 dwt.	gold.
1 dwt.	silver.
4 dwt.	copper.
15 dwt.	

Green gold:

5 dwt. 0 grs.	gold.
21 grs.	silver.
5 dwt. 21 grs.	

Gray gold: (Platinum is also called gray gold by jewellers:)

3 dwt. 15 grs.	gold.
1 dwt. 9 grs.	silver.
5 dwt. 0 grs.	

* When it is not otherwise expressed, it will be understood all these alloys are made with fine gold, fine silver, and fine copper, obtained direct from the refiners. And to insure the standard gold passing the test of the Hall, 3 or 4 grains additional of gold are usually added to every ounce.

Blue gold; scarcely used:
5 dwt. gold.
5 dwt. steel filings.
—
10 dwt.
—

Antique gold, of a fine greenish yellow color:

18 dwt. 9 grs. gold,	or	18· 9
21 grs. silver,	—	1· 3
18 grs. copper,	—	·12
20 dwt. 0 grs.		20· 0

Third group.—Gold solders: these are generally made from gold of the same quality and value as they are intended for, with a small addition of silver and copper, thus:

Solder for 22 carat gold:
1 dwt. 0 grs. of 22 carat gold.
2 grs. silver.
1 gr. copper.
—
1 dwt. 3 grs.

Solder for 18 carat gold:
1 dwt. 0 grs. of 18 carat gold.
2 grs. silver.
1 gr. copper.
—
1 dwt. 3 grs.

Solder for 60*s.* gold:*
1 dwt. 0 grs. of 60*s.* gold.
10 grs. silver.
8 grs. copper.
—
1 dwt. 18 grs.

Solder for 40*s.* gold; but middling silver solder is more generally used:
1 dwt. fine gold.
1 dwt. silver.
2 dwt. copper.
—
4 dwt.

Dr. Hermstadt's imitation of gold, which is stated not only to resemble gold in color, but also in specific gravity and ductility, consists of 16 parts of platinum, 7 parts of copper, and 1 of zinc, put in a crucible, covered with charcoal powder, and melted into a mass.

Gold alloyed with platinum is also rather elastic, but the platinum whitens the alloy more rapidly than silver.

Lead appears to have been known in the earliest ages of the world. Its color is bluish white; it has much brilliancy, is remarkably flexible and soft, and leaves a black streak on paper: when handled it exhales a peculiar odor. It melts at about 612°, and by the united action of heat and air, is readily converted into an oxide. Its specific gravity, when pure, is 11·445; but the lead of commerce seldom exceeds 11·35. (*Brande*, 833.)

Lead is used in a state of comparative purity for roofs, cisterns, pipes, vessels for sulphuric acid, &c. Ships were sheathed with lead and with wood from before the Christian era to 1450, after which wood was more commonly employed, and in 1790 to 1800 copper sheathing became general; of late years, lead with a little antimony has likewise been used, also Muntz's sheathing, an alloy of copper and zinc and galvanized sheet-iron. The most important alloys are those employed for printers' type, namely, about

3 lead, 1 antimony, for the smallest, hardest, and most brittle types.
4 lead, 1 antimony, for small, hard, brittle types.
5 lead, 1 antimony, for types of medium size.
6 lead, 1 antimony, for large types.
7 lead, 1 antimony, for the largest and softest types.

The small types generally contain from 4 to 6 per cent. of tin, and sometimes also 1 to 2 per cent. of copper; but as old metal is always used with the new, the proportions are not exactly known.

Stereotype plates contain about 4 to 8 parts of lead to one of antimony.

Baron Wetterstedt's patent sheathing for ships consists of lead with from 2 to 8 per cent. of antimony; about 3 per cent. is the usual quantity. The alloy is rolled into sheets.

Similar alloys, and those of lead and tin in various preparations, are much used for emery-wheels and grinding-tools of various forms by the lapidary, engineer, and others. The latter also employs these readily fused alloys for temporary bearings, guides, screw-nuts, &c.

Organ-pipes consist of lead alloyed with about half its quantity of tin to harden it. The mottled or crystalline appearance so much admired shows an abundance of tin.

Shot-metal is said to consist of 40 lbs. of arsenic to one ton of lead.

In casting sheet-lead, the metal was poured from a swing-trough upon a long and nearly horizontal table, covered with a thin layer of coarse damp sand, previously levelled with a metal rule or strike. The thickness of the fluid metal was determined by running the strike along the table before the lead cooled, the excess being thus swept into a spill-trough at the lower end of the table; but the sheet-lead now more commonly used is cast in a thick slab, and reduced between laminating rollers; it is known as "milled lead."

The metal for organ-pipes is prepared by allowing the metal to escape through a slit in the trough, as it is slid along a horizontal table, so as to leave a trail of metal behind it; the thickness of the metal is regulated by the width of the slit through which it runs, and the rapidity of the traverse; a piece of cloth or ticken is stretched upon the casting-table. The metal is planed to thickness, bent up, and soldered into the pipes.

Lead pipes are cast as hollow cylinders and drawn out upon triblets; they are also cast of indefinite

* By others, 4 grains of brass are added to the solder; it then fuses beautifully and is of good color. Zinc is sometimes added to other gold solders to increase their fusibility; the zinc (or brass, when used) should be added at the last moment, to lessen the volatilization of the zinc.

length without drawing. A patent was taken out for casting a sheath of tin within the lead, but it has been abandoned.

Lead shot are cast by letting the metal run through a narrow slit, into a species of colander at the top of a lofty tower; the metal escapes in drops, which, for the most part, assume the spherical form before they reach the tank of water into which they fall at the foot of the tower, and this prevents their being bruised. The more lofty the tower, the larger the shot that can be produced; the good and bad shot are separated by throwing small quantities at a time upon a smooth board nearly horizontal, which is slightly wriggled; the true or round shot run to the bottom, the imperfect ones stop by the way, and are thrown aside to be remelted; the shot are afterwards riddled or sifted for size, and churned in a barrel with black-lead.

Mr. Joseph Manton took out a patent for amalgamating the surface of leaden shot with mercury. One pound of mercury was added to every cwt. of shot; they were churned together in a revolving barrel nearly full of water, until the shot assumed a silvery coat. These shot were stated to foul the barrel of the gun in a less degree than others, and also to be less injurious to the game after it had been killed.

Mercury is a brilliant white metal, having much of the color of silver, whence the terms *hydrargyrum argentum vivum*, and *quicksilver*. It has been known from very remote ages. It is liquid at all common temperatures; solid and malleable at —40° F., and contracts considerably at the moment of congelation. It boils and becomes vapor at about 670°. Its specific gravity at 60° is 13·5. In the solid state its density exceeds 14. The specific gravity of mercurial vapor is 6·976. (DUMAS, *Ann. de Ch. et Ph.* xxxiii., *Brande*, 928.)

Mercury is used in the fluid state for a variety of philosophical instruments, and for pressure gages for steam-engines, &c. It is sometimes, though rarely, employed for rendering alloys more fusible; it is used with tin-foil for silvering looking-glasses, and it has been employed as a substitute for water in hardening steel. Mercury forms amalgams with bismuth, copper, gold, lead, palladium, silver, tin, and zinc.

Mercury is commonly used for the extraction of gold and silver from their ores by amalgamation, and also in water-gilding. See *Gold*.

Nickel is a white, brilliant metal, which acts upon the magnetic needle, and is itself capable of becoming a magnet. Its magnetism is more feeble than that of iron, and vanishes at a heat somewhat below redness, 630°, (Faraday.) It is ductile and malleable. Its specific gravity varies from 8·27 to 8·40 when fused, and after hammering from 8·69 to 9. It is not oxidized by exposure to air at common temperatures, but when heated in the air it acquires various tints, like steel; at a red heat it becomes coated by a gray oxide. (*Brande*, 802.)

Nickel is scarcely used in the simple state; Mr. Brande mentions, however, that he has seen a Bavarian coin that had been struck in it; but it is principally used together with copper and zinc, in alloys that are rendered the harder and whiter the more nickel they contain; they are known under the names of albata, British plate, electrum, German silver, pakfong, teutanag, &c.: the proportions differ much, according to price; thus the

Commonest are 3 to 4 parts nickel, 20 copper, and 16 zinc.
Best are 5 to 6 parts nickel, 20 copper, and 8 to 10 zinc.

About two-thirds of this metal is used for articles resembling plated goods, and some of which are also plated, (see *silver;*) the remainder is employed for harness, furniture, drawing and mathematical instruments, spectacles, the tongues for accordions, and numerous other small works.

The *white copper* of the Chinese, which is the same as the German silver of the present day, is composed, according to the analysis of Dr. Fyfe, of

31·6 parts of nickel, 40·4 of copper, 25·4 of zinc, and 2·6 of iron.
17·48 " " 53·39 " 13·0 " *Frick's Imitative Silver.*

The white copper manufactured at Sutil, in the duchy of Saxe Hildburghausen, is said by Keferstein to consist of copper 88·000, nickel 8.753, sulphur, with a little antimony, 0·750, silex, clay, and iron, 1·75. The iron is considered to be accidentally introduced into these several alloys, along with the nickel, and a minute quantity is not prejudicial.

Iron and steel have been alloyed with nickel; the former, (the same as the meteoric iron which always contains nickel,) is little disposed to rust, whereas the alloy of steel with nickel is worse in that respect than steel not alloyed.

Palladium is of a dull-white color, malleable and ductile. Its specific gravity is about 11·3, or 11·8 when laminated. It fuses at a temperature above that required for the fusion of gold. (*Brande*, 938.)

"Palladium is a soft metal, but its alloys are all harder than the pure metal. With silver it forms a very tough malleable alloy, fit for the graduations of mathematical instruments, and for dental surgery, for which it is much used by the French; with silver and copper, palladium makes a very springy alloy, used for the points of pencil cases, inoculating lancets, tooth-picks, or any purpose where elasticity and the property of not tarnishing are required; thus alloyed it takes a high polish. Pure palladium is not fusible at ordinary temperatures, but at a high temperature it agglutinates so as to be afterwards malleable and ductile."—*W. Cock.*

This useful metal was discovered by Dr. Wollaston, in 1803, and it has recently been found in some abundance in the gold ores of the Minas Geraes district; the process now employed for its separation was discovered by Mr. P. N. Johnson. Palladium is calculated thoroughly to fulfil many of the purposes to which platinum and gold are applied in the useful arts, and from its low specific gravity, it may be obtained at about half the price of an equal *bulk* of platinum, and at one eighth that of gold; and it equally resists the action of mineral acids and sulphuretted hydrogen.—*London Journal of Science for* 1840.

Palladium was used in the construction of the balances for the United States' Mint.

Platinum is a white metal, extremely difficult of fusion, and unaltered by the joint action of heat and air. It varies in density from 21 to 21·5, according to the degree of mechanical compression which it has sustained; it is extremely ductile, but cannot be beaten into such thin leaves as gold and silver (*Brande*, 4th Ed. p. 822.)

The particles of the generality of metals, when separated from the foreign matters with which they are combined, are joined into solid masses by simple fusion; but platinum being nearly infusible when pure, requires a very different treatment, which was introduced by Dr. Wollaston, and is now conducted in the following manner by Messrs. Johnson and Cock, of London, the celebrated metallurgists.

The platinum is first dissolved chemically, and it is then thrown down in the state of a precipitate; next it is partly agglutinated in the crucible into a spongy mass, and is then compressed whilst cold in a rectangular mould by means of a powerful fly-press or other means, which, in operating upon 500 ounces, converts the platinum into a dense block about 5 inches by 4, and 2½ inches thick. This block is heated in a smith's forge, with two tuyeres meeting at an angle, at which spot the platinum is placed amidst the charcoal fire; when it has reached the welding point, or almost a blue heat, it receives one blow under a heavy *drop*, or a vertical hammer, somewhat like a pile-driving engine; it then requires to be reheated, and it thus receives a fresh blow about every 20 minutes, and in a week or ten days it is sufficiently welded or consolidated on all sides to admit of being forged into bars, and converted into sheets, rods, or wires by the ordinary means.

The motive for operating upon so great a quantity is for making the large pans for concentrating sulphuric acid, in only two or three pieces, which are soldered together with fine gold. In France, 2,000 ounces are sometimes welded into one mass, so that the vessels may be absolutely entire, a practice which is considered in this country to be unnecessarily costly. For small quantities the treatment is the same, but in place of the drop, the ordinary flatter and sledge-hammer are used.

Platinum is exceedingly tough and tenacious, and "hangs to the file worse than copper," on which account, when it is used for the graduated limbs of mathematical instruments, the divisions should be cut with a diamond point, and which is the best instrument for fine graduations of all kinds, and for ruling grounds, or the lined surfaces for etching.

Platinum is employed in Russia for coin. This valuable metal is used in various chemical and philosophical apparatus, in which resistance to fusion or to the acids is essential.

The alloys of platinum are scarcely used in the arts: that with a small quantity of copper is employed in Paris for dental surgery. For alloys of platinum and steel, see *Quarterly Journal of the Royal Inst.*, vol ix., p. 328. The alloy of equal parts of steel and platinum is therein highly spoken of as a mirror.

"Dr. Von Eckart's alloy contains platinum 2·40, silver 3·53, and copper 11·71. It is highly elastic, of the same specific gravity as silver, and not subject to tarnish; it can be drawn to the finest wire from ⅛th of an inch diameter, without annealing, and does not lose its elasticity by annealing. It is highly sonorous, and bears hammering red-hot, rolling and polishing."

Mr. Ross added to silver one-fourth of its weight of platinum, and he considers that it took up one-tenth its weight. The alloy became much harder than silver, capable of resisting the tarnishing influences of sulphur and hydrogen, and was fit for graduations.

An alloy of platinum with ten parts of arsenic is fusible at a heat a little above redness, and may therefore be cast in moulds. On exposing the alloy to a gradually increasing temperature in open vessels, the arsenic is oxidized and expelled, and the platinum recovers its purity and infusibility.—*Turner's Chemistry.*

Tin also so greatly increases the fusibility of platinum, that it is hazardous to solder the latter metal with tin solder, although gold is so used.

Platinum, as well as gold, silver, and copper, are deposited by the electrotype process; and silver plates thus platinized are employed in Smee's Galvanic Battery.

Rhodium is a white metal, very difficult of fusion; its specific gravity is about 11: it is extremely hard. When pure, the acids do not dissolve it. (*Brande*, 1001.)

Rhodium was discovered in 1803, by Dr. Wollaston, and has been long employed for the nibs of pens, which have been also made of ruby, mounted on shafts of spring gold; these kinds have had to endure for the last 7 or 8 years the rivalry of "Hawkins' everlasting Pen," of which latter, the author from many months' constant use can speak most favorably. "The everlasting pen," says the inventor, "is made of gold, tipped with a natural alloy, which is as much harder than rhodium as steel is harder than lead; will endure longer than the ruby, yields ink as freely as the quill, is as easily wiped, and if left unwiped is *not corroded*." See also *Mec. Mag.*, 1840, p. 554. Mr. Hawkins employs the natural alloy of iridium and osmium, two scarce metals, discovered by Tennant amongst the grains of platinum; the alloy is not malleable, and is so hard as to require to be worked with diamond powder. The metals rhodium, iridium, and osmium, are not otherwise employed in the arts than for pens, although steel has been alloyed with rhodium. See also the *Quarterly Journal*, *Royal Inst.*, vol. ix.

Silver is of a more pure white than any other metal; it has considerable brilliancy, and takes a high polish. Its specific gravity varies between 10·4, which is the density of cast silver, and 10·5 to 10·6, which is the density of rolled or stamped silver. It is so malleable and ductile, that it may be extended into leaves not exceeding a ten-thousandth of an inch in thickness, and drawn into wire much finer than a human hair. Silver melts at a bright-red heat, estimated by Mr. Daniell at 1873° of Fahrenheit's scale, and when in fusion appears extremely brilliant. (*Brande*, 953.)

Silver is but little used in the pure unalloyed state, on account of its extreme softness, but it is generally alloyed with copper in about the same proportion as in our coin, and none of inferior value can receive the "Hall mark." Diamonds are set in fine silver, and in silver containing 3 to 12 grs. of copper in the ounce; the work is soldered with pure tin.

The sheet metal for plated works is prepared by fitting together very truly, a short stout bar of copper and a thinner plate of silver; when scraped perfectly clean, they are tied strongly together with binding wire, and united by partial fusion without the aid of solder. The plated metal is then rolled out, and the silver always remains perfectly united, and of the same proportional thickness as at first. Additional silver may be burnished on hot, when the surfaces are scraped clean, as explained under gold; this is done either to repair a defect, or to make any part thicker for engraving upon, and the uniformity of surface is restored with the hammer. In addition to its use for articles of luxury, the important service of copper plated with silver for the parabolic reflectors of lighthouses must not be overlooked; these are worked to the curve with great perfection by the hammer alone.

Plated spoons, forks, harness, and many other articles, are made of iron, copper, brass, and German silver, either cast or stamped into shape; the objects are then filed and scraped perfectly clean; and fine silver, often little thicker than paper, is attached with the aid of tin solder and heat; the silver is rubbed close upon every part with a burnisher.

The electrotype process is also used, under Elkington & Co.'s patent, for plating several of the metals with silver, which it does in the most uniform and perfect manner; the silver added is charged by weight at about three times the price of the metal; the German silver, or albata, is generally used for the interior substance, as when the silver is partially worn through, the white alloy is not so readily detected as iron or copper.

Silver alloys.—Mr. Brande says, "The alloy with *copper* constitutes plate and coin; by the addition of a small proportion of copper to silver, the metal is rendered harder and more sonorous, while its color is scarcely impaired. Even with equal weights of the two metals, the compound is white; the maximum of hardness is obtained when the copper amounts to one-fifth of the silver. The *standard silver* of this country consists of $11\frac{2}{20}$ pure silver, and $\frac{18}{20}$ copper, or 11·10 silver, and 0·90 copper. A pound of troy, therefore, is composed of 11 oz. 2 dwts. pure silver, and 18 dwts. of copper. Its density is 10·3; its calculated density is 10·5, so that the metals dilate a little on combining. The French silver coin is constituted of 9 silver and 1 copper." (*Brande.*) The French *billon* coin is 1 silver and 4 copper. (*Kelly.*)

"For *silver plate*, the French proportions are $9\frac{1}{2}$ parts silver, $\frac{1}{2}$ copper, and for trinkets, 8 parts silver, 2 copper."

Silver solders are made in the following proportions:

Hardest silver solder, 4 parts fine silver, and 1 part copper; this is difficult to fuse, but is occasionally employed for figures.

Hard silver solder, 3 parts sterling silver, and 1 part brass wire, which is added when the silver is melted, to avoid wasting the zinc.

Soft silver solder for general use, 2 parts fine silver, and 1 part brass wire. By some few, $\frac{1}{8}$ part of arsenic is added, to render the solder more fusible and white, but it becomes less malleable; the arsenic must be introduced at the last moment, with care to avoid its fumes.

Silver is also soldered with tin solder, (2 tin, 1 lead,) and with pure tin.

Silver and mercury are used in the plastic metallic stopping for teeth.

Tin has a silvery-white color, with a slight tint of yellow; it is malleable, though sparingly ductile. Common tin-foil, which is obtained by beating out the metal, is not more than 1-1000th of an inch in thickness, and what is termed *white Dutch metal* is in much thinner leaves. Its specific gravity fluctuates from 7·28 to 7·6, the lightest being the purest metal. When bent it occasions a peculiar crackling noise, arising from the destruction of cohesion amongst its particles.

When a bar of tin is rapidly bent backwards and forwards several times successively, it becomes so hot that it cannot be held in the hand. When rubbed it exhales a peculiar odor. It melts at 442°, and by exposure to heat and air is gradually converted into a protoxide. (*Brande.*)

Pure tin is commonly used for dyers' kettles; it is also sometimes employed for the bearings of locomotive carriages and other machinery. This metal is beaten into very large sheets, some of which measure 200 by 100 inches, and are of about the thickness of an ordinary card; the small-sized foil is stated not to exceed one thousandth of an inch in thickness. The metal is first laminated between rollers, and then spread one sheet at a time upon a large iron surface or anvil, by the direct blows of hammers with very long handles; great skill is required to avoid beating the sheets into holes. The large sheets of tin-foil are only used for silvering looking-glasses by amalgamation with mercury. See *Mr. Farrow's apparatus, Trans. Soc. of Arts*, vol. 49, p. 146. Tin-foil is also used for electrical purposes. The amalgam used for electrical machines, is 7 tin, 3 zinc, and 2 mercury.

Tin is drawn into wire, which is soft and capable of being bent and unbent many times without breaking; it is moderately tenacious, and completely inelastic. Tin tube is extensively used for gas fittings, and many other purposes; it has been recently introduced in an ingenious manner for the formation of very cheap vessels, for containing artists' and common colors, besides numerous other solid substances and fluids, required to be hermetically sealed, with the power of abstracting small quantities.

Tin plate is an abbreviation of tinned iron plate; the plates of charcoal iron are scoured bright, pickled, and immersed in a bath of melted tin covered with oil, or with a mixture of oil and common resin; they come out thoroughly coated. Tinned iron wire is similarly prepared; there are several niceties in the manipulations of each of these processes which cannot be noticed in this place.

Tin is one of the most cleanly and sanatory of metals, and is largely consumed as a coating for culinary vessels, although the quantity taken up in the tinning is exceedingly small, and which was noticed by Pliny.

Tin imparts hardness, whiteness, and fusibility to many alloys, and is the basis of different solders, pewters, Britannia metal, and other important alloys, all of which have a low power of conducting heat.

Pewter is principally tin; mostly lead is the only addition, at other times copper, but antimony, zinc, &c., are used with the above, as will be separately adverted to. The exact proportions are unknown even to those engaged in the manufacture of pewter, as it is found to be the better mixed when it contains a considerable portion of old metal, to which new metal is added by trial.

In order to regulate the quality of pewter wares, the Pewterers' Company published in 1772 "A Table of the Assays of Metal, and of the Weights and Dimensions of the several sorts of Pewter Wares," and they threatened with expulsion from their guild, any who departed from the regulations given in this now scarce and disregarded pamphlet.

The assay is made by casting a small button of the metal to be tried in a brass mould, which is so proportioned that the button, if pure tin, weighs exactly 182 grains; all the metals added to the tin being heavier than the latter: the buttons or assays are the heavier the less tin they contain, and at page 14 of the pamphlet the following scale is given:

Assay of pure tin				182 grains.
Ditto of fine or plate metal	$1\frac{1}{2}$ grains heavier than tin, or			$183\frac{1}{2}$ "
Ditto of trifling metal	$3\frac{1}{2}$	"	"	$185\frac{1}{2}$ "
Ditto of ley metal	$16\frac{1}{2}$	"	"	$198\frac{1}{2}$ "

and it may be added, although an unauthorized addition, that equal parts of tin and lead are about fifty grains heavier than tin, or 232 grains.

Some pewters are now made nearly as common as the last proportion: when cast they are black, shining and soft; when turned, dull and bluish. Other pewters only contain 1-5th or 1-6th of lead; these when cast are white, without gloss, and hard; such are pronounced very good metal, and are but little darker than tin. The French legislature sanctions the employment of 18 per cent. of lead with 82 of tin, as quite harmless in vessels for wine and vinegar.

The finest pewter, frequently called "tin and temper," consists mostly of tin, with a very little copper, which makes it hard and somewhat sonorous, but the pewter becomes brown-colored when the copper is in excess. The copper is melted, and twice its weight of tin is added to it, and from about $\frac{1}{2}$ to 7 lbs. of this alloy, or the "temper," are added to every block of tin weighing from 360 to 390 pounds.

Antimony is said to harden tin and to preserve a more silvery color, but is little used in pewter. Zinc is employed to cleanse the metal rather than as an ingredient; some stir the fluid pewter with a thin strip, half zinc and half tin; others allow a small lump of zinc to float on the surface of the fluid metal whilst they are casting, to lessen the oxidation.

Britannia metal, or white metal, is said to consist of $3\frac{1}{2}$ cwt. of block tin, 28 lbs. antimony, 8 lbs. copper. and 8 lbs. brass; it is cast into ingots and rolled into very thin sheets. This manufacture was introduced in about the year 1770, by Jessop and Hancock.

Tin solders are very much used in the arts, and according to Dr. Turner,

1 tin 3 lead, the coarse plumber's solder, melts at about 500 F.
2 " 1 " the ordinary or fine tin solder " " " 360 F.

Zinc.—A bluish-white metal, with considerable lustre, rather hard, of a specific gravity of about 6·8 in its usual state, but, when drawn into wire, or rolled into plates, its density is augmented to 7 or 7·2. In its ordinary state at common temperatures, it is tough, and with difficulty broken by blows of the hammer. It becomes very brittle when its temperature approaches that of fusion, which is about 773°; but at a temperature a little above 212°, and between that and 300°, it becomes ductile and malleable, and may be rolled into thin leaves, and drawn into moderately fine wire, which, however, possesses but little tenacity. When a mass of zinc, which has been fused, is slowly cooled, its fracture exhibits a lamellar and prismatic crystalline texture.—*Brande*, 770.

Zinc, which is commercially known as *spelter*, although it is always brittle when cast. has of late years taken its place amongst the malleable metals; the early stages of its manufacture into sheet, foil, and wire, are stated to be conducted at a temperature somewhat above that of boiling water; and it may be afterwards bent and hammered cold, but it returns to its original crystalline texture when remelted. It has been applied to many of the purposes of iron, tinned-iron, and copper; it is less subject to oxidation from the effects of the atmosphere than the iron, and much cheaper, although less tenacious, ductile, or durable than the copper. The sheet metals when bent lengthways of the sheet, (or like a roll of cloth,) are less disposed to crack than if bent sideways. In this respect zinc and sheet-iron are the worst: the risk is lessened when they are warmed.

Zinc is applied as a coating to preserve iron from rust.

Zinc mixed with one-twentieth its weight of speculum metal, may be melted in an iron ladle, and made to serve for some of the purposes of brass, such as common chucks. The alloy is sufficient to modify the crystalline character, but reserves the toughness of the zinc; it will not, however, bear hammering, either hot or cold. Four atoms of zinc and one of tin, or 133·2 and 57·9, make a hard, malleable, and less crystalline alloy.

Biddery ware, manufactured at Biddery, a large city, 60 miles N. W. of Hyderabad in the East Indies, and also at Benares, is said by Dr. Heyne to consist of copper, 16 oz.; lead, 4 oz.; and tin, 2 oz., melted together: and to every 3 oz. of this alloy, 16 oz. of spelter or zinc are added. The metal is used as an inferior substitute for silver, and resembles some sorts of pewter.

The foregoing alloys are mostly derived from actual practice, and although it has been abundantly shown that alloys are most perfect, when mixed according to atomic proportions, or by multiples of their chemical equivalents, yet this excellent method is little adopted, owing to various interferences.

For example, it is in most cases necessary, from an economic view, to mix some of the old alloys, (the proportions of which are uncertain,) along with the new metals. In most cases also unless the fusion and refusion of the alloys are conducted with considerably more care than ordinary practice ever attains, or really demands, the loss by oxidation completely invalidates any nice attempts at proportion; and which proportions can be alone exactly arrived at, when the combined metals are nearly or quite pure.

Hardness, fracture, and color of alloys.—The object of this division of our article is to explain, in a general way, some of the peculiarities and differences amongst alloys, in the manner of a supplement to the list; prior to entering on the means of melting the metals, without which process alloys cannot be made: yet notwithstanding that the list contains the greater number of the alloys in ordinary use, and many others, it is merely a small fraction of those which might be made. for, says Dr. Turner, "It is probable that each metal is capable of uniting in one or more proportions with every other metal, and on this supposition the number of alloys would be exceedingly numerous."*

It is also stated by the same distinguished authority, that "Metals appear to unite with one another in every proportion, precisely in the same manner as sulphuric acid and water. Thus there is no limit to the number of alloys of gold and copper." The same might be said of many other metals, and when the alloys compounded of three, four, or more metals, are taken into account, the conceivable number of alloys becomes almost unlimited. "It is certain, however, that metals, have a tendency to combine in definite proportion; for several atomic compounds of this kind occur native." "It is indeed possible that the variety of proportions in alloys is rather apparent than real, arising from the mixture of a few definite compounds with each other, or with uncombined metal; an opinion not only suggested by the mode in which alloys are prepared, but in some measure supported by observation."†

It appears to be scarcely possible to give any sufficiently general rules by which the properties of alloys may be safely inferred from those of their constituents; for although, in many cases, the working qualities and appearance of an alloy, may be nearly a mean proportional between the nature and quantities of the metals composing it; yet in other and frequent instances the deviations are excessive, as will be seen by several of the examples referred to.

Thus, when lead, a soft and malleable metal, is combined with antimony, which is hard, brittle, and crystalline, in the proportions of from twelve to fifty parts of lead to one of antimony, a flexible alloy is obtained, resembling lead, but somewhat harder, and which is rolled into sheets for sheathing ships. Six parts of lead and one of antimony are used for the large soft printers' types, which will bend slightly, but are considerably harder than the foregoing; and three parts of lead and one of antimony are employed for the smallest types, that are very hard and brittle, and will not bend at all: antimony being the more expensive metal, is used in the smallest quantity that will suffice.‡ The difference in specific gravity between lead and antimony constantly interferes, and unless the type metal is frequently stirred, the lead, from being the heavier metal, sinks to the bottom, and the antimony is disproportionally used from the surface.§

In the above examples, the differences arising from the proportions appear intelligible enough, as when the soft lead prevails, the mixture is much like the lead; and as the hard, brittle antimony is increased, the alloy becomes hardened, and more brittle: with the proportion of four to one, the fracture is neither reluctant like that of lead, nor foliated like antimony, but assumes very nearly the grain and color of some kinds of steel and cast-iron. In like manner when tin and lead are alloyed, the former metal imparts to the mixture some of its hardness, whiteness, and fusibility, in proportion to its quantity; as seen in the various qualities of pewter, in which however copper, and sometimes zinc or antimony, are found.

The same agreement is not always met with; as nine parts of copper, which is red, and one part of tin, which is white, each *very* malleable and ductile metals, make the tough, rigid metal used in brass ordnance, from which it obtains its modern name of gun-metal, but which neither admits of rolling nor drawing into wire; the same alloy is described by Pliny as the soft *bronze* of his day. The continual addition of the tin, the *softer metal*, produces a gradual increase of hardness in the mixture; with about one-sixth of tin the alloy assumes its maximum hardness consistent with its application to mechanical uses; with one-fourth to one-third tin it becomes highly elastic and sonorous, and its brittleness rather than its hardness is greatly increased.

When the copper becomes two, and the tin one part, the alloy is so hard as not to admit of being cut with steel tools, but crumbles under their action; when struck with a hammer, or even suddenly warmed, it flies into pieces like glass, and clearly shows a structure highly crystalline, instead of malleable. The alloy has no trace of the red color of the copper, but it is quite white, susceptible of an exquisite polish, and being little disposed to tarnish it is most perfectly adapted to the reflecting speculums of telescopes and other instruments, for which purpose it is alone used.

Copper, when combined *in the same proportions* with a different metal, also light-colored and fusible, namely two parts of copper with one of zinc, (which latter metal is of a bluish white, and *crystalline*, whereas tin is very ductile,) makes an alloy of entirely opposite character to the speculum metal; namely, the soft yellow brass, which becomes by hammering very elastic and ductile, and is very easily cut and filed.

Again, the same proportions, namely, two parts of copper and one of lead, make a common inferior

* Dr. Turner's Chemistry, Seventh Edition, 1841, p. [illegible] † Ibid., p. 359.

‡ In this alloy the antimony [illegible] hardness; antimony [illegible] on cooling, whereas lead contracts very much, and the antimony therefore, within certain limits, compensates for the contraction, and causes the alloy to retain the full size of the mould.

Sometimes from motives of economy the neighboring parts of machinery are not wrought accurately to correspond one with the other, but lead is poured in to fill up the intermediate space, and to make contact. [illegible] the heads of some screw-presses, [illegible] and some other parts of [illegible] machinery. Antimony is quite essential in all these cases to prevent the contraction the lead alone would sustain, and which would defeat the intended object, as the metal would otherwise become smaller than the space to be filled.

§ A little tin is commonly [illegible] types, and [illegible] copper in minute quantity; [illegible] spoken of; the last [illegible] well known property of expanding in cooling [illegible] types to swell in the mould, and copy the face of the letter more perfectly; [illegible] used, it appears to be neither common nor essential in printing types.

metal, called pot-metal, or cock-metal, from its employment in those respective articles. This alloy is much softer than brass, and hardly possesses malleability; when, for example, the beer-tap is driven into the cask, immediately after it has been scalded, the blow occasionally breaks it in pieces, from its reduced cohesion.

Another proof of the inferior attachment of the copper and lead, exists in the fact that if the moulds are opened before the castings are almost cold enough to be handled, the lead will ooze out, and appear on the surface in globules. This also occurs to a less extent in gun-metal, which should not, on that account, be too rapidly exposed to the air; or the tin *strikes to the surface*, as it is called, and makes it particularly hard at those parts, from the proportional increase of the tin. In casting large masses of gun-metal, it frequently happens that little hard lumps, consisting of nearly half tin, work up to the surface of the runners or pouring places, during the time the metal is cooling.

In brass, this separation scarcely happens, and these moulds may be opened whilst the castings are red-hot, without such occurrence; from which it appears that the copper and zinc are in more perfect chemical union, than the alloys of copper with tin, and with lead.

Malleability and ductility of alloys.—The malleability and ductility of alloys are in a great measure referable to the degrees in which the metals of which they are respectively composed possess these characters.

Lead and tin are malleable, flexible, ductile, and inelastic, whilst cold, but when their temperatures much exceed about half way towards their melting heats, they are exceedingly brittle and tender, owing to their reduced cohesion.

The alloys of lead and tin partake of the general nature of these two metals; they are flexible when cold, even with certain additions of the brittle metals antimony and bismuth, or of the fluid metal mercury; but they crumble with a small elevation of temperature, as these alloys melt at a lower degree than either of their components, to which circumstance we are indebted for the tin solders.

Zinc, when cast in thin cakes, is somewhat brittle when cold, but its toughness is so far increased when it is raised to about 300° Fahr. that its manufacture into sheets by means of rollers is then admissible; it becomes the malleable zinc, and retains the malleable and ductile character, in a moderate degree, even when cold, but in bending rather thick plates it is advisable to warm them to avoid fracture; when zinc is remelted it resumes its original crystalline condition.*

Zinc and lead will not combine without the assistance of arsenic, unless the lead is in very small quantity; the arsenic makes this and other alloys very brittle, and it is besides dangerous to use. Zinc and tin make, as may be supposed, somewhat hard and brittle alloys, but none of the zinc alloys, except that with copper to constitute brass, are much used.

Gold, silver, and copper, which are greatly superior in strength to the fusible metals above named, may be forged either when red-hot or cold, as soon as they have been purified from their earthy matters, and fused into ingots; and the alloys of gold, silver, and copper are also malleable, either red-hot or cold.†

Fine, or pure gold and silver, are but little used alone; the alloy is in many cases introduced less with the view of depreciating their value than of adding to their hardness, tenacity, and ductility; the processes which the most severely test these qualities, namely, drawing the finest wires and beating gold and silver leaf, are not performed with the pure metals, but gold is alloyed with copper for the red tint, with silver for the green, and with both for intermediate shades. Silver is alloyed with copper only, and when the quantity is small its color suffers but slightly from the addition, although all its working qualities are greatly improved, pure silver being little used.

The alloys of similar metals having been considered, it only remains to observe that when dissimilar metals are combined, as those of the two opposite groups—namely, the fusible lead, tin, or zinc, with the less fusible copper, gold, and silver—the malleability of the alloys when cold is less than that of the superior metal; and when heated barely to redness, they fly in pieces under the hammer; and therefore, brass, gun-metal, &c., when red-hot, must be treated with precaution and tenderness. Muntz's patent metal, which is a species of brass and is rolled red-hot, appears rather a contradiction to this; but in all probability this alloy, like the ingots of cast-steel, requires at first a very nice attention to the force applied. It will be also remembered the action of rollers is more regular than that of the hammer; and soon gives rise to the fibrous character, which, so far as it exists in metals, is the very element of strength when it is uniformly distributed throughout their substance. This will be seen by the inspection of the relative degrees of cohesion possessed by the same metal when in the conditions of the casting, sheet, or wire, and to which quality or the tenacity of alloys we shall now devote a few lines.

Strength or cohesion of alloys.—The strength or cohesion of the alloys, is in general greatly superior to that of any of the metals of which they are composed.

All nice attempts at proportion, are, however, entirely futile, unless the metals are perfectly pure; for example, it is a matter of common observation that for speculums, a variable quantity of from seven and a half to eight and a half ounces of tin is required for the exact saturation of every pound of copper, and upon which saturation the efficiency of the compound depends; bells of exactly similar quality sometimes thus require the dose of tin to vary from three and a half to five ounces to the pound of copper, according to the qualities of the metals.

Fusibility of alloys.—In concluding this slight view of some of the general characters of alloys, it remains to consider the influence of heat, both as an agent in their formation, and as regards the degree in which it is required for their after fusion; the lowest available temperature being the most desirable in every such case.

"Metals do not combine with each other," says Dr. Turner, "in their solid state, owing to the influence

* It is considered that most of the sheet zinc contains a very little lead.
† Gold alloyed with copper alone is not very malleable when hot.

of chemical affinity being counteracted by the force of cohesion. It is necessary to liquefy at least one of them, in which case they always unite, provided their mutual attraction is energetic." Thus, brass is formed when pieces of copper are put into melted zinc; and gold unites with mercury at common temperatures by mere contact."

The agency of mercury in bringing about *triple* combinations of the metals, both with and without heat, is also very curious and extensive. Thus, in *water-gilding*, the silver, copper, or gilding metal, when chemically clean, are rubbed over with an amalgam of gold containing about eight parts of mercury; this immediately attaches itself, and it is only necessary to evaporate the mercury, which requires a very moderate heat, and the gold is left behind. *Water-silvering* is similarly accomplished.

Cast-iron, wrought-iron, and steel, as well as copper and many other metals, may be tinned in a similar manner. An amalgam of tin and mercury is made so as to be soft and just friable; the metal to be tinned is thoroughly cleaned either by filing or turning, or if only tarnished by exposure, it is cleaned with a piece of emery-paper or otherwise, without oil, and then rubbed with a thick cloth moistened with a few drops of muriatic acid. A little of the amalgam then rubbed on with the same rag, thoroughly coats the cleaned parts of the metal by a process which is described as *cold-tinning;* other pieces of metal may be attached to the tinned parts by the ordinary process of tin-soldering.

In making the tinned-iron plates, the scoured and cleaned iron plates are immersed in a bath of pure melted tin; covered with pure tallow, the tin then unites with every part of the surfaces; and in the ordinary practice of tinning culinary vessels of copper, pure tin is also used. The two metals, however must then be raised to the melting heat of tin; but the presence of a little mercury enables the process to be executed at the atmospheric temperature, as above explained.

In Mr. Mallett's recently patented "processes for the protection of iron from oxidation and corrosion, and for the prevention of the fouling of ships," one proceeding consists in covering the iron with zinc.

The ribs or plates for iron ships are immersed in a "cleansing bath" of equal parts of sulphuric or muriatic acid and water, used warm; the works are then hammered, and scrubbed with emery or sand, to detach the scales and to thoroughly clean them; they are then immersed in a "preparing bath" of equal parts of saturated solutions of muriate of zinc and sal-ammoniac, from which the works are transferred to a fluid "metallic bath," consisting of 202 parts of mercury and 1292 parts of zinc, both by weight;* to every ton weight of which alloy is added about one pound of either potassium or sodium, (the metallic bases of potass and soda,) the latter being preferred. As soon as the cleaned iron works have attained the melting heat of the triple alloy, they are removed, having become thoroughly coated with zinc.

The affinity of this alloy for iron is, however, so intense, and the peculiar circumstances of surface as induced upon the iron presented to it by the preparing bath are such, that care is requisite lest by too long an immersion the plates are not partially or wholly dissolved. Indeed, where the articles to be covered are small, or their parts minute, such as wire, nails, or small chain, it is necessary before immersing them to permit the triple alloy to dissolve or combine with some wrought-iron, in order that its affinity for iron may be partially satisfied, and thus diminished. At the proper fusing temperature of this alloy, which is about 680° Fahr., it will dissolve a plate of wrought-iron of an eighth of an inch thick in a few seconds.

The palladiumizing process.—The articles to be protected are to be first cleansed in the same way as in the case of zincing; namely, by means of the double salts of zinc and ammonia, or of manganese and ammonia; and then to be thinly coated over with palladium, applied in a state of amalgam with mercury.

In the opinion of eminent chemists and metallurgists, *all* the metals, even the most refractory, which nearly or quite refuse to melt in the crucible when alone, will gradually run down when surrounded by some of the more fusible metals in the fluid state; in a manner similar to the solution of the metals in mercury, as in the amalgams, or the solutions of solid salts in water. The surfaces of the superior metals are, as it were, dissolved, washed down, or reduced to the state of alloys, layer by layer, until the entire mass is liquefied.

Thus nickel, although it barely fuses alone, enters into the composition of German silver by aid of the copper, and whilst it gives whiteness and hardness, it also renders the mixture less fusible. Platinum combines very readily with zinc, arsenic, and also with tin and other metals; so much so, that it is dangerous to melt either of those metals in a platinum spoon, or to solder platinum with common tin solder, which fuses at a very low temperature; although platinum is constantly soldered with fine gold, the melting point of which is very high in the scale. Again, the circumstances that some of the fusible bismuth alloys melt below the temperature of boiling water, or at less than half the melting heat of tin, their most fusible ingredient, show that the points of fusion of alloys, are equally as difficult of explanation or generalization as many other of the anomalous circumstances concerning them.

This much, however, may be safely advanced, that the alloys, without exception, are more easily fused than the superior metal of which they are composed; and extending the same view to the *relative* quantities of the components, it may be observed that the hard solders for the various metals and alloys are in general made of the self-same material which they are intended to join, but with small additions of the more fusible metals. The solder should be, as nearly as practicable, equal to the metal on which it is employed, in hardness, color, and every property except fusibility; in which it must excel just to an extent that, when ordinary care is used, will avoid the risk of melting, at the same time both the object to be soldered and likewise the softer alloy or solder by which it is intended to unite its parts.

It would appear as if every example of soldering in which a more fusible alloy is interposed, were also one of superficial alloying. Thus, when two pieces of iron are united by copper, used as a solder

* Being in the proportion of one atom of mercury to forty atoms of zinc.

it seems to be a natural conclusion that each surface of the iron becomes alloyed with the copper; and that the two alloyed surfaces are held together from their particles having been fused in contact, and run into one film. It is much the same when brass or spelter solder is used, except that triple alloys are then formed at the surfaces of the iron, and so with most other instances of soldering.

And in cases where metallic surfaces are coated by other metals, the latter being at the time in a state of fusion, as in tinned-iron plates and silvered copper; may it not also be conceived, that between the two exterior surfaces which are doubtless the simple metals, a thin film of an alloy compounded of the two does in reality exist? And in those cases in which the coating is laid on by the aid of mercury, and without heat, the circumstances are very similar, as the fluidity of mercury is identical with the ordinary state of fusion of other metals, although the latter require higher temperatures than that of our atmosphere.

When portions of the same metal are united by partial fusion, and without solder, as in the process described as *burning together*, and more recently known as the "*autogenous*" mode of soldering, no alloy is formed, as the metals simply fuse together at their surfaces.

Neither can it be supposed that any formation of alloy can occur where the one metal is attached to the other by the act of burnishing on with heat, as in making gilt wire, but without a temperature sufficient to fuse either of the metals. The union in this case is probably mechanical, and caused by the respective particles or crystals of the one metal being forced into the pores of the other, and becoming attached by a species of entanglement, similar to that which may be conceived to exist throughout solid bodies. This process, almost more than any other in common use, requires that the metals should be perfectly or chemically clean; for which purpose they are scraped quite bright before they are burnished together, so that the junction may be next approaching to that of solids generally.

And, lastly, when metals are deposited upon other metals by chemical or electrical means, the addition frequently appears to be a detached sheath, and which is easily removed; indeed, unless the metal to be coated is chemically clean, and that various attendant circumstances are favorable, the sound and absolute union of the two does not always happen, even when carefully aimed at.

METALLURGY. A word derived from the Greek, signifying the art of working metals, or the art by which metals are produced from their ores.

Metals constitute a well-known class of substances, distinguished by characteristics which every one recognizes. They are considered as elementary matter by chemists, because chemistry has failed, up to the present time, to resolve any one of them into more simple forms of matter; they may, therefore, be regarded as an aggregation of elementary atoms, held together by the force of cohesion. Metals are popularly recognized as heavy matter, of great tenacity; of a peculiar metallic lustre, which it is difficult to describe, but which is easily recognized. With one exception, namely, quicksilver, all the metals are solid at ordinary temperatures; they are all capable of liquefaction, and even volatilization, at higher temperatures, the degree of heat being a different one in every instance. Metals, as a class, are characterized by a higher specific gravity than almost all other matter; they are distinguished by opacity, from which rule only gold and silenium are excepted. The capacity of conducting heat and electricity is possessed by metals to a high degree of perfection.

Malleability is the property of metals to change their form permanently, under a certain pressure. The most important considerations for our present purposes are, the chemical qualities, the fusibility of metals, their affinity for other matter, and their affinity among themselves.

Fusibility.—The degree of heat at which metals assume the solid or the fluid state is their fusibility.

Mercury melts at	39°	Silver melts at	1860°
" boils "	600°	Gold " "	1983°
Tin melts "	420°	Cast-iron " "	2700°
Lead " "	600°	Platinum " "	4561°
Zinc " "	666°		

The affinity of the metals for oxygen forms a very important item in our investigations. The oxides of mercury, silver, gold, platinum and the platinum metals, part with their oxygen by the mere application of heat. The following oxides of metals retain their oxygen at any temperature; they require the addition of carbon or hydrogen in order to expel their oxygen: lead, copper, bismuth, antimony, chromium, arsenic, nickel, cobalt, iron, tin, zinc. Most of these oxides may be deprived of their oxygen by carbon only, others by carbon and hydrogen, and some may be reduced by hydrogen only. Hydrogen reduces all these oxides, but with most of them the point of reduction is so low as to leave the metal in the form of a fine powder, which oxidizes as soon as it is exposed to the atmosphere. Iron, copper, nickel, chromium, and other metals cannot be reduced by hydrogen, on account of the low heat by which the process is accomplished. Antimony, arsenic, tin, zinc, lead, mercury, and all the alkaline metals may be reduced by hydrogen. The facility with which metals oxidize is also of importance in metallurgical operations. Lead, copper, bismuth, antimony, chromium, and arsenic do not decompose water at any temperature, but are easily oxidized by atmospheric air. Nickel, cobalt, iron, tin, zinc, manganese, decompose water easily at a red heat. All the terrifiable metals, such as aluminum, and we may add silicon, are easily oxidized at a higher heat, and their oxides readily reduced in the presence of carbon, and of such other metals as these metals can combine with. The alkaline metals oxidize most readily under all conditions, and their oxides are easy of reduction in the presence of other metals, such as lead, antimony, and others with which the alkaline metals may combine. Besides the combination of the metals with oxygen, their union with other matter, such as sulphur, phosphorus, carbon, &c., is of high interest. Most of the metals combine readily with sulphur, such as iron or lead; others are not so easily disposed to enter into that combination, as zinc and gold. The affinity of sulphur for the metals and carbon, and the mode and conditions under which these combinations may be separated, forms a very important part of the metallurgist's knowledge. Of the same importance as the sulphur combinations are those of phosphorus; which combinations are in most cases more difficult of separation than all other or similar compounds. Of equal importance to the smelter of metals, is the relation of the metals among themselves; it is not so much the nature and qualities of these combinations, as the conditions under which the metals combine and separate, which interest him

The art of smelting consists in the knowledge of the nature of metals, their fusibility and relation to other matter. It is not so much the specific qualities of metals which interest the metallurgist, as the mode of manufacturing the metals from their native ores. To produce metal from ore, the first condition is to expose the ore to such a high heat as will melt the metal. Gold, mercury, and the platinum metals may be produced in this way to a certain extent. All or most of the metals in nature are combined with other matter, such as oxygen, sulphur, phosphorus; to remove the oxygen, we add to the ore matter which has a greater affinity for oxygen than the metal, at or near that degree of heat by which the metal melts: carbon is the most generally in use, hydrogen serves in some cases, and metals in others. Metals and sulphur, or other matter, may be roasted, and the metal resolved into an oxide; but if such process is not practicable, the sulphuret or phosphuret, &c., is melted along with another metal, such as sulphuret of lead or copper with metallic iron, where always that condition is complied with, namely, that the newly formed metal is more fusible than the newly formed sulphuret. Metallic ores are in most cases a mechanical mixture of the metal in its pure state, as gold ores; or a mixture of the oxide of metal and other matter, such as is the case in clay—iron—stone: or the ores are a chemical combination of one sulphuret of metal with other sulphurets of metal, as copper-pyrites in connection with iron-pyrites, to which, frequently, silex or clay is added in admixture. The prevailing principle in all metallurgical operations is, with but few exceptions, the transformation of all ores into metallic oxides, and the reduction of these oxides by carbon. Where the metallic oxides are incorporated with matter, such as silex, alumina, or lime, which cannot be reduced at those temperatures and under those conditions by which the metals melt and are reduced themselves, that matter would prevent the agglutination of the metallic globules, and permit but a small portion of the metal to separate from it, even if all other conditions of the reducing process are fulfilled; this foreign matter forms an inclosure to the metallic particles. This inclosure is to be destroyed, which, in many cases, can be done by heat simply; such is the case with some copper ores, where a certain portion of iron is present. In other cases it requires the addition of such matter to the ore which will combine with the impurities of it, melt with it, and liberate the metal. This latter part of the science of metallurgy is the most difficult to obtain, and exerts the most influence upon the practical results of the operation. This branch of our investigation it is beyond the limits of this article to explore fully, we can furnish but a faint outline of the principles involved.

The formation of fusible slags is accomplished by smelting an oxide of one metal together with the oxide of another, or these oxides together with silex. These combinations are subject to the laws of affinity developed by chemistry. They depend upon the quantity of the oxides, their degree of oxidation, their relative position in the scale of affinity, and the conditions under which the oxides meet. The most prevalent in these combinations are the silicates, or a vitrification of a metallic oxide with silex. Either mixed to a silicate, or one mixed to the other, are frequently found the carbonates, chlorides, sulphates, fluates, and other salts, which form in all cases a more or less fusible slag. The nature of the operation requires the formation of a fusible slag as most advantageous to the process. In practice, this principle is frequently modified, on account of the quality of the metal to be produced, or, more generally, for reasons of economy. Silex and alumina are the most pervading admixtures to metallic ores; these are vitrified by all the alkalies and alkaline earths, by protoxides of metals, and the oxides of metals. The fusibility of these combinations is in the following order: alkalies, alkaline-earths, protoxides, and peroxides. A mixture of various oxides or alkalies is more fusible than that of but one alkali or oxide, with silex or alumina; the greater the number of these vitrifying elements, the more fusible and homogeneous is the slag; the greater the affinity between the composing parts of a slag, the easier it melts. The laws involved in this question may be abstracted from chemistry, always, however, with due regard to the temperature by which the operation is performed.

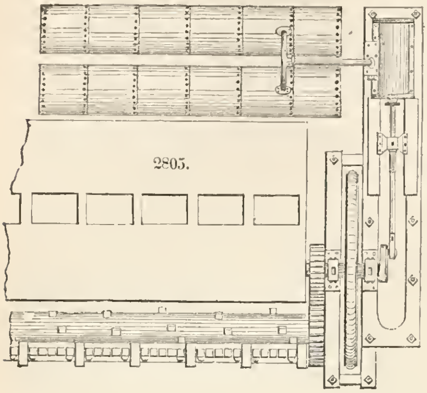
Preparatory metallurgical operations.—Some metallic ores may be made to yield their metal by merely crushing and washing the ore—such are the gold and platinum ores. Other ores may be smelted without any preparation or addition of fluxes; to this class belong a large portion of the copper ores, some iron ores, and most of the lead ores. Some ores require simple roasting, others stamping and roasting, before they are ready for the smelting furnace. Almost all the ores, to be smelted, require the addition of fluxes to make the operation profitable. The manipulations in the smelt-works are divided into the preparation of fuel, preparation of ore, and smelting. The first we consider as too extended for the limits of this article, (see IRON,) and confine the subject to the description of the two latter processes. Preparation of ore is again divided into dressing, roasting, crushing, and washing of ore.

Dressing of ore.—An imperfect picking or sorting of ore is generally performed in the mines; but as a distinct separation and classification cannot be expected in this place, valuable ores are once more picked and cleaned above-ground with greater care than it could be done in the mine. Iron ores, and such ores which cannot bear such expense, are used directly from the mine, without further sorting. Gold ores are necessarily assorted before they are brought to the mill; the same operation is performed on silver ores. If there are pieces among the ore which contain no metal at all, they are thrown away; also such as are so poor as not to pay the expenses of the subsequent operations.

Stamping of ore.—If the mixture of metallic ore and impurities is very intimate, and are the impurities of such a nature as to make smelting difficult, they are moved to the stamping-mill, where the ores are crushed, broken into a more or less fine sand, and washed. Crushing is performed by machinery called a stamping mill.

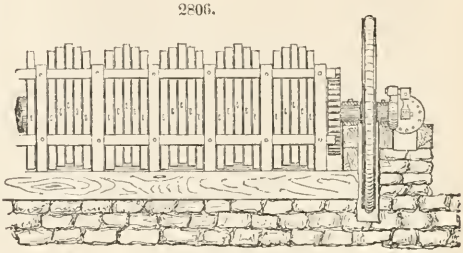
In Fig 2805 a mill of this kind is represented in plan, and in Fig. 2806 in elevation. The machine represented in the engravings has been erected in Virginia during the last year.

For the crushing of gold ore there are 30 stampers connected with the engine, which is of 40 horse-power. These stampers are scantlings of white oak wood, 6 feet long, and 6 × 6 inches thick. Each wooden stamper is provided at its lower end with a cast iron pestle, (stamper head,) weighing from 2 to 2¼ cwts. each. These stamper-heads are made of the finest and hardest kind of cast-iron, such iron as chilled rollers are made of, and are cast in heavy iron chills, so as to harden the whole surface of the head. These heads are fastened to the wooden helve by a wrought-iron tang of two inches square iron, cast in into the head and sunk into the centre of the wood, where it is secured by wrought-iron



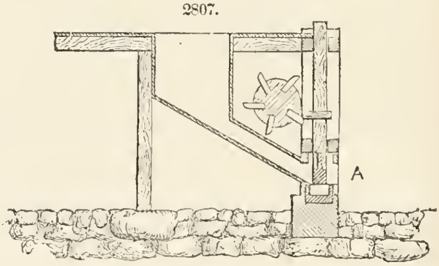
2805.

2806.



hoops laid around the lower end of the helve. The 30 stampers are divided into 3 sets of 5 each; these 5 stampers work into one trough—that is, the whole length of the trough is divided into 6 compartments, of which each forms a set or battery. Each battery has its own feeding apparatus; this is a large, wooden, fixed hopper, as shown in Fig. 2807. Into this hopper the ore is carried as it comes from the hive. It discharges the ore in the middle of the battery or set of five stampers, the middle stamper drawing as much ore as, with the assistance of the two stampers on each side, it can crush. The bottom of each trough is provided with a cast-iron plate; the stampers, however, never touch this plate. Upon this bed-plate a bed of quartz is laid, and kept so that always from 2 to 4 inches high of partly crushed quartz is in the bottom of each battery. This bottom of rocky matter protects the iron bottom, the stampers, and the whole machinery against premature destruction. Each battery is inclosed by a trough made of cast-iron plates, reaching about 7 inches high above the bottom plate. The woodwork to which these plates are fastened is higher, and reaches up to 12 or more inches. Each battery is provided with two sieves, or grates, shown by A; these are made of sheet-iron, or sheet-copper, pierced with holes, or they are made of brass-wire gauze, tweeled, in which wire and spaces are each about $\frac{1}{20}$ of an inch. Round holes punched in plates ought to be $\frac{1}{12}$ or $\frac{1}{16}$ of an inch in diameter. These sieves are 8 inches square, fastened vertically at each end of the trough, about 4 inches or 3½ inches above the bottom. The size and form of the holes in the sieves decide the size of the grains of sand made, for all grains which cannot pass these holes are returned to the stamps.

2807.

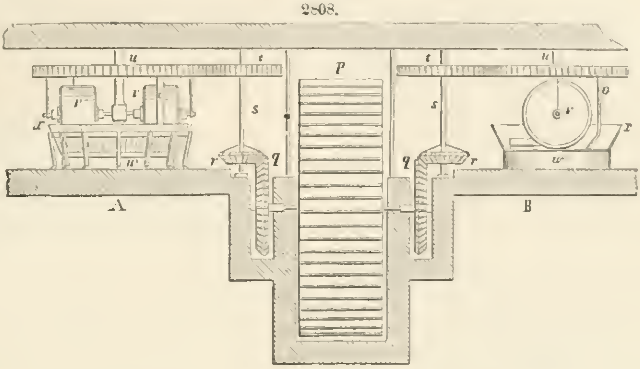


This stamping-machine crushes and washes the ore in the mean time, each stamper receiving 2½ gallons of water per minute. Where ores are stamped dry, the breast-plate and sieves at each battery can be dispensed with. The yield of the machine is about 1000 bushels of quartz converted into fine sand fit for amalgamation in 12 hours, each pestle making from 90 to 100 strokes per minute, having 10 or 11 inches lift. The water in the trough ought to be always high enough to prevent splashing, and loss of good mineral. There is a diversity of opinion respecting the construction of stamping-machines, many machines being now built entirely of cast-iron. We are not aware that any superior results have been achieved by cast-iron machines. It is against the practice and principles of mechanics to build machines which work by concussion of an almost inelastic material such as cast-iron. Wooden machines of this kind are, in the first place, cheaper, and, if well built, are more durable and of greater effect than cast-iron structures.

Gold ores are stamped to liberate the metallic gold inclosed by rocky matter. Lead ores, copper ores, silver ores, &c., are stamped to wash off the gangue. Rocky matter is of a smaller specific gravity than the metallic ores generally are, particularly the sulphurets. When an ore is pulverized, and a current of water passed through the trough containing it, the sand and clay, limestone, &c., will pass off readily in coarse grains, because its gravity is greatly diminished in water: such grains are carried off by the slightest current. Metallic substances more heavy than quartz or rocky matter, will not move until reduced to a certain size, when the particles will follow the current by adhesion, or be so inconsiderable as to be carried off by the wash water. The current of water issuing from the stamps will carry the rocky matter further than the metallic granules, and if the water and sand from the stamps is led into a long wooden trough, the lightest particles will be found furthest off the stamps, and the heaviest matter nearest to the mill. The size of the grains is regulated in the mill, chiefly by the height of the grating or sieve above the bottom of the trough or stamper-bed; further by the size of the holes in the sieve; by the amount of water; by the lift of the stamps, weight of stamps, and particularly by the kind of bottom used. If the bottom is too hard or thin, the mill stamps coarsely; and if the rock bottom is too thick, it stamps too fine.

Other means of grinding or crushing ore are millstones, of considerable weight and size. In Fig. 2808 a mill of this kind is represented. A vertical shaft, to which a cross shaft and two millstones of 4 or 5 feet diameter are appended, revolves slowly around itself, making from 3 to five revolutions per minute. This shaft carries with it the two head-stones, which revolve around the vertical axis, and in the mean time around their own axis, running upon a third millstone, which is laid horizontal, and fixed upon the floor of the millhouse. These stones are of hard material, either of granite, gneiss, trap, or some other tenacious hard rock. Such mills are chiefly used for grinding clay, fire-clay, or kaolin in por-

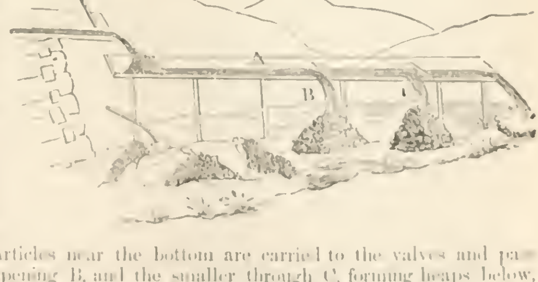
2808.



celain manufactories. Similar mills are exclusively employed in North Carolina for crushing gold ores, also to some extent in Virginia; they are there entirely constructed of iron, or at least the facing, or grinding part of it is made of cast-iron; and are here called Chilian-mills. These mills show one advantage to the stamper-mills; that is, they may be made to grind the ore very fine; and where that is necessary, as it is with many gold ores, these mills are advantageous. But there is one serious drawback to these machines: they require much power in proportion to their effect, and much room. A strong mill of this kind requires from 4 to 6 horse-power, with which it will grind from 40 to 50 bushels of ore in 12 hours, that is, ten bushels to a horse-power. One horse-power will drive one stamper in a stamp-mill, and that stamper will crush at least 30 bushels in the same time,—a consideration which is of importance where wages, power, and time are valuable. Other crushing apparatus, such as common mills, in the form of grist-mills, crushing rollers, and similar machinery, are not in use in this country, at least not to any extent.

Washing of ores.—Ores which contain a considerable amount of clay, lime, sand, and other impurities which may be injurious to the smelting operation, are washed in an abundance of water, so as to carry off the light particles and retain the heavy metallic matter. The simplest form of a washing apparatus, such as is used for washing impure iron ores, is represented in Fig. 2809. A is a long wooden trough of from 20 to 50 feet long, 12 inches wide in the bottom, and 6 or 8 inches high. This trough is a little inclined to the horizon, so as to afford a gentle current. At the upper end a strong current of water is let into it, from a weir or an elevated reservoir, which flows down the channel at a rapid rate. At the entrance of the water a laborer throws in, at intervals, a shovelfull of unclean ore, under the current from the spout of the pool. The water in falling upon the ore moves first the small and light particles, which are carried downwards to the valves B and C. The light, floating particles are carried over these valves, and are discharged at the end of the trough. The heavier particles near the bottom are carried to the valves and pass through these, the coarse through the opening B, and the smaller through C, forming heaps below, from which the remaining light impurities flow off. This apparatus is simple, effective, and may be applied in all instances where washing is to be done. Various modes and machines are used in Europe to remove the earthy matter from the ore by washing. Complicated sifting machines are employed, the grilles or step-washings of Hungary, percussion-tables, shaking-tables, German chests, sleeping-tables, swing-sieves, and a host of other machines, all of which are of no use to us; these machines work too slow, absorb too much labor, and are not advantageous to our modes of working. The above wash apparatus, properly modified in particular cases, is all-sufficient for washing any kind of ore, and purifying it so far as necessary.

2809.



Roasting of ores.—This process is sometimes performed on the ores when brought from the mine, as is the case with iron ore, or it is performed after the ores are crushed, which is the way of working silver ores in North Carolina. The principle involved in this operation is to drive off all that volatile matter from the ore which may be dissipated by heat; such as water, carbon, sulphur, phosphorus, chlorine, arsenic, zinc, &c. The consequence of this operation, if well performed, is in all cases, with but few exceptions, the oxidation of the remaining metals to their highest degree; a condition in which the ores are most easily worked, and reduced by carbon to the metallic state. Roasting is performed in this country almost exclusively in the open air; experiments made on roasting ovens met in but few instances with success. There is no doubt but that roast ovens are more economical in the use of fuel than heaps in the open air, but the ovens require more labor; and as fuel is cheap with us, labor high, the reverse of what they are in Europe, it appears to be natural to follow those modes of working which tend to lessen cost, and do the work in the cheapest way. In Fig. 2810 a roast-heap is represented in section. These heaps are often round, but in most cases are mounds of from 25 to 50 and more feet long. The operation consists in spreading over an area of a certain length, and from 8 to 20 feet wide sticks of fire-wood, which may be of an indifferent kind and form. The spaces between the sticks are filled up by small wood, chips, or any kind of fuel, providing, however, sufficient spaces for the access of air from below. The coarser pieces of ore are now spread over this grating of wood, and a layer of from 8 to 12 inches levelled over it; on this ore fine charcoal, braise, is spread about 2 inches thick. Instead of fine charcoal, mineral coal slack may be used to advantage, or wood chips, or in fact any fuel free of injurious matter, such as sulphur, phosphorus, &c. Ore is now piled again upon this coal, and the operation of laying coal and ore in successive layers repeated until that height of the heap is reached which is calculated to be most advantageous in this particular instance. One inch thick of coal is generally considered sufficient for one foot high of ore, exclusive of the foundation of wood. The ore is broken into uniform sizes, of from 2 to 3 inches thick. Fire is kindled in the lower parts of the heap, which to conduct to advantage requires considerable skill, sagacity, and industry. The chief object in this operation being the dissipation of volatile matter, it is evident that the melting of any particles of the ore is to be prevented, for from such melted ore no degree of heat will separate the injurious matter effectually. The conducting of the degree of heat in the roasting heap is therefore an operation liable to injure the ore instead of benefiting it. Ores which melt readily, such as impure iron ores, silver and lead ores, pyrites of all kinds, require more than common watchfulness to insure success in the operation.

2810.

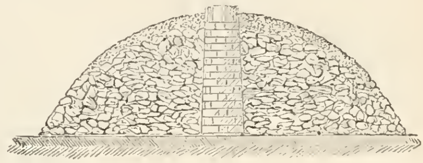
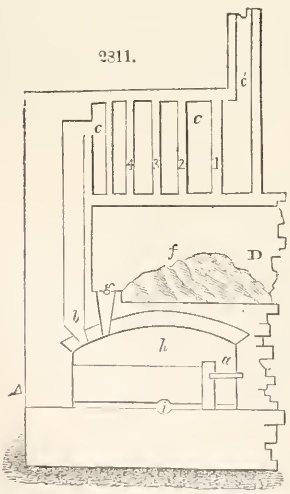
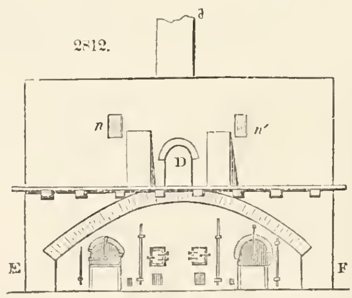


Fig 2811 represents the section of a reverberatory furnace for roasting schliech of lead ore in Germany. These ores contain much sulphuret of zinc, and resemble our silver ores in Virginia and North

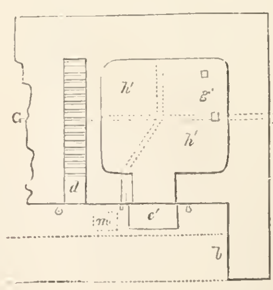
2811.



2812.



2813.



Carolina, for which reasons we allude particularly to this furnace. Fig. 2812 is the drawing of an elevation of that furnace, showing it to be a double furnace; and Fig. 2813 is the plan of half the furnace, or one single furnace. In these several figures, *a* is the furnace or fireplace; *b*, a chimney leading to the condensing chambers *e e*, in which the evaporated metals, as zinc, arsenic, &c., are conducted; *d* is the stack for the escape of the burnt gases and smoke; *e'* is the charging door; *f* the drying chamber for expelling the water from the ore; *g* is the hopper or charging orifice; *h* the hearth of the furnace; *i* channels for the escape of moisture from the ground; *n n'* are openings leading to the condensing chambers. In each of these furnaces nearly half a ton of ore is charged at a time, which takes from 6 to 12 hours work to be roasted; much zinc delays the process. About two thirds of a cord of wood is required to perform one heat. If well constructed and properly managed, these furnaces work exceedingly well, but require a great deal of labor.

As remarked before, roasting ovens are more economical in the use of fuel than heaps in the open air; this advantage, however, is balanced by our having generally cheap fuel. These ovens are liable to do imperfect work; the access of air, which is the chief oxidizing agent, is not so freely admitted as in heaps. In ovens the advantageous access of watery vapors is out of the question, which, as in the case of heaps, are derived from the ground in such quantities and in such conditions as to be most advantageous to the operation. Watery vapors afford in roasting the triple advantage of being a powerful oxidizing element, in the mean time carrying off sulphur in the form of sulphuretted hydrogen, and assisting in keeping the heat more uniform than it can be done without these vapors. The roasting in heaps may be more expensive in some cases; it certainly is more correct in principle than roasting in ovens.

Roasting in reverberatory furnaces may be considered an advantageous operation where sulphur, arsenic, and such volatile matter is to be expelled which cannot well be removed in the yard by roasting in heaps. These furnaces apply particularly where arsenic is to be driven off; but as no arsenical ores are smelted in the Union, there is little use for reverberatory roast-ovens. At the copper smelt-works roasting is done to a certain extent in the reverberatory, but it is not practised in any other instance. This furnace suffers under the same disadvantage as the roast-oven; the work performed by it is expensive, because of the labor it requires to stir and shovel the ore.

Blast machines are auxiliaries in metallurgical operations. We refer to the article on "Iron" for information.

Assay of ores is a very important operation in smelt-works. Assaying is not only performed here to ascertain the quantity of metal contained in the ore; it is employed both for that purpose and for assaying the metal to inquire what kind of metals and how much of each is contained in the samples produced in the smelting-furnace. Assays of gold ores are generally made by pounding the rock, converting it into a very fine powder, and washing the debris of rock away, which latter operation is performed in a sheet-iron pan. The remaining gold, after washing, is either taken up, amalgamated by quicksilver, and the quicksilver expelled by heat, or, if the quantity is large, say one grain or more, it is weighed in its native state. Experienced gold-washers will judge very near correctly how much one bushel of ore will contain in gold by making one or more pan-washes.

Assays for ascertaining the quantity of a certain kind of metal in a specimen of ore, are in this instance chiefly made in the dry way. If an ore is to be assayed for its contents in gold or silver, the ore is finely powdered, sieved, and mixed with its three or fourfold weight of litharge. This litharge must be free from any other metal but lead; the common shop litharge is not quite safe in this respect, and in case a correct assay is required, it is advisable to dry and roast sugar of lead; the litharge derived from it may be considered pure. The fine litharge and fine ore are well mixed, to which a very little carbonate of soda may be added. If not much gold or silver is expected, but little lead is reduced in this process, which is regulated by the quantity of carbon mixed with it. In most cases, half an ounce of lead will contain all the gold and silver in the ore; one grain of charcoal produces 30 grains of lead; if we want, therefore, 240 grains, or one half ounce of lead, we mix 8 grains of fine charcoal powder with the above mixture of ore and litharge. The mixture is put in a dry and warm crucible, covered by a little common salt, and a slab to prevent the falling in of coal, and then exposed to a rapid heat in an air-furnace. One half hour's heat will finish the operation; the crucible is cooled, broken, and the button of lead removed, washed, and cupelled. This button of lead, of half an ounce weight, requires a cupel of half an ounce; better if one ounce. The cupel is a flat crucible, made of bone-ashes, which, when the lead is heated in it, and in the mean time oxidized, it absorbs the oxide of lead, just as a sponge absorbs water; but this cupel will not absorb any metal in the metallic state. Gold and silver have but little affinity for oxygen, and in heating the alloy of lead and other metals, all other metals will be oxidized and absorbed by the cupel, while gold and silver remain in their pure condition. When, in exposing the cupel in a muffle, or in a crucible, to a white heat, all the lead and other metal is oxidized and absorbed, a bright globule of gold or silver, or a mixture of both, remains; in the latter case the globule is analyzed in the humid way, to ascertain the quantity of either metal, gold or silver.

Next to the assays of gold or silver ores, are those of copper. These ores are pounded, roasted, and mixed with from 75 to 100 per cent. of black flux. Black flux is prepared in mixing the powders of equal parts of saltpetre and crude tartar together, heating this mass gently, and stirring it with a red-hot iron; the burnt powder is again pounded, sifted, and kept in a glass stoppered bottle for occasional use. The well pounded and roasted ore is intimately mixed with its flux, put into a crucible, and heated to a bright white heat in the shortest time. The resulting button of copper is broken out of the cooled crucible and washed; it is crude copper, and requires to be refined. This button is pounded in case it is brittle; if not, it is melted in its original form, along with half its weight of black flux, to which a little common salt or saltpetre is added; the first, however, is preferable. While this crucible is melting, another is heated, in which a flux composed of black flux, common salt, and saltpetre, is contained; when the copper is thoroughly melted, and the second crucible hot, the flux melted, the copper is cast from the first into the latter. By these means, metal and flux is mixed without running the risk of losses, which inevitably follow if the crucibles are not shaken, or if they are stirred by an iron rod. If the copper after this second assay is not fine, the process of refining is repeated once more, by which time fine copper is obtained. In this operation, some copper remains always in the scoria; the latter may be gathered together from all the smeltings and melted along with some black flux, which will produce a small button of crude copper; this is added to the first after it is refined, or added by approximating its value in copper. This last grain contains generally a great deal of iron, and looks like iron.

Other ores than those mentioned are commonly not assayed in the smelt-works. Iron, lead, zinc, &c., are of too little value; they cannot bear these expenses. Tin we are not yet smelting, and in so far have no need of assaying it.

Assaying forms a very important branch of the smelting establishment. In this country, owing to the youth of metallurgical operations, most of the smelt-works are connected with the mines; from this rule the copper smelt-works are only excepted. For these reasons, the assay necessary to ascertain the value of ore, in order to establish its price, is not in extensive use. When smelt-works shall be carried on in their proper form, assaying of ore will be more generally executed. At present the assays of ore are only used to ascertain the value of ore specimens, by which assays, as they allude but to a small and in most cases a selected part of the ore, many illusory prices of ore are furnished, which deceive the unwary. All assays made in the dry way are incorrect; they always furnish a smaller amount of metal than the large operation; if, however, the assays are conducted with uniform precision, the loss in each case will be the same, and may be represented by a per-centage of the whole. The second feature of the utility of the dry assay is its affording indications of the amount and nature of the foreign admixtures to the ore: it furnishes a guide to the smelter at the furnace. Experiments as to the mode of smelting an ore to the best advantage, can be made in the crucible with less expense and greater facility than in the smelting furnace. A third advantage arising from the assay laboratory is the analysis of the manufactured metal in respect to its purity and contents of precious metals.

Assay in the humid way.—The chemical analysis of ore, or the assay in the humid way, is not of much practical use to the metallurgist. If this assay is well performed, it furnishes an exact table of the contents of an ore, of slags, and of metals; but it requires more science and experience than commonly is at the disposal of the practical man, to make that use of an analysis which frequently is expected from it. The humid analysis furnishes the facts, the elements for the science of metallurgy; but the application of these facts is subject to more difficulties than at a superficial glance appear: it is moreover a means of inducing young, speculative minds to a waste of time and money which may be better employed than in chemical analysis. This department belongs to the scientific chemist: it is of no use in the smelting-house. There is no doubt but the humid analysis furnishes the most correct estimate of the contents of an ore, slag, and metal, but in all instances it is advisable to verify these results by the dry assay, for there are innumerable instances where the portions of metal obtained in the analysis cannot be yielded by the ore in the most perfect smelting operations. The assay comes nearer to the practical result than the analysis. We cannot deny that the analysis furnishes principles upon which improvements are and may be executed, but these principles and facts are only useful in the hands of a scientific and experienced metallurgist.

The manufacture of metals.—In this part of our labors we shall omit the allusion to iron, because a valuable contribution is furnished under the proper head; we shall further limit ourselves to those metals which are actually manufactured, or are likely to be manufactured in the United States.

Gold.—*Germ.* gold; *Fr.* Or; *Lat.* Aurum. Gold is found almost over the whole globe, but in most cases in small quantities compared with other metals. At the present time California affords the largest amount of this metal in the world. Virginia, North Carolina, South Carolina, Géorgia, and Alabama, in the United States, afford gold in considerable quantity. The production of California amounted in the year 1850 to about $40,000,000 worth of this metal; the other States of the Union together about $2,000,000. Next to the United States, the largest amount of gold is furnished by Russia, from the Ural Mountains. It is found extensively in the South American States, near the Equator, in Africa, Asia, and Europe. Gold is chiefly found in its native condition, in a metallic state, alloyed with silver, and sometimes with tellurium, as is the case in Virginia and North Carolina. In California it is found chiefly in alluvial ground, bedded upon rock in most cases; it is also found inclosed in quartz rock, apparently in veins ramifying the rocks of an extensive mountain range. This California gold is obtained chiefly in large grains, and often in lumps of several pounds weight. In the other States of the Union the gold is in very minute fragments, often invisible to the eye if not aided by a lens, only to be detected by crushing and grinding the rock and washing off the debris. This gold is apparently derived from the decomposition of iron and copper pyrites, chiefly the first; which assertion cannot be objected to, because it is founded in principle that almost all iron pyrites contain gold, that the gold ores of that region are rocks which are colored by iron, and that this iron is evidently derived from the decomposition of the pyrites. Pyritous ores of this kind are worked which contain no visible gold, or which do not yield gold at the first crushing and washing, but which furnish gold in a succession of amalgamations, performed after regular intervals of exposure to the air in a fine powder. Gold is also furnished by the silver ores of North Carolina and Virginia.

A splendid yellow color and brilliant metallic lustre characterizes gold distinctly from other metals; its specific gravity being 19·3 to water, is another quality easily appreciated by the senses. It is preeminently ductile, which qualifies it for an extensive use in the arts. One grain of gold may be drawn into a wire 500 feet long; silver may be coated with gold, of which the thickness is only the twelvemillionth part of an inch, and still the microscope cannot detect the slightest indication of an interruption of the gold coating. Pure gold requires more heat for melting than either silver or copper, but as all native gold is alloyed with some other metal, it may be considered more fusible than those metals. If, in cupelling gold, the hot globule shines with a greenish light, we may consider the gold not much adulterated; if it contains 10 per cent., or from there to one-third of silver, the color of the gold is in the hot cupel white as silver. Pure gold is not very volatile, and may be exposed to a strong heat for a long time without loss of metal; but if gold is alloyed with volatile metal, such as lead, zinc, and antimony, it is liable to be carried off by their vapors. Gold has a considerable cohesion, which inclines it to crystallization. Its crystal form is an octahedron; it is often found in fragments of crystals imbedded in quartz, of which fine specimens are found in California, and also in the gold region of the Southern States. In melting gold along with pure borax it assumes a whitish color, as if adulterated with silver; in melting it again with saltpetre, or common salt, it recovers its rich yellow color.

The geological position of gold is in the primitive rock. It is found in granite, disseminated in grains and spangles through the mass of rock. In the United States gold is chiefly found in the stratified transition series; in California it appears to be disseminated through this rock, imbedded in quartz. Most of the gold, the California gold exclusively, is found in alluvial soil. In the Southern gold region this source is much exhausted, and the gold is here obtained from regular, well-developed veins, running parallel with the general direction of the rock strata, southwest by northeast. The plane of inclination of these veins is also parallel with the plane of inclination of the general formation. It appears from this that the gold-bearing veins are of a simultaneous origin with the rock; at least, they have been introduced when the rock was in a plastic condition. In Virginia and North Carolina the gold-bearing veins are a ferruginous talcose slate, often inclined to mica slate. In North Carolina this slate is found to be very hard in many instances, showing a compact solid mass of rock, apparently the same slate, but having been under the influence of a considerable heat, it is hardened. In Virginia this slate is more soft, the fissures open more readily, and the whole vein shows the appearance of soft slate. This slate is impregnated with small quartz veins, from one-eighth to one-half an inch, and often two inches thick. Where these quartz veins are thin and in great numbers, the ore is always found to be richest in gold. This feature of the ore is well developed throughout Virginia, and at Goldhill, North Carolina. The vein-stone of the gold-bearing veins is strongly impregnated with oxide of iron, showing evidences that this iron is derived from pyrites, because the oxide appears in dots or flowers, and groups of dots. Many of these veins have been traced to that depth where the pyrites are not oxidized; here they appear in their perfect crystal form, and are profusely distributed through the slate. The oxidation of these pyrites appears to depend on the penetrability of the rock by atmospheric agents; where the slate is soft we find it oxidized to the depth of from 50 to 150 feet; where the slate is hard, as is the case at the Sawyer mine, North Carolina, the oxidation reaches hardly ten or twenty feet deep, and is in many places, such as bluffs, not developed at all. At the latter spots the pyrites are in their original form, untouched by oxygen. Where the pyrites are not oxidized the extraction of gold is connected with considerable more expense than it is from soft slate and oxidized pyrites. The crushing of the hard slate is in the first place more expensive; the sulphur of the pyrites destroys a large portion of quicksilver in amalgamation, and the gold cannot be all extracted; the largest portion of it remains inclosed by the sulphuret of iron, which can only be liberated by destroying that envelope.

When we consider the great extension of the Southern gold formation, which is at least 500 miles long; the breadth of the gold-bearing strata in which the veins are imbedded, and which is from 5 to 20 miles wide; further consider the depth of these veins, which may be assumed to be 2000 feet, the body of gold ore in these regions is certainly to be regarded as an important source of national wealth. There is, however, one drawback to the rapid extraction of gold from these deposits—the ores are all, without exception, pyritous in greater depth, and to work these sulphurets to advantage no progress has been made up to this time. Various experiments tending to accomplish this purpose, and affording means of extraction, have been tried, but none of these succeeded so far as to work the poorer class of ores. At Goldhill, N. C., where the ores yield from $1.50 to $3 of gold in 100 pounds or one bushel of ore, the pyritous ores are ground, amalgamated, and a certain portion of gold extracted. The crushed ore, now a fine sand, is exposed to the influence of the atmosphere for one year, after which the process of grinding and amalgamating is repeated, and another portion of gold, almost equal to the first, is extracted. An exposure of another year furnishes another crop of gold, which operation may be repeated four or five times without extracting all the metal from the sand. This way of working is tedious, expensive, and will not answer where the ores yield but 25 cents to the bushel. The process of roasting these ores by artificial fire is too expensive, and all processes which require much labor are out of the question. Here is a promising field for American ingenuity and industry.

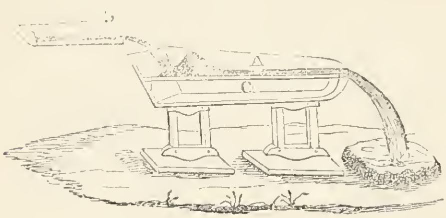
The extraction of gold is performed in California, and also in some parts of the Southern States, simply by washing the alluvial soil, removing the sand, clay, and debris of rock; after these operations the gold, as specifically the heaviest matter, will remain in the vessel in which the washing has been performed. This washing may be done to advantage in a tin pan or a sheet iron pan. Such a pan is filled with sand containing the gold and immersed in water; in stirring it gently by hand the clay and light sand flow off, and, after some of the earthy matter is removed, the pan is shaken so as to bring the heavier gold to the bottom of it; the superstratum of sand is now removed, and the gold found in the bottom of the pan. Where water is abundant, a more effective machine than the pan is employed. This machine is called a rocker. It is represented in Fig. 2814.

This is a machine made of wood, about 6 feet long, 26 inches high, and 16 inches wide in the trough. A is a grating of flat iron bars, set edgeways, leaving an open space of about ½ an inch between each bar. By B a strong current of water is let upon this grating, which flows off at the opposite end of the machine. The machine rests upon two gently curved frames, which admit of a rocking motion upon two planks laid on the ground. This apparatus is set in a rocking motion by a boy, two wooden springs on each side of it limiting that motion, and forcing the rocker back at each vibration. The machine represents in its motion a worn-out cradle, which is used beyond gentle rocking. A laborer supplies the rocker with sand at B, by means of a shovel; the sand which passes through the grating, and also the gold, falls into the trough C, in which quicksilver is kept in case the gold is fine; it forms here an amalgam of gold. The light sand from C is swept off by the water which passes through the grating. The cradle is more or less inclined towards the discharge of the charges, according to the kind of material to be washed. These operations are quite effective; secure, for coarse gold, the fine and floating gold is lost.

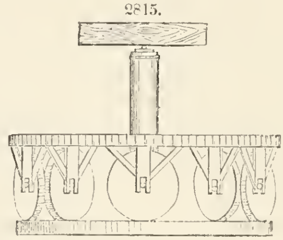
Gold inclosed in rocky matter cannot be washed with success in the foregoing described manner; the rock must be crushed, and is, in this operation, transformed into more or less fine sand. The bulk of this sand is removed by washing, and the rest, with the gold, reserved for amalgamation. The crushing is performed in the stamp-mill, Fig. 2808; the sand, including gold, conducted over hides, which retain the gold, and the sand is floated away. The gold and sand from the hides are removed, when the latter are filled, to an amalgamating machine, which combines the gold with quicksilver, and admits the sand to flow off. Instead of hides, woollen blankets are also used for gathering the gold, and there is a diversity of opinions as to the merits of either. Blankets, it is contended, are more expensive than hides, but they have the advantage of working more uniform. Hides are cheaper, but they lose their hairs or wool very soon, and are then not fit to do good work. Hides of short, curly wool are selected; these are spread on the ground, and over these the water, sand, and gold are led in a broad sheet. In other instances shaking-tables are suspended at the discharge of the stampers, which gather the gold and some sand. Shaking-tables are wooden platforms of 8 or 10 feet long, and from 3 to 4 feet wide, made of 2-inch plank well joined together, and the whole smoothly planed. Around the edges of the table are projecting ribs, which prevent the water from flowing over the edges. In suspending this table, a little inclined to the horizontal, leading the sand and water over it in a broad sheet, and applying a gentle shaking motion to it, the gold will sink to the bottom and move gently down the plane; it is arrested at the lowest end of the table by a projection on the table. In either of the above cases the gold is brought to the amalgamating machine for amalgamation.

Most of the gold-mining establishments are provided with Chilian mills for crushing the ore. We furnish a description of it in its simplest form in Fig. 2808, in which form most of these machines are erected. Still, there are some machines of this kind in North Carolina, which work by four or five runners or crushers in one trough.

2814.

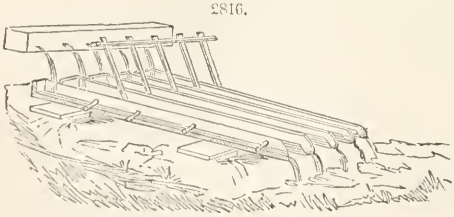


2815.

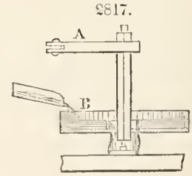


In Fig. 2815 is such a machine represented as it is in operation at Goldhill. It is a cast-iron circular trough of about 16 feet diameter, 10 inches wide, and 6 inches deep; the trough is firmly fixed upon the floor of the mill. In this trough five travellers or head-stones are moving, of 3 feet diameter and 6 inches thick, rounded on the edge, made of cast-iron. These travellers are fixed to the revolving-shaft in the centre, and are moved by it. The circular trough is supplied with coarsely broken ore and a constant current of water, which latter washes off all the light impurities, and leaves the gold in the trough. At the close of every day's work the trough is supplied with some quicksilver, which is worked in it for $\frac{1}{4}$ or $\frac{1}{2}$ hour's time, in which time it absorbs the gold, and is then removed as amalgam. The water from these mills is generally conducted into other machines, in which some of the fine gold which passes from the first machine is gathered. In most cases a shallow round basin, of about 4 feet diameter, is appended, in which a rake moves around with a vertical axis, gently stirring the sediment which may settle from the passing water. It retains only the heavy particles. In other instances, Sullivan bowls (a small machine which derived its name from the inventor, residing in North Carolina) are appended; these gather the heavy parts which may escape the previous machines.

2816.



2817.



A Sullivan bowl is represented in Fig. 2817. A vertical wooden shaft of about 18 inches long and 2 inches square carries on the lower part a shallow vessel or bowl B, about 2 inches deep and 18 inches in diameter. This bowl is formed of a wooden bottom and sheet-iron periphery. This bowl receives the water from the other machines at or near its circumference, and discharges at the centre. By the lever A, the machine is set in a rocking motion, caused by a crank connected with the same. This machine gathers a great deal of fine gold, but it is an expensive machine, because they work but little water, and it requires many machines to do the work of a small establishment.

The gold from the various machines, mixed with some sand and other impurities, is carried to the Chilian mill for amalgamation, in case there is no other machine for doing that work. This is an imperfect machine for amalgamation, and causes losses in quicksilver and gold. In most cases separate machines are used for amalgamation; in North Carolina the cradle is generally employed. The cradle is made from the trunk of a tree, hollowed out so as to form a round trough, closed at one end and open at the other, as represented in Fig. 2816.

Here is a battery of 5 cradles represented: as many as that are frequently connected and moved by a little boy. A cradle is from 10 to 12 feet long, hollowed out of a trunk of at least 24 inches diameter. The bottom part is thicker than the sides. The first cradle in the drawing shows a section. We see here three or more grooves carved in the bottom; in each of these grooves from 3 to 4 pounds of quick-silver are put. At the farthest end sand is shovelled in and water led upon it, the cradles being a little inclined towards the discharge. A gentle current of water will have a tendency to wash sand and every thing else down the trough, the trough being, in the mean time, in a rocking motion, which assists the water in washing off every thing. The quick-silver in the grooves is also in constant motion, by which the heavy granules of gold gliding down on the bottom are arrested by it, while the lighter matters, as sand, &c., are not attracted, and pass over the mercury. These machines are very effective, but work slow, and lose much of the fine suspended gold. Other amalgamating machines have recently been put in operation; their efficacy is, however, not settled, and we hesitate to describe them. In North Carolina the German barrel amalgamation has been introduced within a few months, but we are not informed of the results. In Virginia, amalgamating machines of novel patterns have been tried, but we are not acquainted with their effects.

All amalgamating machines suffer under a common evil,—they cannot work all the water as it issues from the crushing machines to advantage. In all instances half the golden contents of the ore are lost. This is owing partly to the clayish condition of the ore, which clay incloses particles of gold and carries it off, and partly to the extreme division of the gold in the ores of these regions, particularly in North Carolina. This minute division causes the gold to be suspended in water, and in that condition it is carried away by the current. A good amalgamating apparatus, which will work the water directly from the crushing machines, rub off clay and other matter from the particles of gold, so as to make it adhere to the quicksilver, and which does not lose any quicksilver, is still a desideratum in the Southern gold-mining districts.

Gold, gathered by quicksilver, forms a white amalgam. In the amalgamating machines a surplus of quick-silver is used to secure the fluidity of the mercury; for if it gets slimy, or still worse, plastic, like clay, it will not absorb any more gold with facility. The fluid amalgam is pressed through a soft leather or a piece of close canvas, to remove the superfluous mercury; after which a solid amalgam, called quick, remains in the bag. The quicksilver which passes through the bag retains always some gold in solution, the quantity of which varies according to the stuff through which it has been squeezed. The amalgam thus obtained contains from 30 to 70 per cent. of gold, according to the mode of working and the quality of the ore. The quick from the Chilian mills generally contains but from 30 to 40 per cent. of gold, while that from stampers contains seldom less than 40, and in most cases from 50 to 60 per cent. of gold. This circumstance appears to speak in favor of the stamps; the difference in the contents of gold, in the amalgam, is owing to its division; the finer the gold the less of it the amalgam contains. The dry amalgam is distilled in an iron retort, lined with clay; a red heat will drive off the mercury, which is condensed by leading it into cold water. The gold remains in the retort in the form of a powder, which is collected, melted in a crucible along with some saltpetre, and cast into iron moulds, forming square bars of about one pound weight each. One pennyweight of gold of the Virginia mines is generally worth from 90 to 92 cents. North Carolina gold contains more silver than the first, and a pennyweight is seldom more than 90, and in the majority of cases, from 80 to 90 cents to the pennyweight. California gold ranges from 75 to 90 cents.

In Virginia and North Carolina gold ores are mined, crushed, and amalgamated, which yield but the 150,000th part of gold to the bulk of ore, and these ores are worked with profit. The Russel Mining Co, in North Carolina, which operates 12 or more Chilian mills, works ore which yields 10 cents of gold to the bushel, or 100 pounds of ore, with profit. The Louisa Mining Co, which employs stampers for crushing, shows that ores which yield 7 cents in the bushel may be worked, and pay expenses and profit. There are inexhaustible stores of gold ores in the Southern States; it requires nothing but industry to make its production profitable.

Silver.—Argent, *Fr.*; silber, *Germ.*; argentum, *Lat.* Native silver is frequently found; it appears crystallized, but chiefly in irregular concretions, often in the form of fine hairs. Generally it is combined, or alloyed, with gold, quicksilver, antimony, arsenic. It appears as sulphuret in connection with the sulphurets of most other metals.

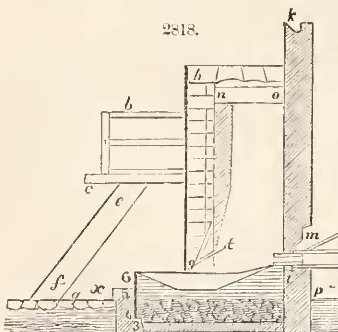
Pure silver is the brightest of the metals, of a beautiful white color and rich lustre. Its specific gravity is 10·47. It is a little more fusible than gold, but in practice we find generally the reverse, which is owing to the alloys of the two metals, which have a more softening influence upon gold than upon silver. Silver is exceedingly malleable, but not so much as gold; it crystallizes very readily when exposed for some time to the influence of heat in a melted state, but not so when alloyed to other metals. This latter quality of silver has been made available in practice, in refining lead for silver. If silver bearing lead is exposed to a melting heat, the silver will not crystallize along with some lead. Lead crystallizes more readily in this case, and these crystals may be removed from the fluid mass by an iron dipper pierced with small holes. The crystals of lead, thus freed from the largest part of their silver, are melted and converted into pigs and sold. After repeated melting and crystallization, the remaining fluid is rich in silver, and is now refined in the common way.

Silver ores are of great variety: there is antimonial silver, found in Mexico and Europe; sulphuret of silver, almost everywhere; also the mixtures of sulphuret of silver, with other metallic sulphurets; chloride, carbonate, and tellurate of silver are curiosities of little practical value. Most of the silver, and in the United States exclusively, is derived from the sulphuret of lead, from galena. In the Union we have but one establishment which manufactures silver to some extent; it is the Washington Mining Co., in North Carolina. As the production of silver from its ore is generally conducted on the same principles, and as the operation at the Washington mine may be considered one of the most difficult cases, on account of the composition of its ore, we will describe the operation in this instance.

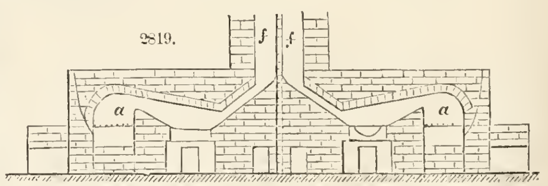
The ore at this establishment consists chiefly of brown sulphuret of zinc, which is largely mixed with galena, copper, and iron pyrites; it contains silver, gold, and other metals. The ore as it comes from the mine is broken into coarse fragments, and roasted in heaps in the open air, in the manner described before. The roasting is performed altogether by wood and wood charcoal. After the first roasting the piles are picked over for such ore which is well roasted, and that which is too much roasted. This is brought to the stampers, crushed into a fine powder, and washed, so as to carry off all the oxidized zinc and quartz. If the ore, after its being crushed, is found to be imperfectly roasted, it is returned to the yard and once more subjected to roasting. That part of the ore which is rejected in the yard is piled and roasted along with some fresh ore from the mine. In this way it may happen that some of the ore is exposed to several heats. The roasting operation is not considered to be finished until all the sulphuret of zinc is destroyed; that is, until the zinc is deprived of its sulphur and converted into oxide of zinc, in which form it may be washed away by the water at the stamping-mill.

The finely powdered ore consists now chiefly of galena, or, in case the roasting operation is well performed, of oxide of lead, oxide of iron, oxide of copper, silver, and other matter. This ore is brought to the smelting-furnace, called a high-furnace, and here smelted along with some fluxes by charcoal. In Fig. 2818 such a furnace is represented; it is a solid work of masonry, calculated to retain its heat if once thoroughly heated. The fire is urged by cylinder bellows, driven by a steam-engine; the air to the furnace is supplied at the tuyere *m*. In consequence of the alternate charges of coal and ore, the basin or hearth *g* is regularly supplied with metal, which is removed at certain intervals of time, so as to afford room for fresh metal and cinder. In this manner about one ton of lead is obtained in 12 hours, which is removed and put aside for refining. The composition of the ore, which makes its perfect roasting difficult, renders it necessary to make large additions of iron ore to the posts of ore. The iron oxide, which is reduced in presence of carbon in the furnace, will absorb the sulphur from the other metals in case there is any sulphur left after roasting. This circumstance renders the operation tedious and slow. It cannot be avoided but by perfect roasting, which may be considered practically impossible in this instance. The presence of zinc is what renders the operation tedious and expensive. If the zinc is not removed to a large extent, it will, in smelting the ore, carry off by evaporation much of the other metals, gold and silver not excepted. The sulphurets of zinc and lead are very fusible if in contact. In roasting the ore these two sulphurets will invariably melt together, which causes the roasting process to be either very expensive or imperfect. All experience with a similar ore in other parts of the world are confirmatory as to this operation being expensive.

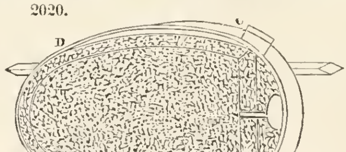
2818.



2819.



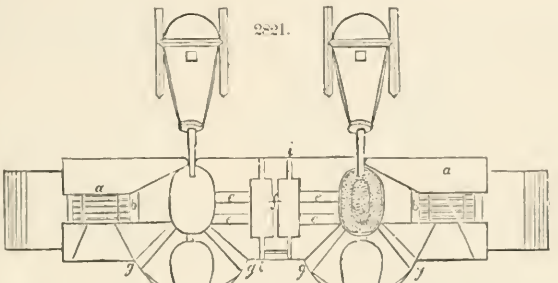
2020.



The lead from these blast-furnaces is transferred to the refining-furnace. Formerly the English refining-furnace was used as it is represented in Fig. 2819, in a longitudinal section. Here is a double, or two furnaces represented, which, as is shown, are reverberatory furnaces. The fireplace *a* throws the flame over the hearth or cupel into a chimney, which is provided with a sliding door at *f f* to shut off the draft and prevent the fumes of metal from escaping through the stack. The cupel is formed of several layers of bone-ashes, mixed with wood-ashes; this mass is rammed into an iron hoop when in a moistened condition. The form of this cupel is represented in Fig. 2820; from above it is a concave egg-shaped dish, of about 5 inches thick, the largest diameter being 4 feet, the smallest 2 feet. When the furnace and cupel are heated, the lead, previously melted in an iron pot, is cast into it; and now the bellows, which are represented in Fig. 2821, are set to work, a gentle current of air is thrown over the hot surface. The action of the blast is here twofold: it oxidizes the lead and forms litharge of it, and drives by its force the melted litharge to the opposite side of the blast, or the tap-hole, where it flows out and falls into an iron basin, from whence it is carried back to the smelting-furnace. The level of the lead is in this way gradually reduced if not kept up to a certain height; this is done by casting in melted lead, which is always ready melted in an iron pot. This process is carried on until a certain quantity of lead has been concentrated so far that a little more than one weight of lead is combined with an equal weight of silver; this rich lead is taken out and refined in a properly prepared cupel. If sufficient rich lead is ready to make from 500 to 1000 ounces of silver, it is refined in a new cupel, and the silver melted into a cake. The operation is carried on as before, with the only difference, that no fresh lead is added.

The Washington mine has more recently introduced the German refining-furnace represented in Fig. 2822, with what success we are not aware. This furnace is larger than the above English furnace, the cupel being at least 6 feet diameter. The drawing shows a section of the furnace, in which the fire-place *y*, the tuyeres *n n*, and the door *q*, into which the lead is charged, are shown. In Fig. 2823 is a ground plan of the furnace shown. Here is the flue *x* visible, which leads to the stack, and which serves in the mean time to clear off from the surface of the melted lead some of the scum. The cupel of this furnace is made entirely of wood-ashes, which are the refuse ashes from the soap-works, and in this respect the furnace has an advantage over the English furnace. The floor or hollow surface of it is well pounded by wooden mallets, to make it solid and smooth. About four tons of lead are charged for one heat; it is carefully laid upon the bottom, and at first gently heated, so as not to injure the fresh bottom

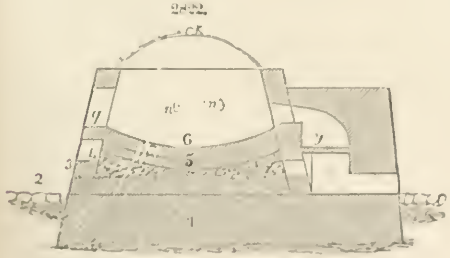
2821.



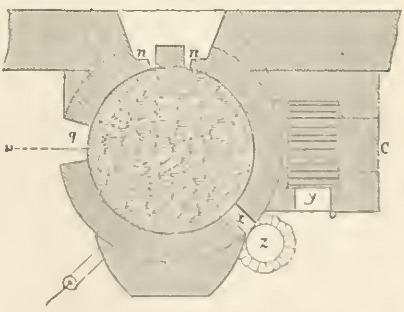
and dome. When the lead is melted, and all ebullition ceases, the blast is thrown in at the tuyeres *n n* by setting the bellows at playing on the surface of the melted metal. At first no litharge is made, but a dirty froth of oxydized metals is raked off, to facilitate which formation of froth, fine charcoal dust is thrown on the surface. When all the impurities of the lead are removed in this way, the formation of litharge begins, which flows off at the flue *x*. The separation of the litharge from the lead must be assisted by a hook, because the blast is generally not strong enough to move the fluid oxide of lead over the large surface of the molten mass. The cupellation of four tons of metal lasts from 18 to 20 hours. Towards the end of the operation some silver is carried off with the litharge, which portion of litharge is therefore carefully preserved, to be remelted by itself or along with other ore. The silver is, in this operation, obtained pure in the first heat; it is melted into the form of a cake in a cavity prepared for its reception in the centre of the hearth.

In all these refining operations there is an inevitable loss of metal, disappearing in the form of fumes, through the chimney. This loss is variable, and may be modified by the skill of the workman and the purity of the lead; it amounts on an average to from 4 to 7 per cent. of the lead melted.

2822.



2823.



The extraction of silver from its ores by amalgamation is not practised in the United States; this process requires rich ores and cheap quicksilver. In the old States of the Union there is no prospect of seeing this process executed; but in California, where rich silver ores and mercury ores abound, there may be a probability of its being executed; still it is a tedious, expensive operation, which, at the rate of wages paid in the United States, will not yield much profit. Amalgamation is a process not adapted to our social condition; it is too laborious to secure success in ordinary cases of common or average ore. For these reasons we do not furnish a description of this operation. In our condition there is no way of working silver ores profitably but by smelting the ore and refining the lead; or, in some instances, the new process introduced last year into European establishments may answer our purposes.

Some of the silver smelt works of Germany have been in a condition of working poor ores, which in many instances, have not covered the expenses of smelting or amalgamation, which must be extreme cases, considering German industry and perseverance. A process has been introduced within a short time, which promises to advance the interest of the metallurgy of silver greatly. The operation is as follows. Silver ores which may be poor or contain more or less silver, are coarsely broken or stamped, and then carried to a reverberatory furnace; here the ore is heated to redness, calcined, and in that state from 2 to 5 per cent. of common salt is added to the ore; the whole kept in that degree of heat, and stirred by iron bars for some hours. The object of this operation is to transform the silver contained in the ore into chloride of silver, which is so much more easy, as silver has a predominating affinity for chlorine. If the operation of heating is perfected, the red-hot ore is drawn from the furnace and thrown hot into a boiling concentrated solution of common salt. The hot salt solution will dissolve the chloride of silver, and it is kept in solution so long as that solution is boiling-hot; it is therefore necessary to filtrate it in this condition. To the hot and filtrated solution a little muriatic acid is added, and then some coarse pieces of crude copper; which latter precipitates all the silver in a metallic state, in the form of a fine powder: this is gathered and melted in a crucible; it is pure silver. This process is, to all appearances, simple, and is in fact so; but it requires an expert chemist to execute the operation. If there is only copper, iron, and silver present in the ore, the operation is simple; but if there is gold, lead, or quicksilver in the ore, the case is not so easily managed; for the gold will not pass with the silver into the solution, and the chlorides of lead and quicksilver, which are soluble in the same manner as chloride of silver, are precipitated by the same means. The application of this process to our Southern ores is difficult, but it may be an extremely useful process in applying it to the argentiferous stamp-work of the Lake Superior copper ores.

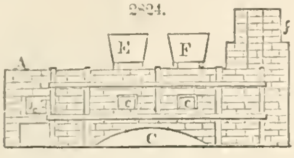
The silver ores of the Southern gold region, such as are smelted at the Washington mines, yield from 200 ounces to 300 ounces of silver in a ton of lead; the ore itself contains on an average 8 per cent. of lead; the other matter is zinc, iron, copper, tin, and chiefly sulphur. The silver is worth $1.80 the ounce, because it is alloyed with a large portion of gold, which raises its value to double the value of pure silver.

Copper.—Germ. Kupfer; *Fr.* Cuivre; *Lat.* Cuprum. Copper was known to the ancients long before iron; most of the metallic instruments of the era preceding ours were made of copper, alloyed with tin and other metals. The ancient nations on the old continent, as well as the inhabitants of America before European invasion, understood the art of hardening copper as well as we now understand hardening steel. This art is now lost, and we doubt its utility if it were recovered. Copper is profusely distributed all over the globe; its ores are found everywhere. Native copper is particularly found in this country and in Russia. The ores of copper are chiefly sulphurets, of which the yellow sulphuret, or copper pyrites, forms nine-tenths of all the ore used in the smelt-works. Besides this ore, there is the gray sulphuret; there are carbonates, arseniates, phosphates, silicates, oxides of copper, and others; all these ores are of more interest to the mineralogist than to the metallurgist. The bulk of ore, particularly in this country, are the yellow pyrites; besides which, the native copper forms an important source of metal to the smelter. The whole amount of copper produced in the world annually is about 33,000 tons, of which Europe produces 25,000 tons; the rest is American copper.

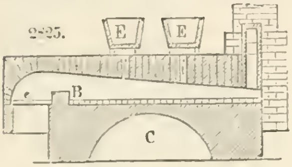
In the United States there are four large copper smelt-works, and some smaller. At Boston, New York, Baltimore, and Pittsburg are smelt-works, working on the English plan; smaller furnaces are in Missouri, Wisconsin, and Michigan. At present most of the smelt-works are stopped for want of ore. If all the furnaces in the Union could be kept in operation, we should produce more copper than we want, and have some for export; for the smelt-works have a capacity of 18,000 tons. The works along the Atlantic coast depend chiefly upon ores from Cuba; Pittsburg and Boston are supplied from Lake Superior. All the States along the Atlantic coast furnish copper ores, but there must be causes which prevent a regular supply to the smelt-works. Our ores are not particularly rich, still there are mines in New Jersey, Pennsylvania, Virginia, and all the Southern States, which will pay handsomely if carried on properly. There is a deposit of native copper in Virginia which will furnish stamp-work equal to Lake Superior. The chief difficulty in our copper-mining business is, that some of these mines have been carried on by ignorant persons; in other cases, swindlers have abused the confidence of the community. If copper-mining in either of the Atlantic States is carried on with discrimination, industry, and not over-sanguine expectations, there is no doubt as to its being a safe and paying business. Many of our copper mines would be, and could be carried on by farmers, or the owners of the soil, if their knowledge of mining and preparation or concentration of the ore were sufficient to make the operation profitable. In these respects the smelt-works can assist a great deal in developing the resources of the country, if they will furnish such instructions to the owners of the mines as will facilitate their operation; for it must be presumed the smelt-works are more qualified to furnish practical information on that subject than any other person or persons can do. Ores do not come now on consignment, because the owner of the ore does not like to run the risk of a sale which appears to him arbitrary. Our Atlantic smelt-works have to exert themselves in developing the sources of ore, and export copper, or they are to stop operations. Lake Superior promises to furnish 6000 tons of copper this year; this will supply nearly the demand of the Union; there is, therefore, little or no choice for the Atlantic works, but to smelt for export. Here are means, that is, ore and fuel, to go into competition with Europe: it requires some industry to make these means available.

The smelting of copper ores in all of our smelt-works is carried on in furnaces resembling the English furnaces at Swansea. The operation of smelting is also similar to the English process, all of which elaborate descriptions are furnished in Ure's Dictionary of Manufactures and Mines. The operation of smelting is divided chiefly into preparing, or washing and crushing of the ore, calcining, smelting and refining. The washing of these ores is performed at the mines, and also the crushing or concentration, and does not differ from similar operations performed on other ores. The furnaces used in the various operations at the smelt-works are all of the reverberatory kind, and fired by bituminous coal, or by wood. Fig. 2824 shows a calcining-furnace in elevation, Fig. 2825 the same furnace in section, and Fig. 2827 shows the ground-plan of the furnace. A is the fire-place, B is the hearth, C an arch into which the ore is drawn; E E are stationary hoppers, or feeders, and *b b b b* four work-doors. The ore in this calcining operation is not fused; it is heated merely to such a degree of heat as will evaporate sulphur and arsenic, and oxidize the metallic ores. These calcined ores are exposed to a second heat, either in the same furnace, or, as in most cases, in a separate or smelting-furnace. Such a furnace is represented in Figs. 2832, 2833, showing the plan and section of it; here A B is the hearth, C the fire-place, L the hopper, and K M a receiving-pot filled with water, in which the copper is granulated. In the second operation, or smelting, some copper is produced along with the matt or slag, which is separated and treated in a peculiar way. The matt, which contains but little copper, is returned to the calcined ore, and smelted along with it. In this operation fluxes are added in case the ore does not contain sufficient flux for smelting. Iron forms the best flux, and for these reasons: copper pyrites, which always contain more or less iron pyrites, are the most profitable ores in the smelting operation. Other fluxes are the metallic oxides of manganese, lead and tin, besides which, lime, fluor-spar, or other fluxes are used.

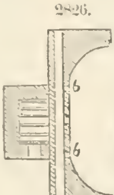
2834.



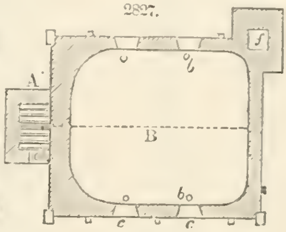
2835.



2836.



2837.



The copper obtained in the first smelting operation is impure, and classes not higher than a rich matt or melted ore; its granules consist of copper, iron, sulphur, &c. This matt or coarse metal is once more calcined in the calcining-furnace, and then subjected to another smelting, by which operation a more refined metal is obtained. The latter product is, however, not yet fine copper; it is matt, which contains 60 per cent. of copper; it is granulated and roasted as before, and once more smelted, by which a richer matt is obtained. These alternate operations of roasting and smelting are repeated from seven to eight times before fine copper is obtained. The cause of this delay, or repetition of calcining, is found in the great affinity of copper for sulphur and arsenic, which it requires repeated fire and cooling to expel successfully.

The refining of copper is done in the smelting-furnace, or a refining-furnace kept for the purpose. The melting of the pigs is conducted slowly, so as to calcine the copper, in case any impurities are left in the fine copper. When the copper is melted, its surface is covered by finely broken charcoal, which operation is repeated as the charcoal consumes. This refining process lasts for 20 hours, and longer, for one heat of from 8 to 9 tons, after which time the copper is ladled out by means of iron ladles coated with clay.

The Germans, and all other European nations, also the new copper smelt-works in Baltimore, smelt their copper ores in furnaces similar to those represented in Figs. 2828 to 2831. The operation is similar to that of smelting lead, silver, or iron ores. In these furnaces, which are about 15 feet high, and 3 feet wide, are two tuyeres C C, and a cinder tap-hole in the line G H. The copper is tapped into the basin *i*, where it is chilled on the surface and forms rosettes, or it is cast into pigs for refining. The latter process is performed in reverberatory furnaces, similar to those described.

The native copper occurring at Lake Superior, in Virginia, and elsewhere, contains a large portion of silver, which at present is lost; to extract this silver by liquation is expensive, and injurious to the quality of the metal; to do it by amalgamation is expensive, and hardly would pay the trouble. There are, however, ores which contain more than one per cent. of silver to the copper, and we may assume the whole body of copper contains the half of one per cent.; this would amount, on the 6000 tons of Lake Superior copper to be furnished this year, to at least $60,000 worth of silver, which silver is now entirely lost. We recommend for the extraction of this silver the process alluded to above.

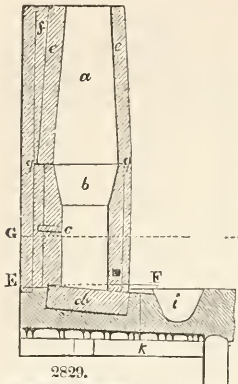
Copper is one of the most useful metals, particularly in its alloys with tin, zinc, and other metals. The native metal is frequently found to be crystallized in concrete, irregular masses, ramifying the rock in which it is found, it is also found in grains, disseminated through the rock. It is less fusible than silver, of a specific gravity of 8·91. It is highly tenacious, and its fracture fibrous.

Lead.—Germ. Blei; *Fr.* Plomb; *Lat.* Plumbum. This metal is, like gold, silver, and copper, known since time immemorial. It is one of the metals the most easily obtained from its ores. The chief ore from which lead is smelted is galena or sulphuret of lead, which contains when pure 86·66 parts of metal, and the remainder sulphur. The United States and Spain are at present the contending parties in the lead market, and there is a prospect of our final supremacy. The amount of lead manufactured throughout the world may be about 100,000 tons annually, of which our Mississippi lead region furnished last year 20,000 tons, Spain 31,000 tons, and England 39,000 tons.

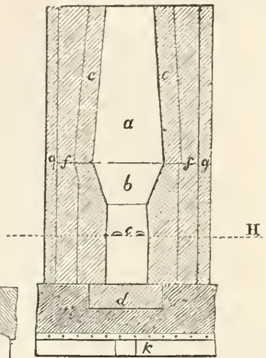
The metallurgy of lead is very simple, particularly in this country, where an abundance of good galena is found, as in Missouri, Iowa, Illinois, Arkansas, Virginia, California, and more or less in all the States of the Union. Very little or no lead is smelted from other ores but galena. In the Northwestern States, Illinois, Wisconsin, and Missouri, are the principal lead smelt works; the operation as it is conducted in these places is very much the same as in other parts of the Union.

Lead is smelted in the above-named States in reverberatory furnaces and in blast furnaces. The reverberatory furnaces resemble those in which copper is smelted, of which Figs. 2832, 2833, show a vertical and horizontal section. About one ton of ore, along with one ton of slag from the previous heats, forms one charge. The whole is thoroughly heated by closed doors and suffocated combustion, so as to produce carbonic oxide gas in the furnace, for reducing as much lead from the slags and ore as possible. When in this way most of the lead is extracted, the doors of the furnace are opened, more heat is given, and the mass, ore and slags, thoroughly melted, with the addition of some pure quick-lime, which is occasionally thrown into the melting mass, and well stirred along with the ore. Most of the lead is yielded by the ore in this operation, still there is more than 25 per cent. of it lost in the slags; these are resmelted in a blast-furnace. Reverberatory furnaces are heated by dry wood, and produce in 24 hours from three to four tons of metal.

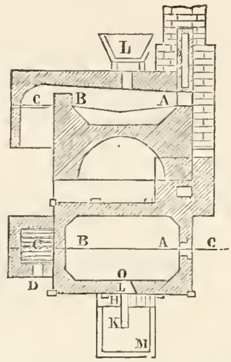
2828.



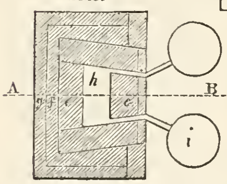
2830.



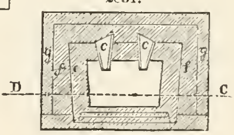
2832.



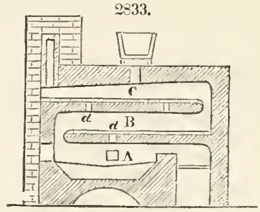
2829.



2831.



2833.



More general than the foregoing are the blast-furnaces for smelting lead. These are furnaces resembling a cupola in which iron is smelted, more than any thing else; they are generally built in a rough manner in appearance, but the inside of the furnace coincides with a cupola; it is generally from six to eight feet high; the blast is introduced by the nozzle *h* to the tuyere *y*. The lead, in gathering in the bottom *f*, is frequently tapped, so as to have but little metal in the furnace at a time. The cinder, or slag, is kept as high as the tuyere, and if it reaches too high some of it is tapped at a tap-hole in the front of the furnace. One blast-furnace will produce in 24 hours about two tons of lead, for which it consumes 6000 lbs. of galena, 25 bushels of charcoal, and about a quarter of a cord of wood. In this operation, as in the reverberatory, a great deal of metal is lost, which in most cases amounts to 20 per cent. or more. The slags contain most of this loss, still a large portion of it is destroyed by evaporation. The blast-furnace has the advantage over the reverberatory so far as regards economy, but it does not furnish so much metal in the same time as the latter.

The slags from the blast-furnace, the reverberatory, and the slags from the old Scotch furnaces, now no longer in use, are gathered, broken into coarse lumps of about two inches, and are then subjected to another smelting in the slag-furnace. The slag-furnace is similar to the above blast-furnace, but it is lower; its extreme height is only four feet, and in many instances it is only three feet high. The slags are here smelted by charcoal, with the addition of some lime and iron ore, by which about two-thirds of the lead contained in the slags is obtained; one-third of the metal in the slags, or 10 per cent. of the ore, is therefore irrecoverably lost. These furnaces are the same in principle as that represented in the above drawing; the work in it differs somewhat from the smelting of ore. The lead and slags flow here continually, the first into a basin nearest the tap-hole in which it gathers; the latter flows from this basin into a somewhat distant reservoir of water, where it is cooled and thrown away. A slag-furnace will smelt in 24 hours about two tons of metal; this, however, depends upon the richness of the slags; it will make more if the slags are rich, and will make less if poor.

The conditions of the lead business are not very encouraging at present; the profits are so small that the smelting of lead is reduced to an occupation which hardly pays the trouble of carrying it on. If an Illinois smelter, who carries on one furnace, can make ten dollars a day, he does very well. When we consider the risk of bad debts, accidents, and stoppages for want of ore or hands, we find that the smelting of lead pays worse than any other trade.

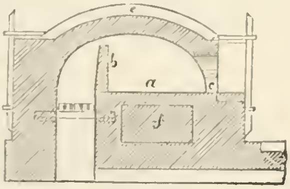
Zinc.—This metal was known to the ancients, who melted oxide of zinc, called galmei by the Germans, together with copper, and formed brass of it. A similar process is performed with the red oxide of zinc in New Jersey. The Chinese have known this process longer than historical reports reach. The most abundant ores of zinc are the sulphurets, blende; these are found in Virginia and North Carolina in inexhaustible quantities, along with galena, silver, and the sulphurets of iron and copper. Another ore is the oxide of zinc, calamine, which is combined with carbonic acid, or silex, or both of these matters. Large deposits of this kind of ore are found in New Jersey, Pennsylvania, and some of it along the northwestern lakes.

Zinc is a brittle metal, of a bluish white color and considerable lustre; it is soon tarnished with an insoluble coating of protoxide of zinc. Its fracture is crystalline and short, and its malleability not remarkable. American zinc, manufactured by the New Jersey Company, is remarkable for its tenacity. Fine wires may be drawn of it, which possess great strength, a beautiful silvery lustre, and fine appearance. The specific gravity of zinc is 6·9 to 7·3; it melts at about 700°, and soon burns with a bluish-white light, forming bright white flowers of zinc, a flocculent matter resembling cotton-wool, or snow-flakes—it is oxide of zinc.

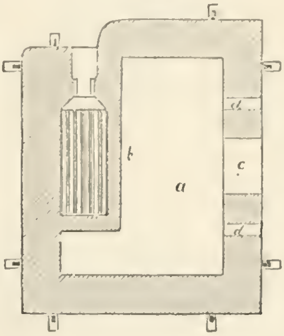
In the United States not much zinc is manufactured in its metallic state at present; the low price of the European zinc will not admit of working our own ores. Some zinc is manufactured in New Jersey, but the quantity is small in comparison to that imported. Considerable use, however, is made of the red oxide for the manufacture of brass. An important business could be done in the Southern States by working the silver blende for zinc, and extracting the silver in the mean time, either before or after the zinc is manufactured from it. The Silesian process of working zinc ore is the best adapted for working this kind of ore, for which reason we shall describe this operation in preference to other processes.

The ore, in this operation, is roasted in a reverberatory furnace, similar to that in which copper ores are roasted, and which have been represented before. After the ore is well roasted, which operation is tedious on sulphurets, it is mixed with an equal volume of culm, that is, bituminous coal-slack, and some small charcoal, in case the ore is fine, to make the mixture porous. The roasted ore, well mixed with its ingredients, is now introduced in lots of 50 pounds of ore into a muffle, which is carefully made of good fire-clay, such clay as fire-bricks are made of—the Mt. Savage, Maryland, and Johnstown, Pa., clay is, for this purpose, the best. Muffles are round pipes; they must be slowly dried, and are then baked in a particular furnace. They are, when red hot, inserted into the reducing-furnace, which is a reverberatory, shown in section in Fig. 2834, and in plan in Fig. 2835. A range of muffles is laid on the

2834.



2835.



hearth, *a*, of the furnace, reaching to the fire-bridge, *b*, their mouth extending to *c*. The muffles are closed by a clay slab at the mouth, in which there are two openings, one at the bottom for the charge and discharge of the ore, and one at the top for inserting an iron pipe which is to conduct the vapors of the distilled zinc to the condensing vessel. The vapors of zinc are conducted into cold water, in which it condenses and forms grains; these are afterwards remelted in an iron pot. One reverberatory contains five muffles, and a double furnace ten. To produce one ton of metal, 10, and from that to 12, tons of bituminous coal are consumed, and one muffle will last for making nearly one ton and a half of zinc.

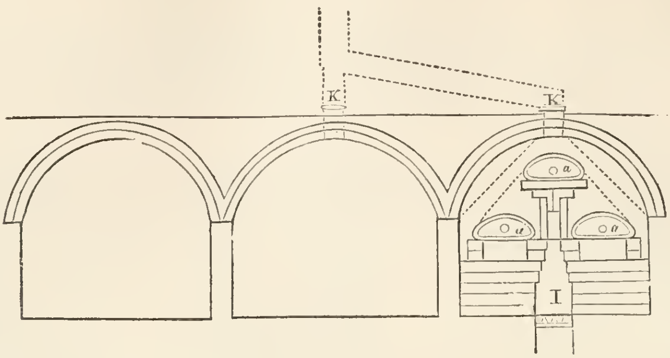
Zinc is a useful metal, if it can be obtained at reasonable prices; it is indispensable in the chemical laboratory, and is very useful in architecture for roofing and for ornaments. Its most important application is, however, in combination with copper, as brass, of which a great variety of shades of the yellow color are produced.

Mercury.—Syn., quick-silver; *Germ.*, quecksilber; *Lat.*, hydrargyrum, has been known from early historical times. The most important mines used to be, and are still, in Spain; besides which, mercury is made in Idria and Western Germany, in Mexico and California. This subject is of more importance to the United States, since the acquisition of California, than it was previous to that time; not only in respect to the manufacture of the metal itself, but in its relation to the gold and silver ores. The quicksilver mines of California had been worked before its annexation, but these mines never attracted so much attention as they have done since that country became a part of the Union. The principal mines in California are the Guadalupe and the New Almadan mines, which are some miles distant from each other, and not far in the interior of the country. The ore in these places is a beautiful sulphuret, cinnabar, of a bright, fiery red color, and yields from 60 to 70 per cent. of mercury. The successful operation of these mines, and a reduction of the price of quicksilver in consequence, is an important object to the silver mines of California, Mexico, and, in fact, to all the silver mines along the Pacific coast.

The extraction of quicksilver from its ores is a very simple operation; but, as economy is desirable in all operations of this kind, we will describe the most perfect apparatus invented for this kind of work—it is that constructed by Dr. Andrew Ure for a European establishment of this kind.

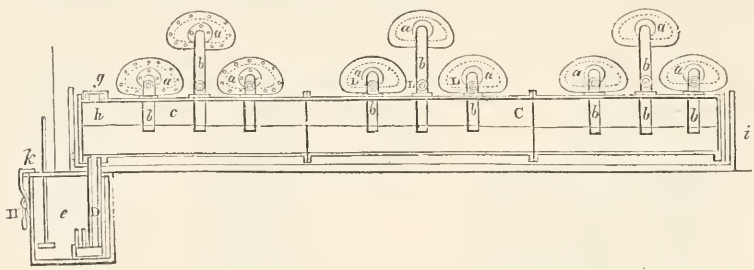
Fig. 2836 shows a section of a furnace parallel with the front elevation represented in Fig. 2837 *a a a* are iron retorts; the whole furnace contains 9 of them. I is the fireplace, designed either for coal or wood. The upper retort is protected against the direct contact of the flame by fire-bricks. K K

2836.



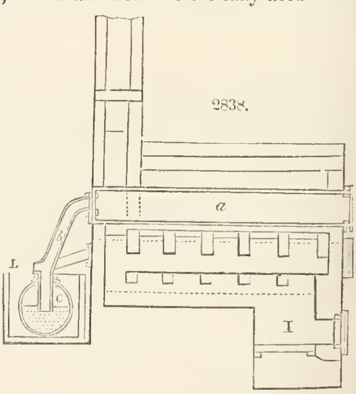
shows the flues for the escape of the burnt gases. The whole arrangement is shown in Fig. 2838 very distinctly. The two ends of the retort, *a*, are shut by two iron lids, secured by cross-bars and screw-bolts, luted with clay. The one end of the retort is provided with an iron pipe *b*, which leads into a long

2837.



condenser *e*, and from thence into the receiver D, *e*. The hole L is designed for the introduction of an iron wire, in case any disturbance should happen in the pipe *b*, where dirt from the ore may accumulate and obstruct the passage of the mercury vapors. The pipe, *c*, is always partly filled with quicksilver, and kept cool by water contained in a trough which surrounds it.

2838.



The retorts are kept in constant ignition, and a charge is worked in three hours' time, each charge consisting of 5 cwts. of ore. The ore is finely broken, and mixed with a portion of quicklime or porous magnetic iron ore, and, if it can be had, with both mixed together. The quantity of lime or iron depends upon the quality of the ore; pure ore requires more of it than impure ore. The quantity of quicksilver made in one retort per day depends also on the richness of the ore: the California ore ought to produce at least 600 lbs. in 24 hours in one retort, which will be for 9 retorts nearly 2 tons and a half per day. The retorts are charged and discharged from behind, so as to leave the condensing apparatus undisturbed.

Tin.—Germ., zinn; *Fr.*, etain; *Lat.*, stannum. Tin has been known for ages, and was used by the ancients long before our era. Tin ore is found chiefly as an oxide of tin: it is, in fact, the only available ore. England, Germany, and the East Indies, furnish almost all the tin in market—some is brought from South America, but it is of an inferior quality. In the United States tin ore is found in Connecticut, and there is said to be a good deposit in Missouri; a small quantity is found in the silver ores of the Southern States. Tin is a beautiful metal, and, next to silver, the whitest of all the metals. Its specific gravity is 7·29. It is a little harder than lead, and emits a peculiar sound, tin-cry, when bent, but the addition of a small quantity of lead diminishes the strength of that sound. Tin is more fusible than lead; it melts at 440°. It is very volatile, and burns in open fire, forming oxide of tin, or putty of tin. The most extensive use of tin is in the manufacture of tin plate, for which purpose a very pure tin is required; it is further employed for making pewter, bronze, bell-metal, &c., for which purpose it is alloyed with other metals, such as lead and copper.

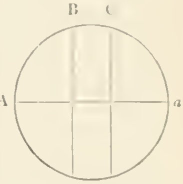
The metallurgy of tin is simple, but it requires experience to succeed well in smelting. The ores are first concentrated by stamping and washing, which is so much the more easy as tin ores are of a high specific gravity, almost equal to galena. The roasting is invariably performed in a reverberatory furnace, which is a tedious operation, and requires from 18 to 20 hours work for one heat; if this operation is not well performed, much trouble and loss is met with in smelting. Tin is the most profitably smelted in a blast-furnace, such as copper or silver ores are smelted in. In England, the reverberatory is employed for smelting some kinds of ore, but the best metal is made in the first furnace. The charges in the blast-furnace consist in charcoal ore, and lime, lead ore or iron ore as fluxes. In the reverberatory, the ore is charged along with lime, and culm, or mineral coal slack, as the means of reduction. At the tap-hole of the furnace a receiving basin is moulded, into which the fluid metal is tapped at certain intervals, the fluid slag being conducted to some other reservoir and gathered, to be smelted once more.

Tin, directly from the smelting furnace, is always impure. It contains all the metals with which the ores are adulterated, and it absorbs, also, metals from the flux. The metal is refined in a reverberatory furnace by eliquation, which process is based upon the ready fusibility of tin. In charging the blocks of tin near the fire-bridge, the hearth being sloped towards the flue, a gentle heat will melt the tin first of all other metals, and it will flow down the hearth, leaving the other metals in the form of skeletons of the original blocks. The pure metal is removed by tapping it at the flue, and then the heat increased and the other metals melted down: these are kept separate. The tin thus obtained is once more subjected to refining, for which purpose it is melted in an iron kettle, and stirred with sticks of green wood. The steam emitted from that wood oxidizes all other metals, and purifies the tin from them; the former form a light scum on its surface, which is removed, and the metal cast in blocks; it is now ready for the market. The whole amount of tin manufactured in the world may be estimated at about 10,000 tons, of which England furnishes the one half.

MICROMETER. An instrument applied to telescopes and microscopes for measuring very small distances, or the diameters of objects which subtend very small angles. A great number of contrivances of various kinds, and depending on different principles, have been employed for this purpose; but it will be sufficient to give a general description of some of the most useful or remarkable ones.

Wire micrometer.—This instrument, when placed in the tube of a telescope, at the focus of the object glass, presents the appearance represented in Fig. 2839. A *a* is a spider's web line, or very fine wire fixed to the diaphragm; and B *b* and C *c* are similar wires stretched across two forks, each connected with a milled-headed screw. By means of these screws the two wires, B *b* and C *c*, which are exactly parallel to each other, are movable in the direction perpendicular to A *a*; and in order that the wire A *a* may be placed in any direction relatively to the meridian, there is an adjusting screw, which works into an interior toothed wheel, and turns the apparatus round in its own plane perpendicular to the axis of the telescope.

2839.

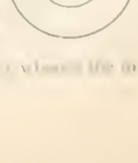


The method of using the micrometer is as follows: Suppose the object to be accomplished were the measurement of the *angle of position* and distance of two very close stars; the telescope being set and kept on the objects, the micrometer is turned by its adjusting screw until the spider line A *a* coincides with the line joining the two stars, or *threads* them both at the same moment. The milled heads of the screws, which carry the two movable wires, are then turned until B *b* bisects one of the two stars, and C *c* bisects the other. The observation is now completed, and it only remains to ascertain the position and distance indicated by the micrometer. For the first of these purposes, the circumference of the micrometer is divided into degrees and minutes, and read by two verniers: this reading gives the position of A *a* in respect of the horizontal and vertical planes, and consequently the angle of position of the two stars. To find their distance, the head of the screw which carries one of the movable wires, for instance C *c*, is turned until C *c* coincides with B *b*; and the number of revolutions, and parts of a revolution, required to effect the coincidence, gives the distance of the stars when the value of the *scale* of the micrometer is known; that is to say, when the number of seconds of space which correspond to one revolution of the screw is known. The screws must be made with great accuracy, and their heads are usually divided into 60 equal parts, representing seconds.

The value of the scale, or of a revolution of the screw, is obtained in the following manner: Set the two wires, B *b* and C *c*, apart to a certain number of revolutions, and place them in the direction of the meridian. Observe the transits of several stars of known declination over the wires; then multiply each interval of seconds by 15, and by the cosine of the star's declination; and, taking the mean, you have the seconds of space which correspond to a known number of revolutions of the screw.

Circular Micrometer.—This instrument, which differs entirely from the above, was first suggested by Boscovich, in the *Leipsic Acts* for 1740, and used by Lacaille in observing a comet in 1742; but seems afterwards to have fallen into disuse until it was revived by Dr. Olbers about 1798. The principle may be explained as follows: If the field of a telescope be perfectly circular, (which may be effected by means of a diaphragm turned in a lathe,) and if its diameter be determined from observation, the paths of two celestial bodies across the field may be considered as two parallel chords, which are given in terms of a circle of known diameter. The difference of the times at which two stars arrive at the middle of their paths will be their ascensional difference; and the distance between the chords, which is readily computed from their lengths, gives the difference of the declination of the two bodies.

2840.



The most approved construction of the annular micrometer is that of the late Fraunhofer. It consists of a disk of parallel plate glass, Fig. 2840, having in its centre a round hole of about half an inch in diameter, to the edges of which a ring of steel is cemented, and afterwards truly turned in a lathe. The disk being mounted in a brass tube, so that it may be accurately adjusted in the focus of the eye piece, and applied to a telescope, the steel ring is alone visible, and appears as if suspended in the atmosphere [illegible] strument is called the *suspended annular micrometer.* The advantage of this construction consists in the accuracy with which the moment of ingress or egress is determined, from the body being seen in the field of view before it comes up to the edge of the steel ring. The annular micrometer is conveniently used for comparing the place of a small star or a comet with that of a known star in nearly the same parallel of declination.

Divided object-glass, or double-image micrometer.—This instrument is formed by dividing the object-glass of a telescope or microscope into two halves, the straight edges being ground smooth, so that they may easily slide by one another. A double image of an object in the field of view is produced by the separation of the segments; and, by bringing the opposite edges of the two images into contact, a measure of the diameter of the object is obtained in terms of the extent of the separation. From its being used to measure the diameter of the sun, this is usually called the *heliometer.* Instead of a divided object-glass, Ramsden preferred a divided lens in the eye-tube, which form of the instrument is called the *dioptric micrometer.* The double-image micrometer was suggested by Roemer, about 1678, but first brought into use by Bouguer, about 1748.

MICROSCOPE. An optical instrument which enables us to see and examine objects which are too minute to be seen by the naked eye. Microscopes are single or compound, according to the nature of their construction; a single microscope being one through which, whether it consists of a single lens or a combination of lenses, the object is viewed directly; and a compound microscope one in which two or more lenses are so arranged that an enlarged image of the object formed by one of them is magnified by the second, or by the others, if there are more than two, and seen as if it were the object itself.

Single microscope.—This instrument is, for the most part, simply a lens or sphere of any transparent substance, which refracts the rays of light issuing from a small body placed in its focus, and gives them such a degree of convergency as is necessary for distinct vision. In order that the rays of light issuing from the several points of a very small body may produce a sensible impression on the retina of the eye, it is necessary that the object be brought very near the eye; but when this is done, the rays coming from its different points are so divergent as to produce only a confused image. Now, if a convex lens be interposed between the object and the eye, and so placed that its distance from the object is a little less than its focal distance, the diverging rays issuing from the object are refracted by the lens, and enter the eye placed behind it, either parallel, or so nearly parallel as to afford distinct vision. The object is then seen in the direction of the refracted rays, and at the distance at which it could be distinctly seen by the naked eye, and consequently magnified in the ratio of the distance of distinct vision to the focal distance of the lens. This ratio is called the *magnifying power* of the lens; hence, for single microscopes, the magnifying power is equal to the distance at which a small object can be seen distinctly by the naked eye, divided by the focal distance of the lens; and, as the distance of distinct vision is constant, (at least for the same individual,) the magnifying power is inversely as the focal distance. If we suppose the distance which limits distinct vision, in respect of minute objects, to be 5 inches (which is about the average for good eyes) and the focal distance of the lens to be 1 inch, the object will be magnified 5 times in linear dimensions, and 25 times in superficial. If the focal distance is one-tenth of an inch, the magnifying power will be 50 in linear extent, and 2500 in superficial.

A single microscope may be obtained very easily by piercing a small circular hole in a slip of metal, and introducing into it a drop of water, which will assume a spherical form on each side of the metal. The substance commonly used for microscopic lenses is plate glass; but they are sometimes formed of rock crystal, which is better. Flint glass, by reason of its great dispersive power, is unfitted for the purpose. The precious stones, as the garnet, ruby, sapphire, and diamond, have been proposed; but the numerous and skilful attempts of Mr. Varley and Mr. Pritchard have proved that the advantages arising from the greater refractive power of those substances are more than counterbalanced by their color, reflective power, double refraction, and heterogeneous structure. The crystalline lenses of minnows and other small fishes give a very perfect image of minute objects.

When the object to be examined is of such magnitude as to subtend an angle of some degrees, the requisite distinctness cannot be given to its whole surface by an ordinary lens, in consequence of the confusion occasioned by the lateral rays; unless, indeed, the rays are only permitted to enter the lens through a very small aperture, whereby the quantity of light is greatly diminished. In order to remedy this inconvenience, Dr. Wollaston contrived a form of lens, to which he gave the name of *periscopic lens.* Its construction is as follows: two plano-convex lenses or hemispheres are ground to the same radius, and between their plane surfaces a thin plate of metal, with a circular aperture, is introduced. The aperture which appeared to give the most distinct image was about $\frac{1}{5}$ of the focal length in diameter; and, when the aperture was well centered, the visible field was as much as 20° in diameter. A lens of this kind possesses the double advantage of having a very short focal distance, and very little spherical aberration. Dr. Wollaston's contrivance may, however, be improved upon in various ways; for example, by filling up the central aperture with a cement of the same refractive power as the lenses, whereby the loss of light from the double number of surfaces is avoided; or by grinding away the equatorial parts of a sphere of glass, so as to leave a deep groove all round it, in the plane of a great circle perpendicular to the axis of vision, and filling the groove with opaque matter. This last construction is called the *Coddington lens,* (from the name of its proposer,) and when executed in garnet, and used in homogeneous light, it is considered by Sir David Brewster to be the most perfect of all lenses, either for single microscopes, or the object lenses of compound ones.

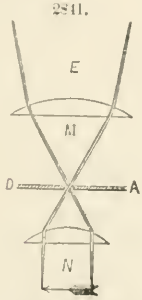
In using a single lens as a magnifier, it is always necessary that the light be made to pass through a very small aperture, in order that the object may be seen distinctly and without distortion. This necessity arises, both from the spherical aberration and the chromatic dispersion of the light falling on the surface of the lens under an angle of considerable obliquity; and the consequence is, that the quantity of light admitted to the eye is so much diminished that the object cannot clearly be seen

To remedy this inconvenience, Dr. Wollaston proposed a combination of two lenses, called, in consequence, *a microscopic doublet*, the optical part of which may be described as follows: M and N, Fig 2841, are two plano-convex lenses, whose focal lengths are in the ratio of 3 to 1, or nearly so, and placed one over the other so that their plane sides are towards the object. The adjustment of the distance between the lenses is best accomplished by trial; and they must, accordingly, be so mounted that the distance may be varied at pleasure. A D is a diaphragm or stop for limiting the aperture. Though it does not appear that the stop was contemplated by Dr. Wollaston, who makes no allusion to it, the performance of the microscope depends much on its nice adjustment. It is obvious that as each of the pencils of light from the extremities of the object is rendered eccentric by the stop, and made to pass through the two lenses on opposite sides of the common axis, they are affected by opposite errors, which, in some degree, serve to counteract each other. This doublet, when correctly made, is infinitely superior to any single lens, and will transmit a pencil of from 35° to 50° without any very sensible errors. The original description by Dr. Wollaston is given in the *Philosophical Transactions* for 1829.

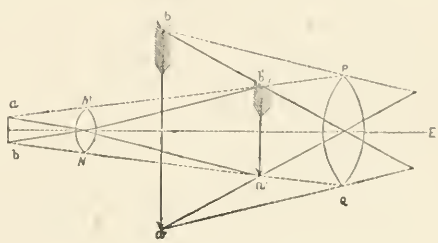
The above construction has been improved upon by substituting two plano-convex lenses for N in the doublet, the plane side of the one being in contact with the convex side of the other, and the stop being retained between them and the third. This combination is called a *triplet;* and its advantage is, that the errors of the doublet are still further reduced by the greater approximation to the object, in consequence of which the refractions take place nearer the axis.

When the magnifying power of the lens is considerable, and, consequently, its focal distance very small, it requires to be placed at the proper distance from the object with great precision; and, as it cannot be held in the hand with sufficient steadiness for any length of time, it requires to be mounted in a frame having a rack and screw, by means of which its distance from the object can be adjusted with accuracy. Mirrors for collecting the light and throwing it upon the object are also necessary for many purposes.

2841.



2842



Compound microscope.—The simplest kind of compound microscope is formed by the combination of two converging lenses, whose axes are placed in the same straight line. The arrangement of the lenses, and the path of the rays, will be readily understood from the annexed diagram, Fig. 2842. M N is the object-glass, which has a very short focal distance, and P Q the eye-glass. A small object, *a b*, being placed before the object-glass, a little further from it than the focus or parallel rays, a reversed and enlarged image, *a' b*, will be formed at some distance behind M N. The lens P Q is placed at such a distance from M N that its principal focus is in the line at *a' b'*; consequently the rays of light from every point of the image *a' b'* emerge nearly parallel from P Q, and to the eye at E the image *a' b'* is magnified, as if it were a real object, into *a'' b''*, and appears at a distance equal to the limits of distinct vision, which, as stated above, is about 5 inches.

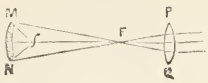
The magnifying power of this microscope, or the ratio of *a'' b''* to *a b* is found as follows: In the first place, if we assume *d* to denote the distance of the first image *a' b'* from M N, and *f* the distance of *a b* from M N, or the focal distance of M N, we have this proportion, $a'b' : ab :: d : f$. In the second place, if *l* denote the limit of distinct vision, or distance of the second image *a'' b''* from P Q, and *f'* the focal distance of P Q, (or distance of *a' b'* from P Q,) we shall also have $a'b'' : a'b' :: l : f'$. These two proportions, being multiplied together, give $\frac{a''b''}{a\ b} = \frac{dl}{ff'}$; which, therefore, is the magnifying power of the microscope. It thus appears that the magnifying power is inversely as the product of the focal distances of the two lenses, and directly as the distance between them. The magnifying power will therefore be increased by increasing the distance between the object-glass and eye-glass; but a limit is soon placed to this increase by the indistinctness of the image, and, in practice, it is not advisable to make the distance of *a' b'* from M N more than from 5 to 7 inches. Suppose the focal distance of M N to be ¼ of an inch, and the distance of *a' b'* from M N to be 5 inches, then *a' b'* will be 20 times greater than *a b;* and if the focal distance of P Q be ½ an inch, and the distance of *a'' b''* from P Q be 5 inches, then *a'' b''* will be 10 times greater than *a' b'*, and consequently 200 times greater than *a b*, or the magnifying power is 200.

The great defects of the microscope, when constructed in the manner now described, consist in the smallness of the field of view and want of achromatism in the object glass, in consequence of which the images *a' b'* and *a'' b''* are fringed with the prismatic colors. For the sake of enlarging the field of view, a third lens, larger than either of the others, and called the field glass, is usually interposed between the image *a' b'* and the object glass.

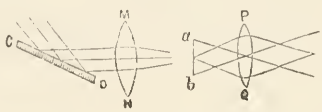
Reflecting microscope.—The principle of the reflecting microscope is very simple, and easily con ceived. Suppose M N, Fig. 2843, to be a concave speculum, and a small object to be placed before it at *f*. A reflected image of the object will be formed at F, where the rays issuing from each point of the object intersect each other, and magnified in the proportion of F M to *f* M. If the image at F is viewed with the naked eye, the instrument is a single reflecting microscope; but if the image is viewed through a refracting lens P Q, (or a combination of lenses forming an eye-piece,) by which the rays are made to converge towards the eye at E, it becomes a compound reflecting microscope.

The reflecting microscope was first proposed by Sir Isaac Newton in the form now described; but, on account of the impracticability of illuminating the object, it was long disused. It has, however been recently revived, under a modified form, by Professor Amici, of Modena, who places the object outside the tube of the microscope, below the line N F; and, in order that an image may be formed in the speculum, the rays issuing from the object fall upon a small plane mirror placed at *f*, inclined to the axis of the speculum in an angle of 45°, whereby they are thrown upon the speculum in the same manner as if the object itself were placed at *f*. By this means the object can be illuminated with perfect facility. The concave speculum M N is ground into an ellipsoidal surface; the diagonal mirror is placed at the nearest focus *f*, and the image is consequently formed at the other focus F. The image at F is viewed with a single or double eye-piece, as in other microscopes.

2843.



2844.



Solar and oxyhydrogen microscopes.—The solar microscope is composed essentially of a mirror and two converging lenses. The plane metallic mirror C D, Fig. 2844, reflects the sun's rays upon the lens M N, by which they are concentrated upon the object *a b* placed in its focus. The object being thus strongly illuminated, is placed before a second lens P Q, (a little before the principal focus,) by which the rays are rendered still more convergent, and produce a magnified image of the object upon a screen suitably placed at a distance of some feet behind the lens. The object is here supposed to be transparent; if opaque, the light must be thrown upon it in such a manner as to be reflected by it to P Q. The mirror and lens M N are placed in the hole of a window-shutter in a darkened room; and the mirror must be movable, in order that the sun's rays may always fall upon it under a proper angle to be reflected to the lenses. But the solar microscope is now almost entirely superseded by the *oxyhydrogen microscope;* so called because the illumination, instead of being produced by the sun's rays, is produced by burning a small piece of lime or marble in a stream of oxyhydrogen gas. In this case the plane mirror C D becomes unnecessary; and instead of the lens M N a concave speculum is employed, in front of which the ball of lime is placed, and an intense light thus thrown upon the object *a b*, the rays from which are brought to foci upon the screen by the lens P Q. For full details respecting the management of this apparatus, which forms a very popular exhibition, the reader is referred to *Goring and Pritchard's Micographia.* For descriptions of the various kinds of microscopes see *Brewster's Treatise on New Philosophical Instruments;* or *Ency. Brit.*, art. "Microscope."

MILE. A long measure, equal to 1760 yards. See WEIGHTS and MEASURES, for miles of different countries.

MILL. The term is most commonly applied to machines for grinding corn, but it is likewise used in a more loose sense to denote machines intended for other purposes, as the grinding of bark, for felling wood, for preparing flax, cotton, &c. See WATER-WHEELS, GEERING, and the various processes of manufacture commonly classed under this head.

MILLSTONE, or BURR-STONE. This interesting form of silica, which occurs in great masses, has a texture essentially cellular, the cells being irregular in number, shape, and size, and are often crossed by thin plates, or coarse fibres of silex. The burr-stone has a straight fracture, but it is not so brittle as flint, though its hardness is nearly the same. It is feebly translucent; its colors are pale and dead, of a whitish, grayish, or yellowish cast, sometimes with a tinge of blue.

The burr-stones usually occur in beds, which are sometimes continuous, and at others interrupted These beds are placed amid deposits of sand, or argillaceous and ferruginous marls, which penetrate between them, filling their fissures and honeycomb cavities. Burr-stones constitute a very rare geological formation, being found in abundance only in the mineral basin of Paris, and a few adjoining districts. Its place of superposition is well ascertained: it forms a part of the lacustrine, or fresh-water formation, which, in the locality alluded to, lies above the fossil-bone gypsum, and the stratum of sand and marine sandstone which covers it. Burr-stone constitutes, therefore, the uppermost solid stratum of the crust of the globe; for above it there is nothing but alluvial soil, or diluvial gravel, sand, and loam.

Burr-stones sometimes contain no organic forms, at others they seem as if stuffed full of fresh-water shells, or land shells and vegetables of inland growth. There is no exception known to this arrangement; but the shells have assumed a silicious nature, and their cavities are often bedecked with crystals of quartz. The best burr-stones for grinding corn, have about an equal proportion of solid matter and of vacant space. The finest quarry of them is upon the high ground near *La Ferte-sous-Jouarre* The stones are quarried in the open air, and are cut out in cylinders from one to two yards in diameter, by a series of iron and wooden wedges, gradually but equally inserted. The pieces of burr-stones are afterwards cut in parallelopipeds, called *panes*, which are bound with iron hoops into large millstones. These pieces are exported chiefly to this country and England. Good millstones of a bluish white color, with a regular proportion of cells, when six feet and a half in diameter, fetch 1200 francs a-piece, or £18 sterling. A coarse conglomerate sandstone or breccia is, in some cases, used as a substitute for burr-stone, but it is a poor one.

MINERAL KINGDOM, *materials from, used in the mechanical and ornamental arts.* The materials from the mineral kingdom may be divided, so far as regards these pages, into two groups: the earthy, and the metallic.

The earthy materials, when employed in the mechanical and useful arts, are generally used in their natural states.

The metallic minerals consist in general of metallic oxides, combined with a larger quantity of some base, such as silex, clay, or sulphur, which are the most common mineralizers; the cohesion of the mass has in general to be overcome by heat, which destroys the affinity of the component parts, and allows of the separation of the metals in various ways. Of these processes the author will have scarcely any thing to say, but the metals themselves, when so obtained, will be treated of at some length hereafter.

The earthy and crystalline mineral substances are less frequently worked by the amateur than the metallic, and therefore they will be noticed rather briefly, and in the order of their hardness, as derived from the following table:

Table of Hardness, etc.

1. Talc	Lead, Steatite or Soapstone, Meerschaum	23
2. Compact Gypsum.	Tin, Ivory, Potstone, Figure-stone, Cannel-coal, Jet, &c	20
3. Calcareous spar	Gold, Silver, and Copper, when pure; soft Brass, Serpentine, Marbles, Oriental Alabaster, &c	71
4. Fluor spar	Platinum, Gun-metal	53
5. Apatite	Soft Iron	43
6. Felspar	Soft Steel, Porphyry, Glass	52
7. Silex	Hardened Steel, Quartz, Flint, Agate, Granite, Sandstone, Sand	26
8. Topaz	Hardest Steel	6
9. Sapphire	Ruby and Corundum	1
10. Diamond	Cuts all substances	1

The above table exhibits the relative degrees of hardness of the several substances in the estimation of the mineralogist; thus talc may be scratched by gypsum, gypsum may be scratched by calcareous spar, the last by fluor spar, and so on throughout; in the second column are named some of the minerals, metals, and other substances of similar degrees of hardness, and the last column contains the number of minerals which, in respect to hardness, are ranked under each of the ten grades.

In the several practices of working these numerous substances, *structure* must also be taken into account, or the mode in which their separate particles are combined; thus hardened steel, quartz, granite, and sandstone, are each included under the number 7. The particles of the steel, however, are much more firmly united than those of the glassy crystalline quartz, which is far more brittle; and still more so than the aggregations of crystals in the granites; the last may be wrought by sharp-pointed picks, and chisels of hard steel, which crush and detach, rather than cut the crystals; and although sandstone consists almost entirely of particles of silex cemented with silex, still, as the grains of the sandstone are but loosely held together, it may be turned with considerable facility with the tools used for turning marble, and which is the every-day practice in turning the grindstone. Whereas granite, which contains from half to three-fifths felspar, a substance softer than silex, and porphyry, which consists of crystals of felspar imbedded in a base of felspar, cannot be turned with steel tools at all.

Several mineral substances are formed by the successive deposition of their component parts in uniform layers, as in mica and slate; or in alternate depositions, as in the Yorkshire flags or sandstones. Mica may in consequence be split into leaves even so thin as the one 50,000th of an inch; it is used by the optician in mounting objects for the microscope, and is often misnamed talc; slate may be split into very thin leaves of considerable size, and those sandstones which result from the recomposition of granite are most readily split through the layers of minute scales of mica, which, being lighter than the other ingredients, are deposited in separate layers.

Many hard substances, as the agates, carnelians, and flints, show neither the crystalline nor lamellar structure, and break with a fracture termed the conchoidal, of which the broken flakes of glass, flint, and pitch, may be taken as familiar examples.* Hard crystalline gems, on the other hand, are formed of laminæ, arranged in various directions, and may be readily split by the hammer and chisel through their natural cleavages or joints; but in most of the earthy minerals, grinding is resorted to for obtaining the ultimate and defined shapes, the consideration of which methods are for the present deferred. Should none of these processes be resorted to by my readers they will at any rate serve to explain the broad features of the respective influence of the mineral materials (amongst others) upon tools, which is undoubtedly an important link in our subject, and one full of general interest and variety, from the diversity of the methods which are pursued in such of the useful and ornamental arts as require these natural mineral substances, that include both the softest and hardest solids with which we are acquainted.

The hard mineral substances are mostly attached to the lathe by resinous cements, as driving them into hollow chucks, like pieces of wood or metal, would endanger their being broken, from their crystalline nature. The soft cements consist of about half a pound of resin, one ounce of wax, and any fine powder, often the fine dust from the stones that are turned; pounded brickdust and coarse flour

* [illegible], when first raised, may be split with remarkable precision, with the [illegible] conchoidal fracture, as may be well observed in gun-flints; the perfection of the keen edges thus produced, exceeds that of any which may be obtained upon similar substances by art; when the water is completely dried out of the flint it breaks with the ordinary conchoidal fracture.

are used, and pitch also enters into the composition of other kinds. Shellac, either alone or mixed with half its weight of finely powdered pumice-stone, is sometimes employed; and fine sealing-wax, which is principally shellac, is used, as well as many other kinds of cement. The stone is in general warmed to the melting point of the cement, but sometimes the latter is melted by friction alone.

Clay.—This material is only worked in the soft and plastic state. In pottery, it is attached to the potter's wheel or horizontal lathe, by its own adhesiveness alone, and is turned by the hands and blunt wooden tools; it is also pressed into moulds of metal and plaster of Paris, some of which are mounted on the lathe when the objects are smoothed within and moulded without. Lathes with vibrating mandrels, or possessing the movement of the rose-engine, are likewise employed for the production of some works in pottery and china. The artists who model in clay, use blunt instruments, mostly of wood, which are rounded at the ends; and all artisans cut or divide this material with a stretched pack-thread, or a metal wire. The clay for superior pottery works and modelling, often called pipe-clay, is decomposed felspar—it is mostly obtained from Cornwall and Devon; and the importance of the Stourbridge, and some other refractory clays, in the construction of crucibles and fire-bricks for a variety of other purposes in the arts, must not be overlooked.

Meerschaum—Amber.—These are principally used for smoking-pipes. Previously to being turned, the *meerschaum* is soaked in water; it is then worked with ordinary tools, and is described "to cut like a turnip." After having been dried in a warm room, it is polished with a few of its own shavings, and rubbed with white wax, which penetrates its surface. Sometimes the pipes are dipped into a vessel containing melted wax.

Jet, cannel coal, &c.—Jet is found at Whitby, Scarborough, and Yarmouth, and is also imported from Turkey, but it is not generally met in large pieces. It may be turned with most of the tools for the soft and hard woods, and worked with saws and files, all used in the ordinary way. Jet, until polished, appears of a brown color, and is manufactured by the lapidary into a variety of ornaments, such as necklaces, ear-rings, and crosses.

Cannel coal is principally obtained in England from Yorkshire, Shropshire, Derbyshire, and Cumberland. It is also found in parts of Scotland and North Wales. It occurs in seams, generally about three inches, but occasionally one foot thick, amongst ordinary coal; sometimes, as at the Angel Bank Colliery, near Ludlow, it constitutes the entire bed. Compared with jet it is much more brittle, also heavier, and harder; it is less brown when worked, less brilliant, but more durable when polished; neither of them are at all influenced by acids or moisture, although they temporarily expand by heat.

Cannel coal may be thought to be a dirty and brittle material, but this is only partially true; it is far better suited to the lathe than might be expected, although a peculiar treatment is called for in the entire management, which commences with the selection of pieces free from flaws, of a compact grain, and of a clean conchoidal rather than flaky structure.

All the tools for cannel coal are ground with two bevels exactly like the chisel for soft wood turning, but they are held *horizontally;* a small gouge, from one-quarter to three-eighths of an inch wide, also slightly bevelled off from within, is used for roughing out, or rather bringing the work as near as possible to the shape, to save the finishing tools: these should be ground with *thin* and *very sharp* edges, otherwise they burnish instead of scrape the work. The ordinary tools for ivory and hard wood, if employed, must be held downwards at an angle of about twenty degrees. These tools are sometimes used with a wire edge turned up in the manner of a joiner's scraper.

The plankway surfaces turn the most freely, and with shavings much like those of wood; the edges yield small chips, and at last a fine dust, but which does not stick to the hands in the manner of common coal. Flat objects, such as inkstands, are worked with the joiner's ordinary tools and planes; but with these likewise it is also better the edge should be slightly bevelled on the flat side of the iron. The edges of cannel coal are harder and polish better than the flat surfaces.

Alabaster.—This is a sulphate of lime, or compact gypsum, which occurs in various places; in England the finest is found near Derby, where the pure white is employed for the purposes of sculpture, but the finest white alabaster is from Italy; the variegated kinds are turned into vases, pillars, and other ornamental works.

The Italian alabaster, when first raised, is semi-transparent like spermaceti; it is wrought in this state. The works are generally rendered of a more opaque white by placing them in a vessel upon little fragments of the stone, so that they may be entirely surrounded by the cold water, which is then poured in and very slowly raised to nearly the boiling temperature; this should occupy two hours. The vessel is then allowed to cool to 70° or 80° Fahr., the object is taken out, closely wrapped in a cloth, and allowed to remain until dry. The alabaster at first appears little altered, but it gradually assumes the opaque white; for the first six months it is considered to remain softer than at first, but to become ultimately somewhat harder from the treatment.

Alabaster readily absorbs grease and dirt of any kind, but it is cleaned by the Italians very dexterously; some use weak alkaline and acid solutions. Soap and water are not to be recommended, as the unpolished parts absorb the oil of the soap.

There are but few kinds of tools employed in turning alabaster, namely, points for roughing out, flat chisels for smoothing, and one or two common firmer chisels, ground convex and concave for curved lines. The point tools used in Derbyshire are square, and described under marble; the Italians prefer a triangular point, as an old triangular file driven into a handle and ground off obtusely at the end. The carved parts are done by hand with small gouges, chisels, and scorpers of various forms and sizes; drills, files, and saws are also employed, and the surface, unless polished, is finished with fish-skin and Dutch rush.

The fibrous gypsum, called from its brilliant appearance satinstone, is much softer; it is turned into necklaces and small ornaments by a sharp, flat chisel, held obliquely; a square point would split off the fibres. All the above kinds of alabaster or gypsum produce, when calcined, the well-known plaster of Paris, a substance used for cementing together such of the vases as are made of detached parts: plaster of Paris also renders other and far more important services in a variety of the useful and ornamental arts.

Oriental alabaster is a very different substance from the above; it is a stalagmitic carbonate of lime, compact or fibrous, generally white, but of all colors from white to brown, and sometimes veined with colored zones; it is of the same hardness as marble, is used for similar purposes, and wrought by the same means.

Slate.—The common blue and red slates consist of clay and silex in about equal parts; the largest slate quarries, perhaps in the world, are at Bangor in Wales. The blocks, when quarried, are split into sheets, sometimes exceeding eight feet by four, by means of long, wide, and thin chisels, applied on the edge, parallel with the laminæ, and struck with a mallet or hammer. The sheets are sawn into rectangular pieces and slabs, by ordinary circular saws with teeth, moved rather slowly; and these are afterwards planed for billiard-tables, &c., in machines nearly resembling the engineer's planing-machines for metal, but with tools applied at about an angle of thirty degrees with the perpendicular. The process of sawing slate appears rather crushing than cutting, or a trial of strength between the tool and the slate, as the latter is carried up to the saw by machinery, and cannot recede from the instrument; the saw is sharpened about four times a day, and is worn out in about two months. The planing tools for common slabs are six inches wide, and when made of the best cast-steel and properly tempered, they last a day and a half without being sharpened; the jambs for chimney-pieces and other mouldings, not exceeding about six inches wide, are planed with figured tools of the full width.

Slate is also turned in the lathe with the heel or hook, tools used for iron, and also with ordinary tools, used with or without the slide rest, which are, however, rapidly blunted when applied superficially; it is much tougher at the ends or edges of the laminæ than at the flat sides. Slate has been recently worked into chimney-pieces, and a variety of objects for internal decoration, which are ornamented by a patent process, in the manner of *papier mâché* and china; imitations of marbles and granite are thus made at about one-third the prices of marble. Some of the substances known to mineralogists as slates are exceedingly hard, and vary from the hardness 2½, to that of flint or 7. Many varieties, including the Turkey oilstones, are used for sharpening tools; and this family also includes the touch-stones formerly used in assaying gold.

Serpentine, potstone, steatite.—These are natural compounds of magnesia and silica. They are generally worked immediately on being raised, being then much softer; but with the evaporation of their moisture they assume the general hardness of marble. The serpentine and steatite are found abundantly in Cornwall; serpentine is often called green marble, and by the Italians *Verde di prato.* It is much used; but some of the serpentines will not polish well.

Potstone is an inferior variety of serpentine; in Germany it is abundantly turned into various domestic articles in common use, whence its name.

Steatite is called soapstone, from its smooth, unctuous feel, and when first raised it may be scratched with the finger-nail; but it becomes nearly as hard as the others. A variety of steatite is carved by the Chinese into images employed as household gods, and is named figure-stone: until lately, it was supposed to be a preparation of *rice.* Steatite enters into the composition of porcelain.

Marbles, limestones.—The term marble is applied by the mason to any of the materials that he employs which admit of being polished; but the mineralogist designates thereby the compact carbonates of lime variously colored. The principal kinds worked in the ornamental arts, are the white or statuary marble from Italy, a variety of colored marbles, principally from Devonshire and Derbyshire, and the black bituminous marble from Derbyshire, Wales, and various parts of Ireland.

The marbles are turned with a bar of the best cast-steel, about two feet long and five-eighths of an inch square, drawn down at each end to a taper point, about two inches long, and tempered to a straw-color; this point is rubbed on two opposite sides on a sandstone, and held to the marble at an angle of twenty or thirty degrees: the tool soon gets dull, and must be again rubbed on the sandstone to sharpen it. Water should drop on the marble, to prevent the tool from becoming heated and losing its temper. The point will keep getting broader by constant grinding, till it forms a kind of chisel an eighth of an inch wide, after which, it will require drawing out again. For cutting in the mouldings a more delicate point is used, and these are the only tools employed; a flat tool will not turn marble at all.

Many of the limestones, although chemically like the marbles, are less compact, and therefore do not readily admit of being polished; of these may be noticed the Bath-stone and other oolites, which are aggregations of egg-shaped particles, like the roes of fish; when first raised, they may be cut very readily with an ordinary toothed saw, and turned with great freedom. The Maltese stone, of which many beautiful turned and carved works were recently sold in London, belongs likewise to this group. It is very compact, and nearly as soft as chalk, from which, in fact, it scarcely differs in any respect, except in its delicate brown cream color. The natives of the island of Malta display considerable taste in the objects turned and carved in this limestone.

Fluor spar is a natural combination of lime and fluoric acid, and the workable variety is peculiar to Derbyshire, where the art of turning it is carried to great perfection. The most costly varieties are the deep blue and purple, found only at Castleton in that county. Fluor being an aggregation of crystals, all having a fourfold cleavage, is very difficult to turn, as the laminæ are easily split; few even of the best workmen can turn it into very thin hollow articles. The following is the process.

The stone is first roughed out with a point and mallet, then heated till it will readily frizzle yellow resin which is applied all over it: this penetrates about one-eighth of an inch, and holds the crystals together. It is next rough-turned, and a little hollowed; it is again heated and resined, and turned still more into form; then it is bound round with a thin wire, and again resined, and so on until it is sufficiently thin to show the colors. It is then resined for the last time, and polished in the same manner as marble, but the process is more difficult, and ultimately but very little resin remains on the surface of the work. The only tool used is the steel point.

The blue color of fluor is often so intense that the works cannot be wrought thin enough to show it. When this is the case, the stone is very gradually heated in an oven until it becomes nearly red-hot, when the blue changes to an amethystine color. Great care is required, for if suffered to remain too long the color would entirely disappear. The white and lighter kinds of fluor are not worth one-tenth of the value of the blue, but are wrought in the same manner for commoner works.

Freestones, sandstones.—Freestone is a term commonly applied by the mason to such of the sandstones used for building purposes as work *freely* under the tools; namely, the stone-saw, a smooth iron blade, fed with sand and water, and the ordinary picks and chisels, which are too familiar to require more than to be named. The freestones are frequently turned into balustrades, pedestals, and vases. The term is used in this country to designate the sandstones used in building.

Sandstones, from their relatively slight cohesion, may be turned with the point tool used for marble, although, in the workshop, the grindstone is commonly turned with an old file drawn down for some two or three inches to about one-eighth of an inch square, and held downwards upon the rest at the angle of 20 or 30 degrees. It is rolled over and over, which continually produces a new point; the stone is then smoothed with a flat piece of iron or steel, or rubbed with a broken lump of another grindstone.

Porphyries, elvans, granites.—The division and preparation of the softest of the former materials, namely, clay, can be accomplished by the hands alone; in others, as alabaster and slate, with the ordinary toothed saws; and for those of a harder nature, the stone-saw, fed with sand and water, is an economical mode of dividing them with great exactness and little waste, from their original forms to those in which they are ultimately required, and which is greatly facilitated by the structure of such as occur in stratified beds; but the use of the stone-saw may be considered to cease with the sandstones.

Different and far more troublesome methods of working are necessary with those materials now to be considered, that are much harder, and in which the existence of stratification is considered but rarely and imperfectly to exist; namely, in the compact and cemented porphyries, principally from Egypt and Sweden. The crystalline granites, and some other varieties, appear to merge from the porphyries to the granites, are used for similar purposes, worked by the same means, and ask for an intermediate position.

In detaching the masses of granitic rock from their natural beds, the points of least resistance are first determined by an experienced eye, and holes are sunk at those points, vertically or inclined, as circumstances may require: the diameters of these holes vary according to the mass and the amount of resistance, and their depths according to the thickness of the blocks to be detached.

The holes are made with an iron rod, terminating at foot in a chisel-formed edge of hardened steel; the tool is held by one man, who changes its position at every blow received from sledge-hammers worked by other men who stand around. When the holes are thus made sufficiently deep, they are charged with gunpowder, in order to effect a separation of the mass by blasting; the ordinary process of tamping confines the powder, and the fuse communicates the blast. The art of the quarryman consists in placing the blast (or *shot*) where the smallest amount of powder will remove the largest mass of rock with the least breakage, simply dislodging or turning it over ready for converting.

In converting the rude masses of granite to their intended forms, the line of the proposed division is first marked, and holes from two to three inches deep, and four to six inches asunder, are bored upon this line, by means of an iron rod, terminating at each end in chisel-formed edges of hardened steel, with a bulb in the middle to add weight; this tool, called a *jumper*, is made to fall on one spot. It rebounds, and is partially twisted round to present the edge continually in a different angular position. In this manner a very expert workman will bore about a hundred holes a day. Every one of the holes is then filled with two half-round pieces of iron, called *feathers*, with an iron-pointed wedge between them; the wedges are progressively and equally driven until the stone splits, and the fissure will be in general moderately flat, even should the mass be four or six feet thick, although in such cases the holes are sometimes continued round the ends also.

The *scouters*, the next class of men, employ the jumpers' feathers and wedges for removing any large projections, by boring holes sideways, and thus casting off large flakes; the *spallers* employ heavy axe-formed or *muckle*-hammers, for spalling or scaling off smaller flakes; and the *scablers* use heavy pointed picks, and complete the conversion, so far as it is effected at the quarry, ready for the masons employed in erecting the buildings for which the blocks are used, who complete their formation on the spot. All these materials are likewise used in the ornamental arts.

Porphyry is worked in the lathe with remarkable perfection, and many excellent specimens from Sweden, of vases, slabs, pestles, and mortars, and bearings intended for the gudgeons of heavy machinery, may be seen in London. These objects are first worked as nearly as possible to the required forms with the pick, are then mounted in lathes driven by water-power, and finished by grinding them with other lumps of porphyry, supplied with emery and water; the machinery is kept going day and night, and the gangs of men relieve one another at certain intervals.

Granite is incapable of being turned in the lathe; it is therefore treated like porphyry, that is, shaped with heavy picks, and finally with smaller points used with a hammer; it is afterwards ground with circular or reciprocating motion, according to the figure, by means of iron plates fed with sharp sand, next with emery, progressively finer and finer, upon wooden rubbers, the endways of the grain; and lastly, the polish is perfected with felt rubbers and crocus. The process is tedious and difficult from the unequal hardness of the particles; in this respect granite is inferior to porphyry.

Of late years numerous vases and other circular and ornamental objects have been admirably executed in polished granites and elvans, which occur of various colors and degrees of hardness; when decomposed they are friable, and furnish the china stones extensively used as one of the materials for porcelain and china, and also for making very refractory crucibles.

Agate, jasper, chalcedony, carnelian, &c., are all composed of silex nearly pure; they break in general with a conchoidal fracture, and to divide them into plates it is necessary to resort to the lapidary process. They may be slit with emery, but it is far more economical to employ diamond powder, as the time then required is only one-third of that called for when emery is used; these stones are always ground with emery, and polished with rotten-stone.

Agate is used as the bearing planes for the knife-edges of delicate balances, for pestles and mortars, burnishers for gilders, and bookbinders, and also for some other purposes in the mechanical arts; the whole of the stones in this group are largely employed for the purposes of jewelry, the handles of knives, snuff-boxes, and a variety of ornaments.

Topaz, sapphire, ruby.—These may be split with *plane* surfaces through their natural cleavages, and which method is continually employed; otherwise, they can be only slit with the diamond powder. The first and similar stones may be smoothed with emery, but emery being in hardness only equal to 9, produces but little effect upon topaz, upon sapphire and ruby it is almost inert, and on diamond quite so; the sapphire and ruby, and also diamonds, are therefore always polished with diamond powder.

On account of the peculiar interest attached to the mechanical applications of the hard gems, it is proposed to depart a little from the subject and order of these pages, to advert to some few of their uses, which may not be generally understood. The sapphire, the ruby, and also the diamond, are commonly used for the construction of certain parts of the best time-pieces and watches, such as the pivot-holes, pallets, and other parts of the escapements.

The jewelling consists mostly of two stones: the one, commonly sapphire or ruby, is turned convex above and concave beneath, of two different sweeps, to thin it away at the part where it is to be pierced with the hole, and which is made a little smaller in the middle to lessen the surface bearing.

The other, which is called the "*top-stone*," or "*end-stone*," is generally a ruby, in the form of a plano-convex lens, or else it is a diamond cut into facets; the flat side of this touches the end of the pivot.

Each stone is burnished into a brass or steel ring, like some of the lenses of telescopes, and the two stones (separated a slight distance for the retention of oil by capillary attraction) are inlaid in a counter-sunk recess in the side-plate, or other part of the watch, and retained therein by two side-screws, although unimportant variations are made by different artists in the shapes and proportions of the parts.

The delicacy of these jewelled holes will be imagined, when it is added that in the axis above referred to, the pivot is the one two-hundredth part of an inch diameter.

The wire for making the pendulum springs for chronometers is sometimes drawn through a pair of flat rubies with rounded edges; the stones are cemented into the ends of metal slides having screw adjustments. Sometimes two pairs of rubies are placed one before the other, to constitute a rectangular hole of variable dimensions, for equalizing the wire both in width and thickness.

Rubies and other gems are drilled with holes conical from both sides, for drawing the slender silver gilt and silver wires used in the manufacture of gold and silver lace; the wires are afterwards flattened, wound spirally upon silk, and then woven into the lace. Ruby holes are also employed for rounding the leads of ever-pointed pencils; but for this use they are chamfered from the one side only, and the lead is pushed through from the small side, the ruby is then used as a cutting tool; whereas the hole in the draw-plate is slightly rounded upon the ridge, and acts more as a burnisher or compresser; the action of the wire, which is pulled through in the direction of the arrow, tends to draw the stone more firmly into its seat. The finest holes of all are made by barely allowing the point of the drill to penetrate into the apex of the conical hole, previously formed on the opposite side of the ruby.

All these applications are adopted on account of the very great hardness of the stone, but they could scarcely exist were there not one substance still harder than the ruby to serve for the tools by which these several forms are wrought, and the brief consideration of which will now be proceeded with.

Diamond.—The diamond is the hardest substance in nature, and in common with some other crystalline bodies, it is harder at the natural angles and edges, and also at the natural coat or skin of the stone than within, or in its general substance. Its peculiar hardness is probably altogether due to its highly crystalline form, as by analysis the diamond, charcoal, and plumbago, are found to be nearly identical; the first is absolutely pure carbon, the others are nearly so.

The principal use of the diamond is for jewelry, its preparation for which will be touched upon in the slightest possible manner; but from its peculiar hardness the diamond fulfils some more really important although less *brilliant* services as tools, without which several curious and highly valuable processes must be altogether abandoned, and others accomplished in an inferior although more costly manner by other means.

The diamond is prepared for the purposes of jewelry by three distinct processes, namely, splitting, cutting, and polishing, which will be adverted to in a very few lines. In order to split off the portions not required, the stone is fixed in a ball of cement, about as large as a walnut, the line of division is sawn a little way with a pointed diamond fixed in another ball of cement, and the stone is afterwards split with the blunted edge of a razor struck with a hammer; the small fragments removed, when they are too small for jewelry, are called *diamond bort*.

In cutting diamonds, two stones are operated upon at once; they are cemented in the ends of two sticks, which are supported on the edges of a box three or four inches wide, rested against two pins as fulcra, and forcibly rubbed against each other; by which means they abrade each other in nearly flat planes and remove a fine dust called *diamond powder*, which falls through the fine holes in the bottom of the box, and is there collected.

The diamonds are lastly polished upon an iron lap or *skive*, charged with diamond powder, the stone being guided mechanically; it is fixed by soft solder in a copper cup, or *dop*, attached by a stout copper wire to the end of the *pincers*, a flat board terminating at the other extremity in two feet, which rest upon a fixed support, the whole forming a long and very shallow triangular stool, loaded at the end near the stone. In the last two processes the stone is readjusted for producing every separate facet. We will now proceed to the applications of the diamond as tools.

The invaluable instrument, the glazier's diamond, although employed for a considerable period, was for the first time investigated scientifically by Dr. Wollaston, in 1816, who pronounced its operation to depend upon a peculiarity of crystallization in the diamond, the facets of which are frequently *round* instead of flat, and therefore the edges are *circular* instead of straight. The rounded edge first indents the glass, and then slightly separates its particles, forming a shallow fissure, with a splitting rather than a cutting action, none of the material being removed.

The primitive form of the diamond is that of a regular octohedron; it is like two square pyramids joined base to base; the four sides of the pyramids meet at the angle of 90°, their bases at the angle of 109° or thereabouts. Many of the diamonds merge from the form of the octohedron into that of the sphere, or a very long egg, in which cases although a disposition to the development of the six points, each formed by the meeting of four surfaces, exists, they are curiously twisted and contorted. The Count de Bournon has published upwards of one hundred forms of crystallization of the diamond, but the irregular octohedrons with round facets are those proper for glaziers' diamonds.

The extreme point of any diamond may be employed to *scratch* glass with a broad white streak, and detach its particles in a powder, but such glass will break with difficulty, (if at all,) through such a scratch; whereas the almost invisible fissure, made when the rounded edge is slid over the glass with but slight pressure and almost without causing any sound, is that which produces the effective *cut;* and the cut or split thus commenced will be readily extended through the entire thickness of the glass, when the extremities of the sheet are bent with the fingers or appropriate nippers.

If we could obtain a diamond in the form of a circular button, the edges of which were turned to the angle of 90 or 100 degrees, it would be the perfection of the instrument, as there would be then no point to interfere with its action, and any part of its edge might be used. But as the *natural diamond*, unaltered by the artisan, is always employed, it must be so applied upon the glass, that one of its curved edges bears upon the intended line of division of the glass, and with the extreme point just out of contact: this, in so small an object, necessarily confines the position within very narrow limits.

The patent swivel diamond insures the one condition, by placing the edge of the stone upon the line of the cut, and a few trials at different elevations, generally from 70 to 80 degrees, will soon give the other position. At the commencement a slight force is applied, until the stone appears to bite or hang to the glass, it is then drawn steadily along, with but little pressure, and the good cut will be scarcely either seen or heard.

To show that the diamond possesses nothing in itself that should adapt it to cutting glass, beyond its peculiar form and hardness, Dr. Wollaston succeeded with great labor in giving the same form to the ruby, the spinel ruby, topaz, and rock crystal, with all of which likewise he effected the cutting of glass, but they were of course far less economical than the natural angle of the diamond itself, which requires no such tedious preparation, and lasts very much longer.

It must not be supposed, however, the diamond endures forever; the ordinary painter and glazier may use one diamond throughout his lifetime, by having it reset to expose other angles; but in some glass-works, where enormous quantities of this useful material are cut up, the consumption of diamonds amounts to one and two dozen or upwards *every week*, as the sides from being convex, become rapidly concave, and the principle is lost.

The following figures represent, say two or three times magnified, the forms of diamonds that would be most proper for various tools; but it will be remembered they are only *selected* as near to the respective shapes as they can be found, either amongst imperfect diamonds, or from fragments split off good stones in the first stage of their manufacture for jewelry; these pieces are known as *diamond bort.* The diamonds are mostly fixed in brass wires, by first drilling a shallow hole for the insertion of the stone, which is imbedded slightly below its largest part, and the metal is pinched around it. Shellac is also used for cementing them in, and spelter or tin solders may be fused around them with the blow-pipe, but pinching them in annealed brass is preferred.

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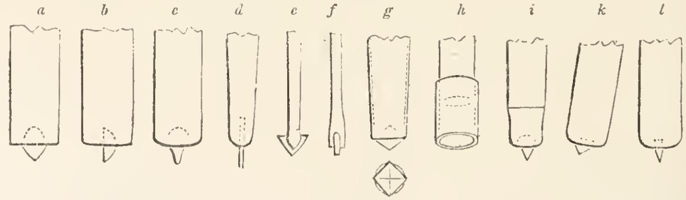


When diamond tools larger than those made of crystals or thin splinters are required, diamond powder is applied upon metal plates and tools of various forms, which serve as vehicles, and into which the particles of diamond powder are imbedded, either by slight blows of the hammer, or by simple pressure.

In the construction of the jewelled holes, and in similar works, the rubies and sapphires, although sometimes split, are more commonly *slit* with a plate of iron three or four inches diameter, mounted on a lathe, and charged on the edge with diamond powder and oil. When sliced they are ground parallel one at a time on a flat plate of copper, (generally a penny-piece,) mounted on the lathe, and into the turned face of which small fragments of diamond have been hammered; this is called a roughing-mill. A similar plate with finely washed diamond powder is used for polishing them.

The rubies are afterwards cemented with shellac, on the end of a small brass chuck, turned cylindrical on their edges, and bevelled for burnishing into the metal rings. They are also turned concave and convex on their respective faces, the turning tool being a fragment or splinter of diamond, fixed in a brass wire. Fig. *a* represents the flat view, and Fig. *b* the edge view of such a tool, but of the form more usually selected for turning hardened steel, namely, an egg-shaped diamond split in two, the circular end being used with the flat surface upwards; the watch jeweller uses any splinter having an angular corner.

The *convex* surfaces of the rubies are polished with *concave* grinders of the same sweeps; the first of copper, the next glass, and the last pewter, with three sizes of diamond powder, which is obtained principally from Holland, from the men who *cut* diamonds for jewelry, an art which is more extensively followed in that country than elsewhere. The watch jewellers wash this powder in oil, after the same manner that will be hereafter explained in regard to emery.

In drilling the rubies they are chucked by their edges, and a splinter of diamond, also mounted in a wire, is used. Should the drill be too conical, the back part is turned away with a diamond tool to reduce it to the shape of Fig. *c*, and from the crystalline nature of the stone, some facets or angles always exist to cause the drill to cut. The holes in the rubies are commonly drilled out at two processes, or from each side, and are afterwards polished with a conical steel wire fed with diamond powder.

In producing either very small or very deep holes, a fine steel wire, Fig. *d*, is used, with diamond powder applied upon the end of the same, the limit of fineness being the diameter to which the steel wire can be reduced.

In drilling larger holes in china and glass, triangular fragments of diamond are fixed in the cleft extremity of a steel wire, as in Figs. *e* and *f*, either with or without shellac. Another common practice of the glass and china menders, is to select a tolerably square stone, and mount it as in Fig. *g* in the end of a taper tin tube, which wears away against the side of the hole so as to become very thin, and by the pressure to embrace the stone by the portions intermediate between its angles.

The stone is, from time to time, released by the wearing away of the metal, but these workmen are dexterous in remounting it; and that the process is neither difficult nor tedious to those accustomed to it, is proved by the trifling sum charged for repairing articles, even when many of the so-called rivets or rather staples are cemented in; they employ the upright drill with a cross staff.

A similar diamond drill mounted in brass was used by Mr. Ellis, with the ordinary drill-bow and breast-plate for drilling out the hardened steel nipple of a gun, which had been broken short off in the barrel; no material difficulty was experienced, although the stone appeared to be so slenderly held.

For larger holes, metal tubes such as Fig. *h*, fed with diamond powder, are used; they grind out an annular recess, and remove a solid core; copper and other tools fed with emery or sand may be thus used for glass, marble, and various other substances. The same mode has been adopted for cutting out stone water-pipes from within one another by the aid of steam machinery.

Fig. *i* represents the conical diamond used by engravers for the purpose of etching, either by hand or with the various machines for ruling etching grounds; for ruling medals and other works. Conical diamonds are turned in a lathe by a fragment of another diamond, the outside skin or an angle being used, but the tool suffers almost as much abrasion as the conical point, from their nearly equal hardness; therefore the process is expensive, although when properly managed entirely successful.

To conclude the notice of the diamond tools, Figs. *k* and *l* show the side and end views of a splinter suitable for cutting fine lines and divisions upon mathematical instruments. The similitude between this and the glazier's diamond will be remarked, but in the present case the splinter is selected with a fine acute edge, as the natural angle would be too obtuse for the purpose.

Mr. Ross, with a diamond point of this kind, was enabled to graduate ten circles upon platinum, each degree subdivided into four parts; at the end of which time the diamond, although apparently none the worse, was accidentally broken. A steel point would have suffered in the graduation of only one-third of a single circle upon platinum, so as to have called for additional pressure with the progress of the work, which in so delicate an operation is of course highly objectionable.

MINES, ENGINES FOR. The locality of a mine will determine the manner in which it ought to be drained. Where the mine is situated on the top or side of a hill, a shaft is led from the bottom of the mine to the nearest valley, and the water runs off in this way without the application of pumps wrought by steam-engines. Where the mine is situated in a level country pumping becomes necessary; and should the mine be deep, say from 100 to 150 fathoms, very powerful steam-engines are required. Where the pumping requires great power, suppose of 200 horses, it is better to construct two small engines than one large one. Where a single engine is used one set of pumps are wrought, and the ascending motion of the piston is employed to raise a weight equal to half the pressure of the water in the pumps. Where two engines are used there are commonly two sets of pumps, one set wrought by a diagonal spear attached to the piston end of the beam, and the other set are wrought by the other end. Steam-engines for mines should be simple in form and proportioned to the work they have to perform. The pump-shaft is divided into lifts, which should not exceed 150 feet each; there is a cistern for the reception of the water, at the top of each lift. Rather than make the diameter of the pump more than sixteen inches an additional set should be added. Mining work is irregular, more resistance having to be overcome at one time than another. Tredgold gives it as his opinion that an engine does good duty when it raises 70,000 lbs. of ore by the consumption of one pound of coal. The weight to be raised at one draught varies from 3 to 7 hundred weight. Engines at mines are sometimes used to break the ore by means of stampers.

For a more complete treatise on mines, see *Ure's Dictionary of Mines*. For the engines used, see article PUMPS AND PUMPING, and also ENGINES, in this Dictionary.

MINT. See COINING.

MODULUS. The *modulus of the elasticity* of any substance is a column of the same substance, capable of producing a pressure on its base which is to the weight causing a certain degree of compression, as the length of the substance is to the diminution of its length.

The modulus of elasticity is the measure of the elastic force of any substance.

A practical notion of the modulus of elasticity may be readily obtained. Let *c* be the quantity a bar of wood, iron, or other substance, an inch square and a foot in length, would be extended or diminished by the force f; and let l be any other length of a bar of equal base and like substance; then

$$1 : l :: \varepsilon : \Delta, \text{ or } l\,\varepsilon = \Delta, \text{ the extension or diminution in the length } l.$$

The modulus of elasticity is found by this analogy: as the diminution of the length of any substance is to its length, so is the force that produced that diminution to the modulus of elasticity. Or, denoting the weight of the modulus in lbs. for a base of an inch square by m; it is

$$\varepsilon : f :: 1 : m = \frac{f}{\varepsilon}.$$

And, if w be the weight of a bar of the substance one inch square and one foot in length; then, if M be the height of the modulus of elasticity in feet, we have

$$\frac{f}{w\,\varepsilon} = \text{M}.$$

When a force is applied to an elastic column of a rectangular prismatic form in a direction parallel to the axis, the parts nearest to the line of direction of the force exert a resistance in an opposite direction; those particles, which are at a distance beyond the axis, equal to a third proportional to the depth, and twelve times the distance of the line of direction of the force, remain in their natural state; and the parts beyond them act in the direction of the force.

The weight of the modulus of the elasticity of a column being m, a weight bending it in any manner f, the distance of the line of its application from any point of the axis D, and the depth of the column d, the radius of curvature will be $\frac{d^2 m}{12\,\text{D} f}$.

If a beam is naturally of the form which a prismatic beam would acquire, if it were slightly bent by a longitudinal force, calling its depth d, its length l, the circumference of a circle of which the diameter is unity c, the weight of the modulus of elasticity m, the natural deviation from the rectilinear form Δ', and a force applied at the extremities of the axis f, the total deviation from the rectilinear form will be

$$\Delta' = \frac{d^2 c^2 \Delta m}{d^2 c^2 m - 12\, l^2 f}$$

Scholium.—It appears from this formula, that when the other quantities remain unaltered, Δ' varies in proportion to Δ, and if $\Delta = 0$, the beam cannot be retained in a state of inflection, while the denominator of the fraction remains a finite quantity: but when $d^2 c^2 m = 12\, l^2 f$, Δ' becomes infinite, whatever may be the magnitude of Δ, and the force will overpower the beam, or will at least cause it to bend so much as to derange the operation of the forces concerned. In this case $f = \left(\frac{d\,c}{l}\right)^2 \cdot \frac{m}{12}, .8225\, \frac{d^2}{l^2} m$, which is the force capable of holding the beam in equilibrium in any inconsiderable degree of curvature. The modulus being known for any substance, we may determine at once the weight which a given bar nearly straight is capable of supporting. For instance, in fir wood, supposing its height 10,000,000 feet, a bar an inch square and ten feet long may begin to bend with the weight of a bar of the same thickness, equal in length to $\cdot 8225 \times \frac{1}{120 \times 120} \times 10{,}000{,}000$ feet, or 571 feet; that is, with a weight of about 120 pounds; neglecting the effect of the weight of the bar itself. In the same manner the strength of a bar of any other substance may be determined, either from direct experiments on its flexure, or from the sounds that it produces. If $f = \frac{m}{n}, \frac{l^2}{d^2} = \cdot 8225\, n$, and $\frac{l}{d} = \sqrt{(\cdot 8225\, n)} = \cdot 907 \sqrt{n}$; whence, if we know the force required to crush a bar or column, we may calculate what must be the proportion of its length to its depth, in order that it may begin to bend rather than be crushed.

The weight of the modulus of the elasticity of a bar is to a weight acting at its extremity only, as four times the cube of the length to the product of the square of the depth and the depression.

If an equable bar be fixed horizontally at one end, and bent by its own weight, the depression at the extremity will be half the versed sine of an equal arc in the circle of curvature at the fixed point.

The height of the modulus of the elasticity of a bar, fixed at one end, and depressed by its own weight, is half as much more as the fourth power of the length divided by the product of the square of the depth and the depression.

The depression of the middle of a bar supported at both ends, produced by its own weight, is five-sixths of the versed sine of half the equal arc in the circle of least curvature.

The height of the modulus of the elasticity of a bar, supported at both ends, is $\frac{5}{32}$ of the fourth power of the length, divided by the product of the depression and the square of the depth.

From an experiment made by Mr. Leslie on a bar in these circumstances, the height of the modulus of the elasticity of deal appears to be about 9,328,000 feet. Chladni's observations on the sounds of fir wood afford very nearly the same result.

The modulus of elasticity has not yet been ascertained in reference to so many subjects as could be wished. Professor Leslie exhibits several, however, as below. That of white marble is 2,150,000 feet, or a weight of 2,520,000 pounds avoirdupois on the square inch; while that of Portland stone is only 1,570,000 feet, corresponding on the square inch to the weight of 1,530,000 lb.

White marble and Portland stone are found to have, for every square inch of section, a cohesive power of 1811 lb. and 857 lb.; wherefore, suspended columns of these stones, of the altitude of 1542 and 945 feet, or only the 1394th and 1789th part of their respective measure of elasticity, would be torn asunder by their own weight.

Of the principal kinds of timber employed in building and carpentry, the annexed table will exhibit their respective modulus of elasticity, and the portion of some of them which limits their cohesion, or which lengthwise would tear them asunder.

	feet.		feet.
Steel	9,300,000	Rosewood	3,600,000
Bar-iron	9,000,000	Oak, dry	5,100,000
Ditto	8,450,000	Fir bottom, 25 years old	7,400,000
Yellow pine	9,150,000	Petersburg deal	6,000,000
Ditto	11,840,000	Lancewood	5,100,000
Finland deal	6,000,000	Willow	6,200,000
Mahogany	7,500,000	Oak	4,350,000

Teak	6,040,000 feet.	168th.
Oak	4,150,000 feet.	144th.
Sycamore	3,860,000 feet.	108th.
Beech	4,180,000 feet.	107th.
Ash	4,617,000 feet.	109th.
Elm	5,680,000 feet.	146th.
Memel fir	8,292,000 feet.	205th.
Christiana deal	8,118,000 feet.	146th.
Larch	5,096,000 feet.	121st.

Annexed we give a table of the *modulus of cohesion*, or the length in feet of any prismatic substance required to break its cohesion, or tear it asunder.

	feet.		feet.
Tanned cow's-skin	10,250	Garden matting	27,000
——— calf-skin	5,050	Writing-paper, foolscap	8,000
——— horse-skin	7,000	Brown wrapping-paper, thin	6,700
——— cordovan	3,720	Bent grass, (holcus)	79,000
——— sheep-skin	5,600	Whalebone	14,000
Untanned horse-skin	8,900	Bricks, (Fenny Stratford)	970
Old harness of 30 years	5,000	——— (Leighton)	144
Hempen twine	75,000	Ice	300
Catgut, some years old	23,000	Leicestershire slate	7,300

Teak	12,915 lb.	36,049 feet.
Oak	11,880 lb.	32,900 feet.
Sycamore	9,630 lb.	35,800 feet.
Beech	12,225 lb.	38,940 feet.
Ash	14,130 lb.	42,080 feet.
Elm	9,720 lb.	39,050 feet.
Memel fir	9,540 lb.	40,500 feet.
Christiana deal	12,346 lb.	55,500 feet.
Larch	12,240 lb.	42,160 feet.

MOMENTUM, in mechanics, is the same with impetus, or quantity of motion, and is generally estimated by the product of the velocity and mass of the body. This is a subject which has led to various controversies between philosophers, some estimating it by the mass into the velocity, as stated above, while others maintain that it varies as the mass into the square of the velocity. But this difference seems to have arisen rather from a misconception of the term, than from any other cause. Those who maintain the former doctrine, understanding momentum to signify the momentary impact; and the latter, as the sum of all the impulses till the motion of the body is destroyed. See FORCE.

MORTAR. A mixture of *slaked lime* in the state of paste with *sand;* it possesses the property, when spread in thin layers between bricks, of gradually hardening to the consistence of limestone, and thus cementing the bricks together. In order to understand the principles upon which mortar is mixed, it is necessary to become acquainted with certain facts which here exert the greatest influence.

Conditions of hardening.—Simple lime, in the state of paste, likewise hardens, but only to form a loose mass of too slight consistency to bind the parts of a wall or building firmly together. It is only when the layer of lime forms a very thin stratum, as between two polished stones, that a firm and solid cement is produced. The lime must be prevented from forming masses of any considerable thickness, as these always possess a very slight degree of cohesion. The lime attaches itself firmly only to the surface of the building stones, which differ from it in character, and this surface should be extended, as it were, by mixing a *granular powder* with the lime. This leads directly to the object and use of sand in the mortar, which is only intended to bring about more intimate contact between the surfaces of the stones and the lime. The shape of the bricks and hewn stones is so irregular, that crevices of a line at least, and in hewn stones often of an inch in width, are left between them when laid one upon another. Lime alone placed between the stones, would consequently be in layers of a line to an inch in thickness, and in such masses would never bind. If, however, a sandy powder of any kind of stone is mixed with it, the mass of lime is thus divided into a great number of thin layers, or, as it were, fills up the interstices between the sand, and finding everywhere points of attachment, binds the grains of sand together, and extends this binding action to the stones themselves.

It is further known that even the best mortar, when quickly dried, as, for instance, on the stove, does not harden, but remains friable and porous. Although, therefore, mortar placed under water remains porous and will not bind, yet the action of moisture is essential to make it harden in the air. Lastly, the free access of air is also absolutely necessary to the setting of mortar.

Proportions of mixture.—When these facts are borne in mind, the rules to be observed in mixing mortar will be obvious. Although many kinds of stone in the form of coarse sand are applicable for making mortar, as limestone, for instance, yet quartz-sand is always most easily obtained; the grain of the sand, however, is a matter of some importance. Very fine sand renders the mortar too dense, and impedes the free access of air; sand in grains of the size of hay-seed, particularly if it is angular or sharp, is very good; the interstices become too large to be entirely filled with lime if very coarse sand is employed. It is then advantageous, particularly when irregularly shaped building-stones are used, to mix two kinds of sand together, coarse and fine. Fine sand can only be mixed with the lime when the mortar is intended for a thin coating upon the surface of walls, &c. The more irregular the sand is, the better. The proper proportion of sand and lime is a most important point in preparing mortar; and the good quality and solidity of the mortar are more influenced by it than by any thing else. Errors committed in the mixing can never be subsequently corrected.

As a general rule, the lime should be sufficiently fine to cement all the grains of sand together, but should form at the same time the thinnest possible stratum between them. The surfaces of the grains of sand, or the interstices between them, should therefore be only just covered with the lime in a half-liquid state, and no more. The rule might be laid down in the following terms: let as much lime be mixed with the sand as it will take up without having its volume increased. Practically, about 3 to 4 cubic feet of sand (or 6 times the weight) are added to 1 cubic foot of half-liquid lime, provided the lime be fat, or very fat; poor lime, which may be viewed as already containing a certain portion of sand, will not bear the addition of more than $2\frac{1}{2}$ cubic feet of sand to 1 cubic foot of lime. The sand should be pure, *i. e.*, it should not contain too much iron or clay, and least of all, bog-earth, or vegetable matter.

Hardening or setting—time required.—Although mortar sets sufficiently in a few days, or weeks, to enable a wall to withstand pressure and the like, yet the hardening proceeds so slowly and gradually, that it only attains its maximum (in which case a wall appears as if constructed of one piece of stone) after years, or even centuries. The apparent superiority of mortar in olden times over that in the present, is solely attributable to the longer time which has been allowed it to harden and set, as no essential difference can be traced in the mixture of the ingredients. Although we see, on the one hand, that old buildings can only be destroyed with the aid of powder, yet it must not be forgotten on the other, that in some buildings the direct converse is observed, and that the durable portions only have been enabled to withstand the ravages of time, while the weaker and less durable parts have long since disappeared. In the same manner, it is probable that some buildings erected in our own age will stand forward to posterity as patterns of solid architecture, just as those of the middle ages and of the ages of Greece and Rome appear to us at present.

Cause of setting.—The hardening of mortar upon exposure to the air is not so easily explained as would at first appear. It has even been disputed whether it is the result of mere physical (mechanical) or only of chemical agencies. And it appears probable, when every thing is taken into consideration, that the hardening cannot be attributed to any one cause in particular, but to all collectively, and in such a manner that the formation of a silicate of lime and crystallization are the causes of the durable solidity and conversion into stone, while the absorption of carbonic acid induces the rapid setting of the mortar.

The hydraulic mortar employed in building the Eddystone lighthouse was mixed by Smeaton from equal proportions of lime, slaked to powder, and Puzzolana. Trass and Puzzolana are generally mixed with one-half their weight of lime, as was the practice amongst the Romans. It is desirable to ascertain the best proportions by experiment in all cases where no certain knowledge of the nature of the two substances can be obtained.

Good hydraulic mortar, whether made from natural limestone or composed of lime and cement, should not show any tendency to crack when hardened under water, even when no sand is mixed with it. It then forms a very dense and solid mass, which, in a short time, neither suffers water to permeate it, nor is attacked by the water, but acquires a considerable degree of hardness. For this reason, it is well to use nothing but hydraulic mortar for those parts of walls which are constantly under water. If the mortar is not only required to harden, but also to bind well, a very important point must never be neglected, and that is to moisten the surfaces of the stones to which the mortar is to be applied. When this is not done, the surface of the stone (by its power of absorbing moisture) dries the mortar, and prevents proper adhesion from taking place; the joint then remains open to a greater or lesser extent.

It does not by any means follow, that because hydraulic mortar is the only durable material for building under water, it cannot consequently be used for dry walls. It is, on the contrary, of the greatest service wherever protection is required against the infiltration of moisture and damp; and dwellings or buildings can often be rendered very much less damp by a judicious application of a hydraulic coating; a layer of this kind, when once hardened, is not calculated, like ordinary mortar, to attract moisture and allow it to pass through. The hydraulic mortar must, of course, when used for covering dry walls or otherwise, be kept moist and watered, until it has acquired its proper degree of hardness. If this is not attended to, a soft, friable, useless coating is the certain result. If moisture enters from below, for instance, between the wall and the coating of mortar, it will continue confined there in consequence of the impenetrability of the latter, which, on the occurrence of a frost, will most certainly peel off and be destroyed. Care must also be taken that the mortar does not dry up of itself immediately in the air, in which case it contracts and cracks. It is, therefore, necessary to add sand or some other substance which obviates the shrinking. Hydraulic mortar will bear a very considerable quantity of sand without injury to its hardness, even as much as one and a half times its own weight and more. This addition, therefore, is important in an economical point of view. The grain of the sand employed, however, requires attention, as was the case with ordinary mortar; sharp, angular sand is decidedly preferable to blunt, rounded sand, and it is better to use a mixture of coarse with fine sand, than that the sand should be all of the same sized grain. The sand should likewise be as free as possible from earthy particles and dust. In mortar composed of lime and cement, the rule is, to proportion the sand to the quantity of cement used. Slaked lime will not bear more than a certain quantity of these substances, which quantity must not be exceeded, the cement itself being for the greater part inactive, and playing the part of sand.

Hydraulic mortar that sets with sufficient rapidity, and to which a proper proportion of sand has been added, may be employed for casting tolerably massive objects, which are not subject to crack when dry. This enables hydraulic mortar to be employed for architectural ornaments which then combine great sharpness with durability, are very light as compared with similar figures of sandstone, and have the great advantage of being easily multiplied.

A similar application is that for casting water-pipes, on the spot where they are required, as proposed by Gasparin. The mould employed is a linen hose, like those attached to the fire-engines, a few meters in length, which is filled with water and closed at both ends. A thick kind of bolster is thus produced, over which sand is sifted, and it is then laid upon a deposit of hydraulic lime and covered, by pouring over it the same substance. When the whole has hardened, the hose is drawn forwards, about the length of one foot being left inserted in the tube, and a fresh length is cast. Water-courses thus constructed must, however, have a certain amount of fall, or the sand cannot be washed out, and will impede the delivery of the water.

When hydraulic lime is mixed with small stones, or with shingles from the bed of a river, or the sea, walls can be directly constructed of it, and a mass is obtained which resembles the erections with ordinary mortar, and is called *béton* by the French.

At Toulon a mixture was used for the construction of the harbor consisting of 3 parts lime, 4 Puzzolana, 1 smithy ashes, 2 sand, and 4 parts of rolled stones or shingles.

The great strength of walls constructed with hydraulic mortar is most clearly shown by the experiments undertaken with a view to break beams constructed of brick-work. A 25 feet long and 2½ feet wide beam, constructed with 19 layers of bricks, bound together by Roman cement, in which, here and there, parallel strips of iron were inclosed, was capable of bearing, when supported at both ends, a weight of 22 tons, suspended from the middle, before it showed signs of fracture.

Mr. Frederick Ransome has lately taken a patent for preparing different articles with a kind of vitrified cement. The following is the principle of his process:

Flints are suspended in wire baskets in a boiler of caustic alkali, which is heated to about 300° Fahr., under a pressure of 50 to 80 pounds per square inch. A solution is thus obtained of silicate of soda or potash, (of a specific gravity of from about 1·3 to 1·6.)

This is the cementing substance, the composition of which is said to be

Silica	20·43
Soda	27·05
Water	52·52*
	100·00

One part of this liquid cement is ground up with one part of pipe-clay and one part of powdered flint, which are well mixed in a pug-mill with 10 parts of sand or road-drift. The mixture is pressed into plaster moulds, and is then dried in the air on flat surfaces, to prevent warping. It can now be handled, and is stove-dried previously to being placed in a potter's kiln, where it is heated slowly for 24 hours, and up to a fair red-heat for 24 hours more, and then gradually cooled during 5 days.

This gradual annealing is essential, because the silicate of soda, during the firing, takes up more silica and alumina from the flint and clay, forming a true insoluble glass, which would crack if not properly annealed. The stone is not affected by boiling in nitric acid, which proves that an insoluble glass has been formed.

Sand and road-drift produce a white stone suitable for the face of ornaments, which are backed up with composition made of loam and silicate of soda.

According to the quantity of silicate of soda used, the stone may be either porous or impervious. If sufficient is used to fill up all the interstices between the grains of sand, the stone will be impervious. Some of Mr. Ransome's stone has been exposed for two years to the weather without the sharp edges being in the slightest degree injured; many porous stones will stand weather and frost better than impervious ones, and it is therefore still a question whether this stone will resist the action of air and rain loaded with sulphurous acid, as is the case in London. Some of the blocks of stone quarried at the island of Portland for St. Paul's Cathedral, and *left there*, are now quite perfect, whilst the stones in the Cathedral have become very much decayed.

Mr. Ransome in his patent, 22d October, 18[illegible], merely directs the stone to be dried at 212° Fahr., or at a higher temperature, and does not say any thing about *baking* it; he directs about one-sixth part of the silicate to be used in the mixture.† It was stated at the Institution of Civil Engineers, that slabs of 7 feet long by 9 in. × 3 in. had been made perfectly flat and true, and that the reason they did not warp was, that the particles of sand were in contact with one another, and the cement only filled the interstices. If, on the contrary, too much cement were used, the shrinking of the cement would warp the slabs. Square blocks of this stone, we believe, may be procured for 3s. per cubic foot in favorable localities for the materials, fuel, &c., but the principal application for which it is intended is for ornaments, as mouldings, rosettes, coats of arms, mullions, &c.; for elaborate forms may be given to it at very little more expense than is required for the simplest form. Terra cotta has been used for these purposes, but it warps in baking, and produces so many waste pieces that it becomes more costly and is less correct than stone worked by hand in the usual manner.

* Faraday, however, states the amount of water to be 75 per cent.

† See Chem. Gazette, vol. [illegible], p. 364.

Mr. Buckwell has also proposed a plan for making large masses, slabs, and pipes from stone and cement; but his invention does not apply to the manufacture of cubical blocks.

He uses fragments of stone as large as will go freely into the mould, mixed with other smaller fragments, of various sizes, to fill up the interstices as much as possible, the remaining space being occupied by the cement, composed of chalk and Thames mud burnt together.

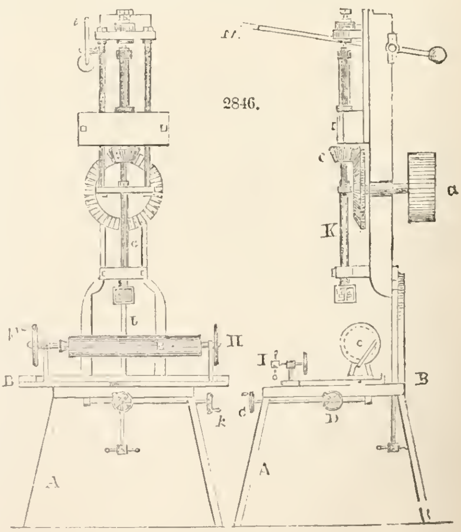
One part of this cement is mixed with eight or more parts of fragments of stone, and wetted with the smallest quantity of water sufficient to moisten the whole; a portion of the mixture is then put into the mould to a depth of 1½ inch, and rammed down by hammers or monkeys; another 1½ inch is then added and rammed down, and so on. The mould is perforated, and, although so little water has been used, it oozes out at all parts, showing that the effect of the ramming is to bring the particles of stone into much closer contact than could be done by any *simple pressure*. When taken out of the mould, the stone is hard enough to ring, and is fit for use in two days; it becomes still harder by exposure to air or water for some months.

New Portland stone fragments cannot be used for this conglomerate, because they crush into powder under the hammer; old Portland stone, which has become hardened by exposure, answers very well, and makes an artificial stone of greater specific gravity than Portland stone itself. The cement is harder than the Portland stone. Flaws, repaired by the mixture laid in with a trowel, are much softer than the cement in the body of the stone which has been consolidated by the ramming. The moulds are made of metal and are very expensive, which prevents the material being applied to ornamental purposes.

Separate pieces of stone can be joined by well ramming or caulking in the composition between them. For this purpose, of course, the pieces should be firmly fixed before beginning to caulk between them. Mr. Buckwell states that he could execute entirely in his artificial stone the ordinay system of sewage, with improvements, at the same cost as the present mode of executing it in bricks. It may, therefore, be doubted whether it would be advisable to employ it. A new arrangement of sewage, which he proposes, would cost $12 in his stone, for what would cost $75 in brick-work; but it does not as yet appear why, in one case artificial stone should cost as much, and in the other only one-sixth the price of brick.

An illustration of the effect of percussion in consolidating materials may be taken from the fact that *concrete*, a mixture of gravel and lime, sets harder and better the greater the height from which it is allowed to drop into its place: in building the Royal Exchange, it was shot in from a platform 30 feet above the foundation. It seems probable that concrete might be rendered still harder by mixing it with rather less water, and ramming it well in its place. In Malta the roofs of the houses consist of flag-stones placed in a nearly horizontal position; over the flag-stones a bed of fragments of stone and a little clay is laid, which is moistened with water, and beaten and rammed until nearly dry; it is then covered with a layer of cement, formed of 4 parts of lime to 3 of Puzzolana, moistened with water, and well beaten down until it begins to dry; this again is covered with a layer of dry stone fragments to prevent the sun from cracking it, which being swept off after a few days, a fine smooth impervious roof is obtained.

Hydraulic fresco-painting.—In conclusion, we must notice a discovery of Fuchs and Schlotthauer, which was lately communicated to the Academy at Munich, and which has reference to a new mode of fresco-painting. While the fixing of the colors in the antique as well as in the modern fresco-paintings is due to the hardening property of caustic lime, when exposed to the atmosphere, the colored surface upon this new method is converted into a silicate of lime. The two older methods stand, therefore, in the same relation to the new one, as ordinary to hydraulic mortar. While fresco-paintings of the former kind are not very durable, (except in cases, as at Pompeii, where their preservation is due to the entire exclusion of light and air,) and artists have reason to mourn over the destruction of the greatest master-pieces; those obtained upon the new principle are capable not only of withstanding the action of water, weak acids, and alkalies, but also the great changes of climate during a severe German winter without injury to the freshness of the coloring; and the colors are so firmly attached to the ground that they exhibit no tendency to separate from it themselves, nor can they be removed by mechanical agency. The particulars of the process have not been made known, but it appears probable that it is dependent upon the silicification of the lime mortar, by means of a solution of an alkaline silicate, of which we have previously spoken under soluble glass.



MORTISING MACHINE. Fig. 2846 represents a mortising machine invented and patented by A. Swingle, formerly of Texas, now of Boston.

A A are the legs, B the bench; C is a set-screw for the out-and-in movement of the bench, and D for the lateral, in any kind of work. E is a hub to be mortised; it is mounted on centres turned by the handle F, and there is a retaining ratchet and wheel H on the nigh side. There is a rest below the hub, operated by a steadying set-screw I. J, inverted, is a hollow augur, or rather hollow chisel within which is the augur; and the movement of the latter is followed by the box-shaped chisel, so that the result is a square hole or mortise. The augur inside receives a very rapid motion from a bevel-wheel, geering into a pinion which drives the spindle K of the augur. *a* is a pulley to drive the wheel O. M is a lever, and by flanges the spindle is made steady to the back of the frame, and works down in guide-collars. When the hub, or whatever it may be, is in a correct position, the spindle K of the augur is set in motion, and the operator gently brings down the weighted lever M, cutting out the rectangular mortise. There is but little work for the outside chisel of the augur to perform.

The lever rests on the top of the spindle, and it (the spindle) works by feather and groove to run down through its geer-pinion, to follow the cut to the bottom of the mortise. These machines are highly recommended by those who have used them.

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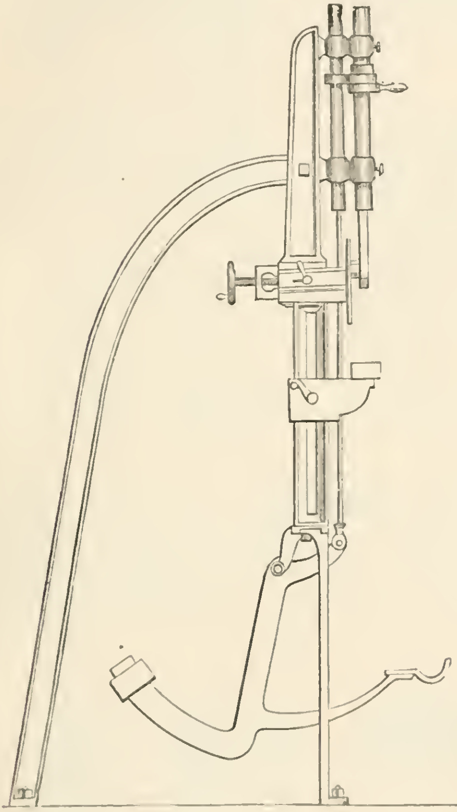

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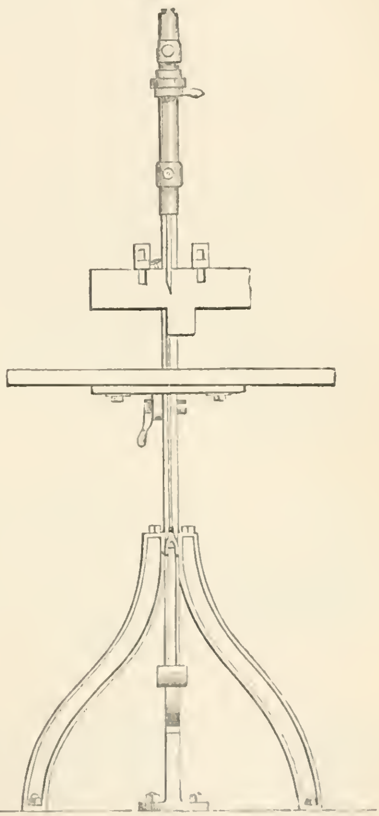

MORTISING MACHINE. Figs. 2847 and 2848 represent a machine manufactured by W. R. & A. Isstar, Newark, N. J., and from the simplicity of its plan it is much less liable to get out of order than others of a more complicate character.

The action of the machine is sufficiently obvious.

MOTION, in mechanics, is a change of place, or it is that affection of matter by which it passes from one point of space to another. Motion is of various kinds, as follows: *Absolute motion* is the absolute change of places in a moving body, independent of any other motion whatever—in which general sense, however, it never falls under our observation. All those motions which we consider as absolute are, in fact, only relative, being referred to the earth, which is itself in motion. By absolute motion, therefore, we must only understand that which is so with regard to some fixed point upon the earth, this being the sense in which it is delivered by writers on this subject. *Accelerated motion* is that which is continually receiving constant accessions of velocity. *Angular motion* is the motion of a body as referred to a centre, about which it revolves. *Compound motion* is that which is produced by two or more powers acting in different directions. *Uniform motion* is when the body moves continually with the same velocity, passing over equal spaces in equal times. *Natural motion* is that which is natural to bodies, or that which arises from the action of gravity. *Relative motion* is the change of relative place in one or more moving bodies: thus two vessels at sea are in absolute motion (according to the qualified signification of this term) to a spectator standing on the shore, but they are only in relative motion with regard to each other. *Retarded motion* is that which suffers continual diminution of velocity, the laws of which are the reverse of those for accelerated motion.

Table of the Analysis of Motion.

Rectilinear motion continued in	Rectilinear	Continued	Figs. 1, 2, 3, 4, 5.
		Alternate	....
	Circular...	Continued	Figs. 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19.
		Alternate	Figs. 20, 21, 22, 23, 24.
Circular motion continued in....	Rectilinear alternate		Figs. 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45.
	Circular....	Continued.	Figs. 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58.
		Alternate...	Figs. 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76.
Alternate rectilinear motion continued in..........................	Rectilinear alternate		
	Circular alternate		Figs. 77, 78, 79, 80, 81, 82, 83, 84, 85, 86.
Alternate circular motion continued in..................	Circular alternate............		Figs. 87, 88, 89, 90, 91.
Supplement..			Figs. 92, 93, 94, 95, 96, 97, 98.

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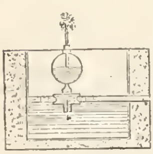

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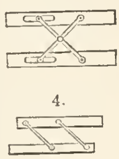

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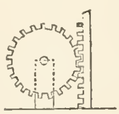

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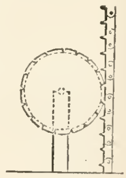

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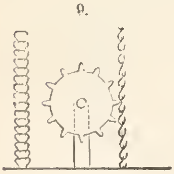

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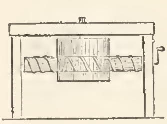

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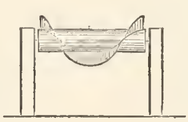

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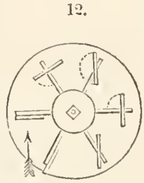

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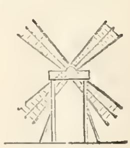

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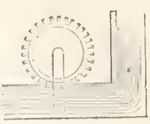

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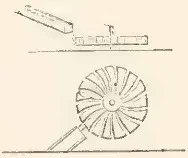

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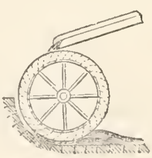

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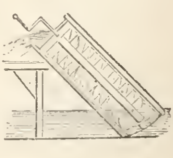

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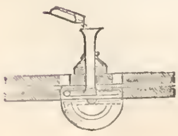

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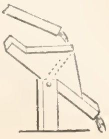

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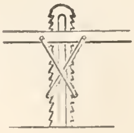

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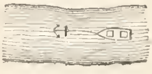

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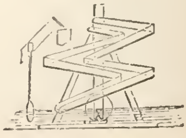

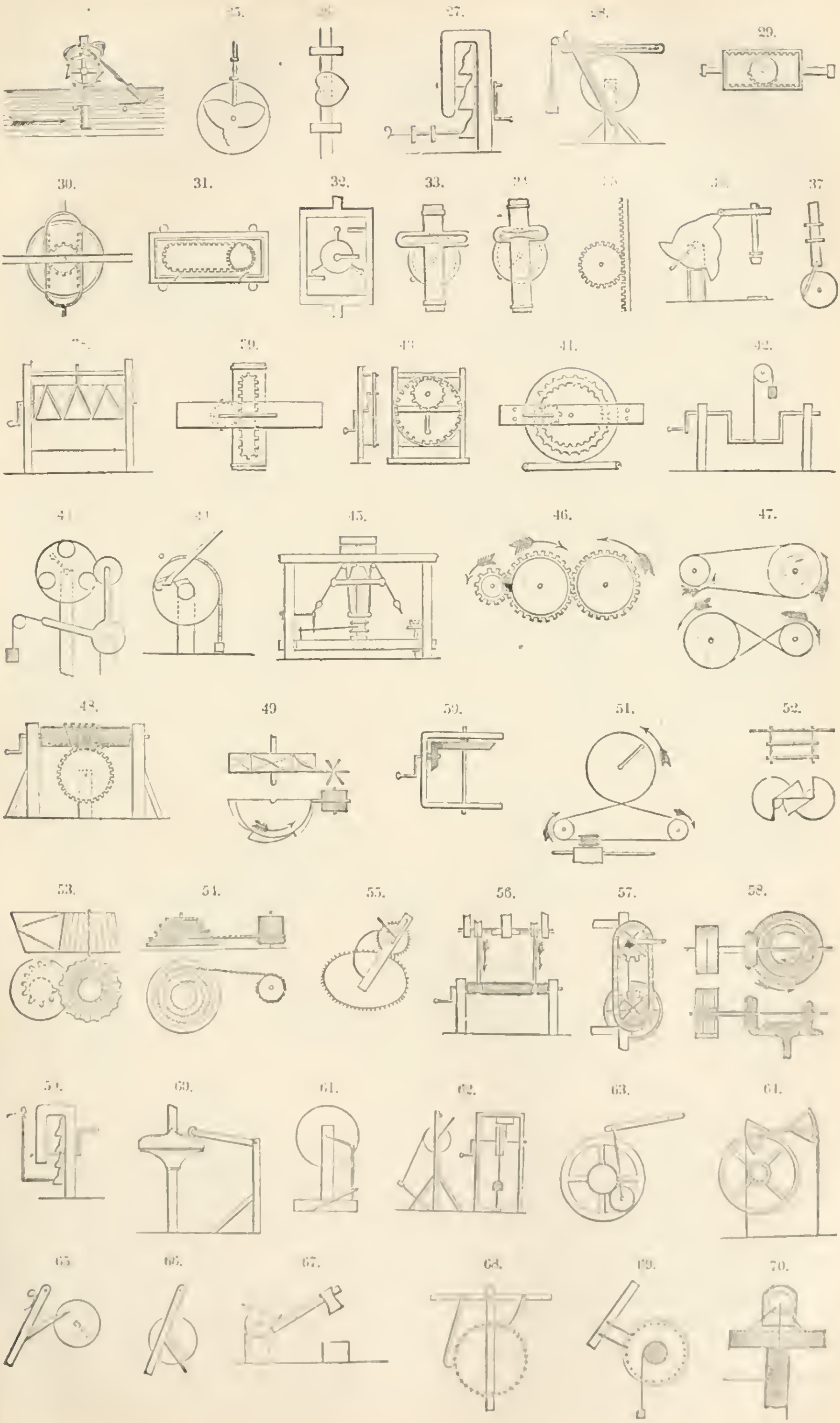
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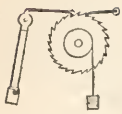
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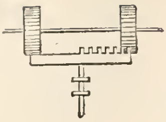
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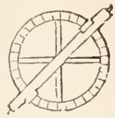
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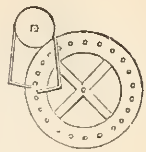

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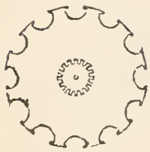
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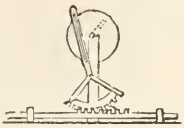
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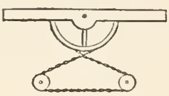
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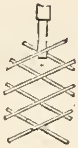
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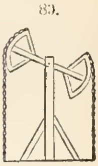

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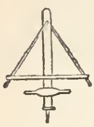
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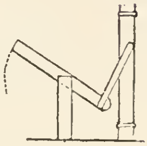
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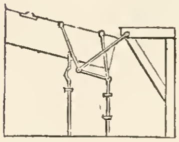
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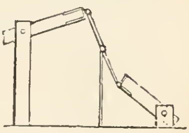

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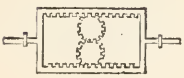
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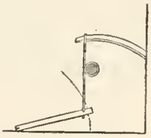
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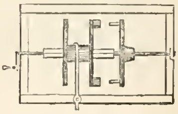

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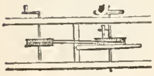
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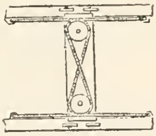
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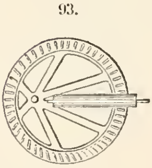
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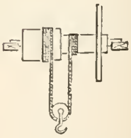

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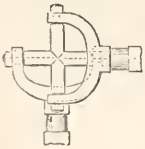
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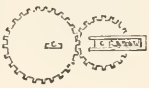
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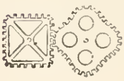
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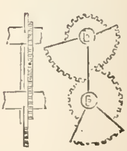
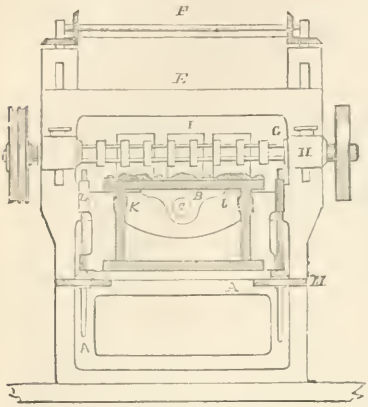


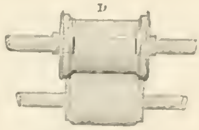
MOULDING MACHINE. This invention consists of certain mechanical arrangements for producing architectural, cabinet, or other mouldings. Our engraving represents an end elevation of the machine, which, with the aid of the letters of reference, will be readily understood. A, is a cast-iron bed-piece with V grooves, and constructed in some respects similar to planing machines now in use for planing iron, &c., having a driving-screw placed in the centre of the bed-piece, so as to give a slow alternating motion to the travelling-table, when power is applied thereto. The ordinary reversing geer is employed, the construction of which is well known; B is the bed or traversing-table which is shown in section, for the purpose of more clearly representing the various arrangements in detail, such as the mode of fastening the planks of wood to the table by the means of lateral clamps inserted in their sides; J J the position of the driving-screws together with the inverted V rail, and standards K K; C is the driving-screw, also shown in section, and which passes longitudinally through the machine from end to end, in geer with the bed or table by a nut, or any other suitable means usually applied to such purposes when reversing. There are two vertical standards, supporting in bearings the bridge E, with the cutter-bars, or mandrils, attached. Each of these standards contains a spring of the same pitch, geering into, and attached to the bridge, so that by turning the horizontal bar F, both screws are made to revolve at the same rate, and the bridge is thereby caused to ascend and descend as may be required; G is a horizontal bar, which revolves rapidly in its bearings H H, and carries a number of cutters or chisels, each having its cutting edge so shaped as to produce the required mouldings, or any parts thereof, which can be produced by revolving cutters on a horizontal shaft. Motion is communicated to this axis by bands from an overhead power-wheel. Its course, after leaving the power-wheel,

2947.

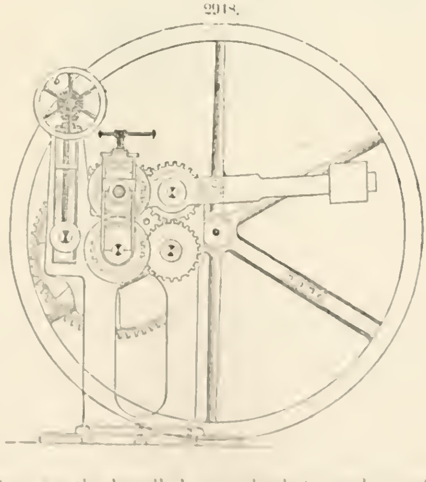


is first directed down to a tightening pulley, which is clamped on to a part of the standard frame on one side, having a vertical slot therein for the purpose of enabling the operators at any time to obtain the requisite tension; it then passes up and over the upper half of one groove of the cutter-pulley, down again at the back, and over the driving-pulley: it is then pressed in at the starting point to make the endless band. I I are the chisels or cutters, which are mounted upon the horizontal shaft G, which admit of being arranged and set up in any convenient or necessary form and number suitable to the production of compound mortises; each chisel being of the most simple form and construction, having its cutting edge shaped to form the numerous mouldings, either simple or compound by either using them separately or in conjunction with each other, as the case may require; L L are bosses cast on the standard on each side and on each end, on a level with the surface line of the bed or table B. These bosses are bored to receive a vertical rod through each, the lower end of which has a thread run upon it, in geer with a nut and a hand-wheel M M, whilst the upper end forms a shackle or forked head, (but which is not shown in the above view,) it being readily understood to constitute merely a single bearing to carry a horizontal shaft from one side of the machine to the other transversely, on which elastic friction rollers are mounted: the object of such bearings being that when a different moulding is to be substituted for the one in the course of formation, the shaft containing the corresponding shaped friction rollers by the mouldings last completed may easily be exchanged for that of any other, by removing it from the forked head in which it revolves. At the back of the bridge E a horizontal and vertical slide is fixed, having a slot parallel to the bed of the machine, for the purpose of carrying two traversing cutter-heads, affixed to which, through the intervention of revolving mandrils, are the cutters which work at any angle to the bed or table, as well as on the same surface level, as the cutters I I. The cutters thus referred to receive their direct motion from the power-wheel over head, independently of other parts of the machine, by an endless rope or chain passing round the wheel mounted in the cutter-heads in such a manner that when this part of the apparatus is not required to work in connection with the other it can be thrown out of geer at any time, even while the running mouldings are in action.

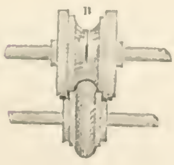
2949.



2948.



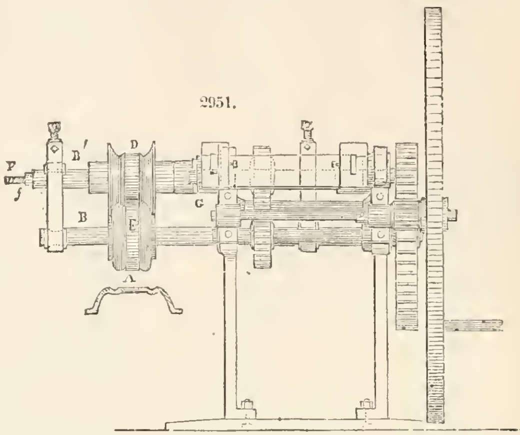
2950.



In connection with the above the inventor uses the bevelled cone wheels to produce rotary motion to give full effect to the cutting tools I I, by the motion of the vertical mandril working in a broad beam the cutter-head, while the work to be cut is held down nicely by vulcanized India rubber rollers. The principal feature in the invention is the revolving horizontal bar, whereby, like borders made of type, the inventor is enabled to make compound and various patterns by simple chisels, by their transposition.

SHEET METAL MOULDING MACHINE, by Mr. R. Roberts, of Manchester. This machine, Figs. 2951-2955, has two shafts B and B', which project beyond one of the side frames in which the lower shaft B turns; the upper shaft B is mounted in a balance swing frame, and is connected by spur geer with the lower shaft in such a way that the distance between the shafts may be adjusted to any re quired extent, without altering the depths of the wheels in geer. On the projecting ends of these shafts, the rollers D E are put, with which the mouldings are to be formed; the lower roller is in one piece only, but the upper roller is made in one or more parts transversely, as may be best adapted to form the required mouldings, as shown in the enlarged figure: the which parts, when more than one, are made to approach each other by being slid along the shaft B′, which is hollow, by means of a screw F that acts within on the back part of the top roller D by means of a cotter, which passes through the shaft and the screw, and on the front part by a nut *f*, which is screwed, from time to time, by hand.

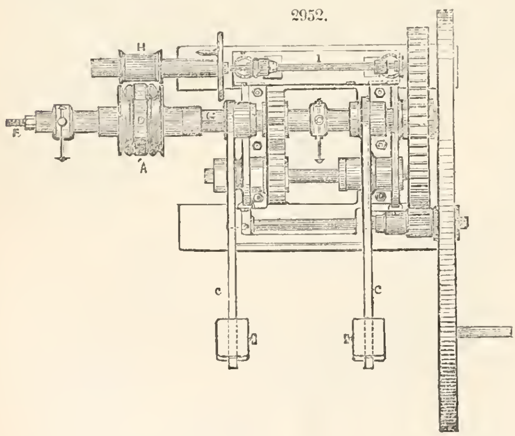
2951.



The advantage of making the rollers in two or more parts is, that it allows the metal to be gradually compressed sideways as well as vertically, and avoids puckering. The curved mouldings shown in the engraving were made on the first machine of the kind that was constructed, and the straight mouldings on a similar machine subsequently made. Almost any degree of curvature can be given to the moulding, by means of the third roller H, which, with its shaft and sliding bearings J, is lowered by the geering *h*, Fig. 2951, in front of the pair of rollers to produce the required curvature.

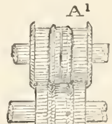
The engravings A, Fig. 2951, and A′, Fig. 2953, are representations of two pair of rollers for forming simultaneously the cap mould of each of the two brass domes for locomotive engines; the rollers A, Fig. 2951, being for the purpose of creasing the metal, and the rollers A′ for finishing the two cap-moulds, which may be afterwards divided in the middle by a lathe or with a saw. Two mouldings are in this case made together, owing to the peculiar form of the moulding rendering it more facile to do so than to make one separately.

2952.



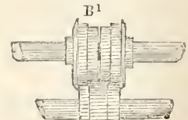
2953.

A^1



2954.

B^1



2955.

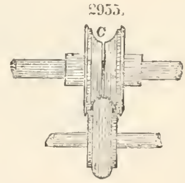


Fig. 2950 and 2954 show two pair of rollers for forming the "astragal," to which the upper and lower plates of the chimney of a locomotive are riveted; the rollers B^1 B^2 are used in the order the drawings are lettered.

Fig. 2953 shows a pair of rollers for forming the "base mould," and Fig. 2949 for forming the body of the brass dome of the locomotive engine, one pair of rollers only being used in both these last mentioned cases.

MULE. A machine employed in spinning cotton and other fibrous materials. For producing fine threads, a process analogous to that performed with carded cotton, upon a common spinning-wheel, and called *stretching*, is resorted to. In this operation, portions of yarn, several yards long, are forcibly stretched in the direction of their length, with a view to elongate and reduce those parts of the yarn which have a greater diameter and are less twisted than the other parts, so that the size and twist of the thread may become uniform throughout. To effect the process of stretching, the spindles are mounted upon a carriage, which is moved backwards or forwards across the floor, receding when the threads are to be stretched, and returning when they are to be wound up. The yarn produced by mill spinning is more perfect than any other, and is employed in the fabrication of the finest articles. The sewing-thread, spun by mules, is a combination of two, four, or six threads. Threads have been produced of such fineness that a pound of cotton has been calculated to reach 167 miles.

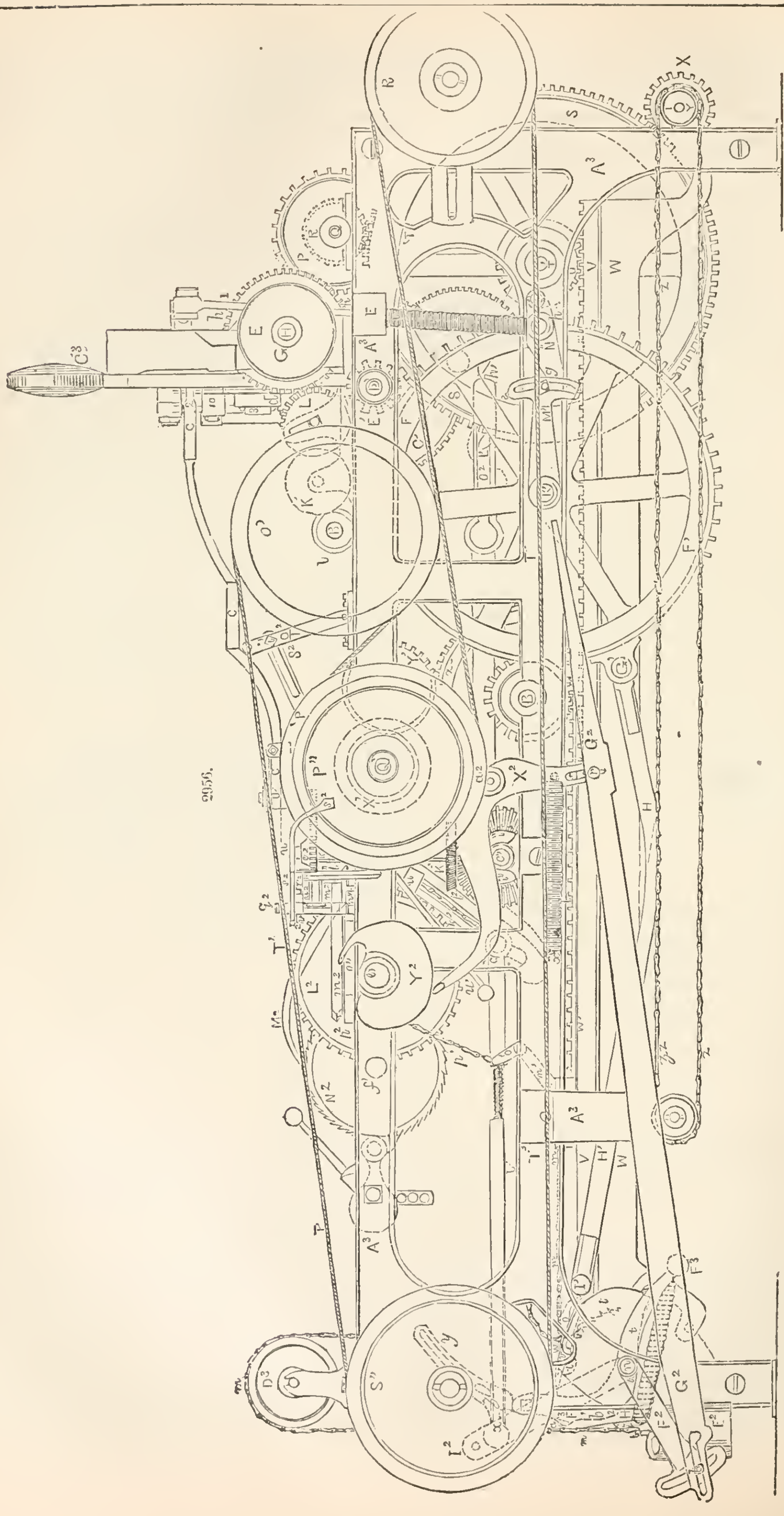
MULE, *Mason's self-acting.* This machine, invented by J. W. Mason, of Taunton, Mass., for spinning cotton and other fibrous substances, stands first in the first class of machines.

Fig. 2956 is an elevation of the mule and carriage. Fig. 2957 an elevation of the other side. Fig. 2959 a plan. Fig. 2960 an elevation. Fig. 2961 a longitudinal vertical section, taken through the line X X of Fig. 2959. Fig. 2963 a front elevation. Fig. 2962 a section through the friction-clutch. Fig. 2958 a separate view of the scroll or volute cam. Fig. 2964 a cross section of the head. The same letters indicate like parts in all the figures.

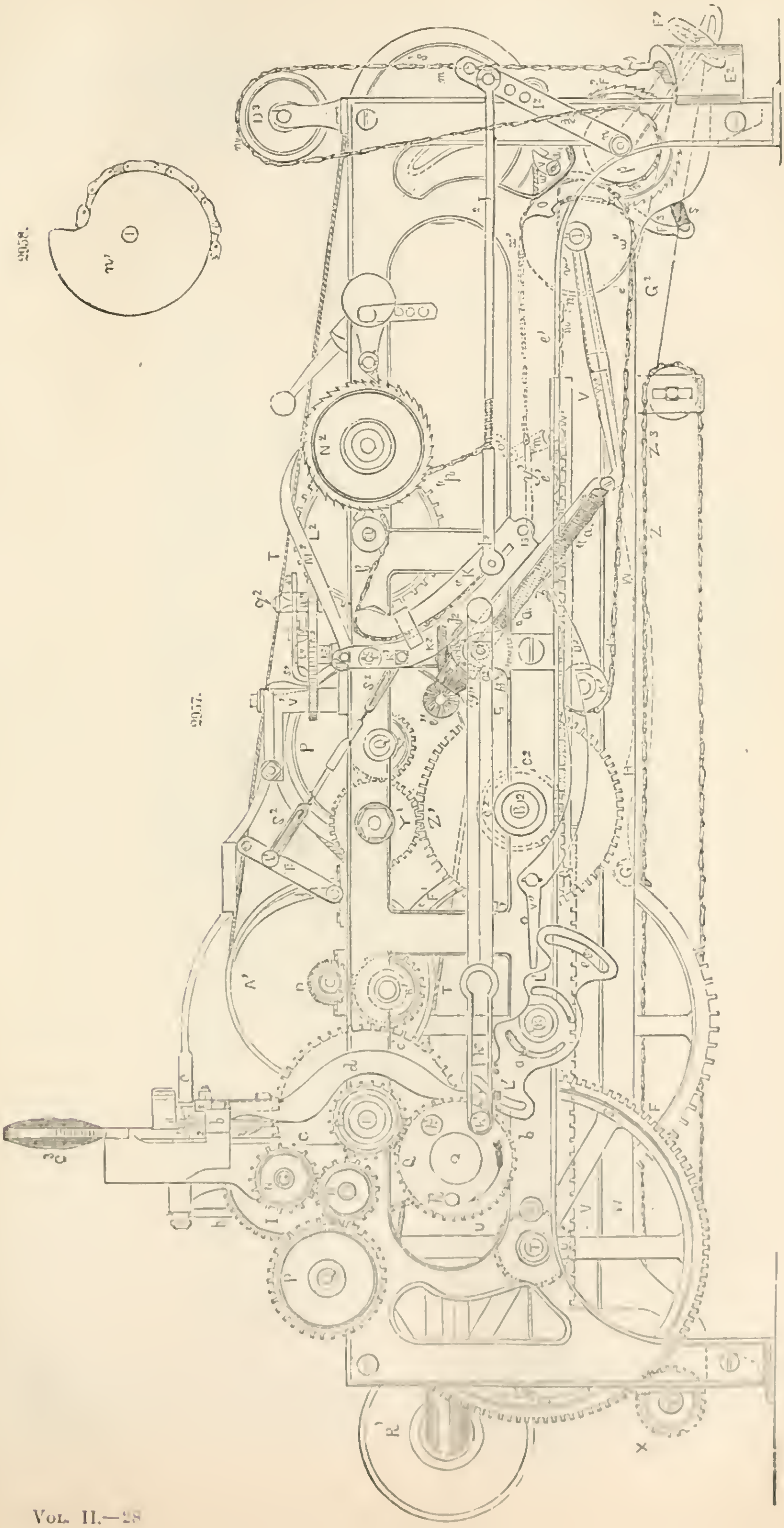
A^3 represents a frame properly adapted to the operative parts of the head; the carriage is not represented, as it is similar to those of other mules.

A A′ A″ three pulleys of equal diameter, placed side by side on the main shaft B′. A is the first fast pulley attached to and turning with the shaft B. A′ is the second fast pulley, carrying a pinion D, and turning freely on the shaft B. A″ a loose pulley placed between the other two, and turning freely on the shaft. A driving-belt passes over these pulleys, and is guided to either of them by a shipper-lever C, that vibrates on a stud-pin U, and connected with a weighted balance-lever C^3 by which the belt is moved from one of the pulleys to either of the other two. At the commencement of the first series of operations, the belt runs on the first fast pulley A′, to give the first series of motions. The pinion J, on the shaft B, communicates a positive and regular motion to the shaft G (which is in connection with the draw collars in the usual manner) by means of the first train of wheels K L I, and from the shaft G by the second train of wheels N O P R S X, to the line shaft Y that drives the carriage by means of endless chains Z, connected with the carriage by one of the links, Z^3. There is but one of these chains represented in the drawings, and the shaft is shown broken off, as the connections with the carriage present nothing new, and therefore need not be represented. The spindles at the same time rotate by the usual band T, driven by the pulley O′, on the same pulley shaft B. This completes the first series of motions, namely, drawing out the carriage, turning the draw rollers and spindles to draw out, spin, and twist the threads. Near the end of the running-out motion of the carriage, the belt is shipped from the first fast pulley A to the loose pulley A″, which removes the driving power from these motions. The shifting of the belt is thus effected: the weighted balance-lever C^3 is jointed to the shipper-lever at 2, above the stud-pin 3, on which it vibrates. The lower end of this balance-lever is T-shaped, and one of its short arms is joined by a link 4, with a short lever 5, that turns on the stud-pin 6. This lever is also connected by a link *d*, with another lever *p*, that turns on a stud-pin *e*, and this last lever is depressed when the belt is to be shipped by means of a pin *a*, on a vibrating arm L′, on the shaft K′ of the wheel that carries the connecting-rod by which the carriage is run in. The balance-lever is by this means carried a little beyond the vertical line, and then carried entirely over by the weight of the lever C^3. On this shaft, K′, and on the opposite side of the frame, there is another arm M′, provided with a pin *g*, which at the same time depresses another lever N′, connected by means of a jointed rod *h*, with an elbow-lever 7, that moves a clutch M on the shaft G, by means of which the cog-wheel I is clutched, which liberates the draw rollers and the second train of wheels that communicate motion to the carriage from the parts that drive the spindles. The clutch M is held open until the belt is again carried to the first fast pulley at the end of the third series of motions by a pin *j*, on one arm of the balance-lever C^3, which bears against one side of the arm of the clutch-lever 7, for the lever N′, that moves the clutch-lever, is provided with a helical *c*′ attached to it and the frame, for the purpose of forming the clutch the moment that the pin *j* of the balance-lever C^3 liberates the clutch lever 7. The band T′ that carries the spindles, and which, as we have before stated, passes round and is carried by the pulley O′ on the main shaft B, passes around a guide-pulley R′ at one end of the frame, and another S′ at the other end, and also around another pulley P′ that runs freely on a shaft Q′ which slides endwise on its bearings and on the friction pulley, which is prevented from sliding endwise with the shaft by a collar S, so that when this shaft Q′ is moved in one direction, the pulley P′ is clutched to it by the friction of the conical surfaces, and when moved in the reverse direction it is unclutched and turns freely on the shaft. This clutching and unclutching is effected by an arm Z^2, Fig. 2961, on the spindle U′ of the shipper-lever C, which embraces a collar on the shaft Q′, so that when the shipper C shifts the belt from the first fast pulley A, it at the same time gives the requisite movement to clutch the friction-clutch that connects the spindles with the shaft Q, which will be carried by their momentum; and as this shaft is connected by the train of wheels X′, Y′, Z′, and C‴, with a horizontally sliding rack W′, the rack is carried for a short distance in the direction of the arrow, Fig. 2961. When the shipper transfers the belt from the first fast to the loose pulley, a clutch D^2, Fig. 2961, on the shaft D^1, is shifted by the forked lever *f*, which turns on the stud pin 10, and is worked by a spur 11 on the balance lever C^3, which bears on the end of the volute spring 12 attached to the lever *f*, the tension of which forces the sliding part of the clutch against the permanent part. The sliding part of the clutch is feathered to the shaft D′, which is carried by a train of wheels C′ B′ and pinion D on the second fast pulley A′, driven by the driving belt when it is shifted by the shipper that carries it from the first fast pulley A to the loose pulley A″ and then to this: the time required for this transfer of the belt by the motion of the shipper being sufficient for the preparative movement.

So far it has been shown that the second fast pulley carries the shaft D′ of the clutch D^2 a part of a revolution before clutching the pinion E′ which geers into the wheel F′ that runs the carriage in, (as will be hereinafter described,) this period of time being required to enable the momentum of the spindles to run back the rack *u* preparatory to the backing-off motion. As the rack *u*′ is carried by the momentum of the spindles in the direction of the arrow preparatory to the backing-off motion it is necessary gradually to arrest this motion, which is effected by a friction spring brake constructed and connected with the rack in the following manner. To the end of the rack is attached a chain *m*, which passes over a pulley *o*, and then around a spur wheel *p*, attached to a ratchet wheel H^4, and with it turning freely on a rock shaft *n*; and then it passes over another loose pulley D^4, and to the end of it is suspended a tension weight L^4, which takes up the slack of the chain. On the said rock shaft *n*, and

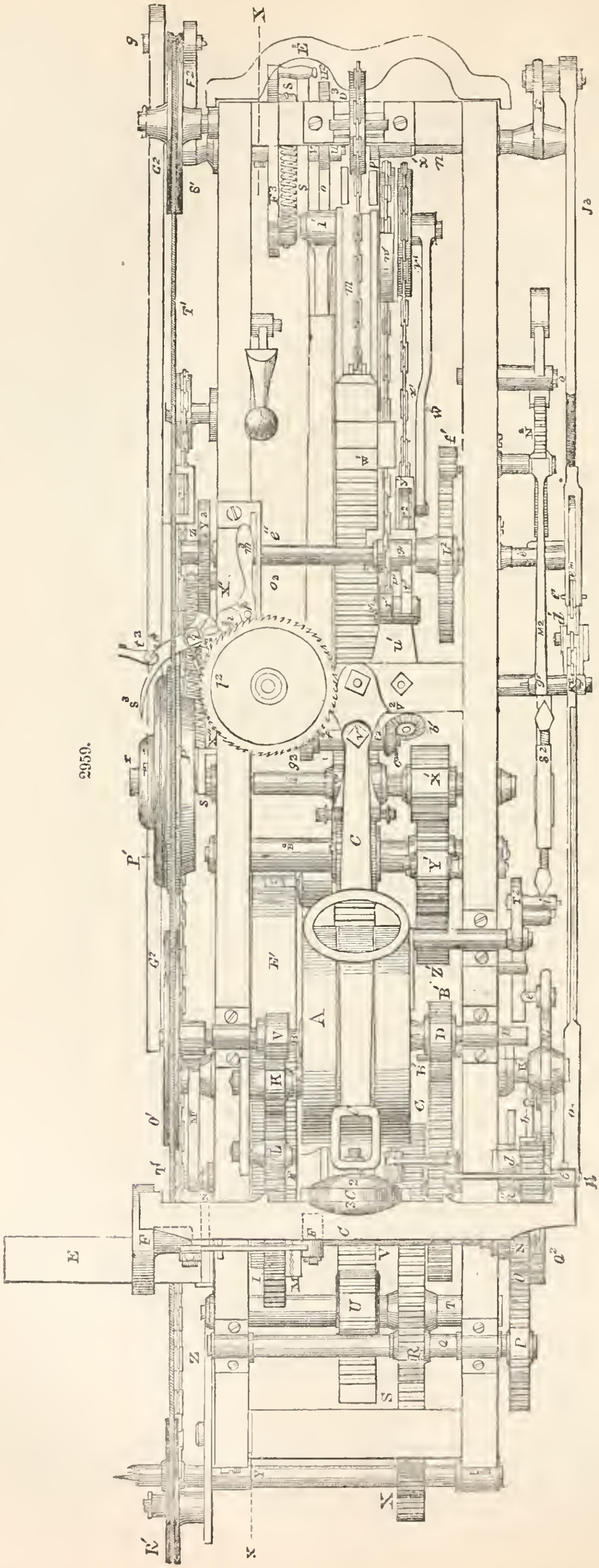


2956.



2958.

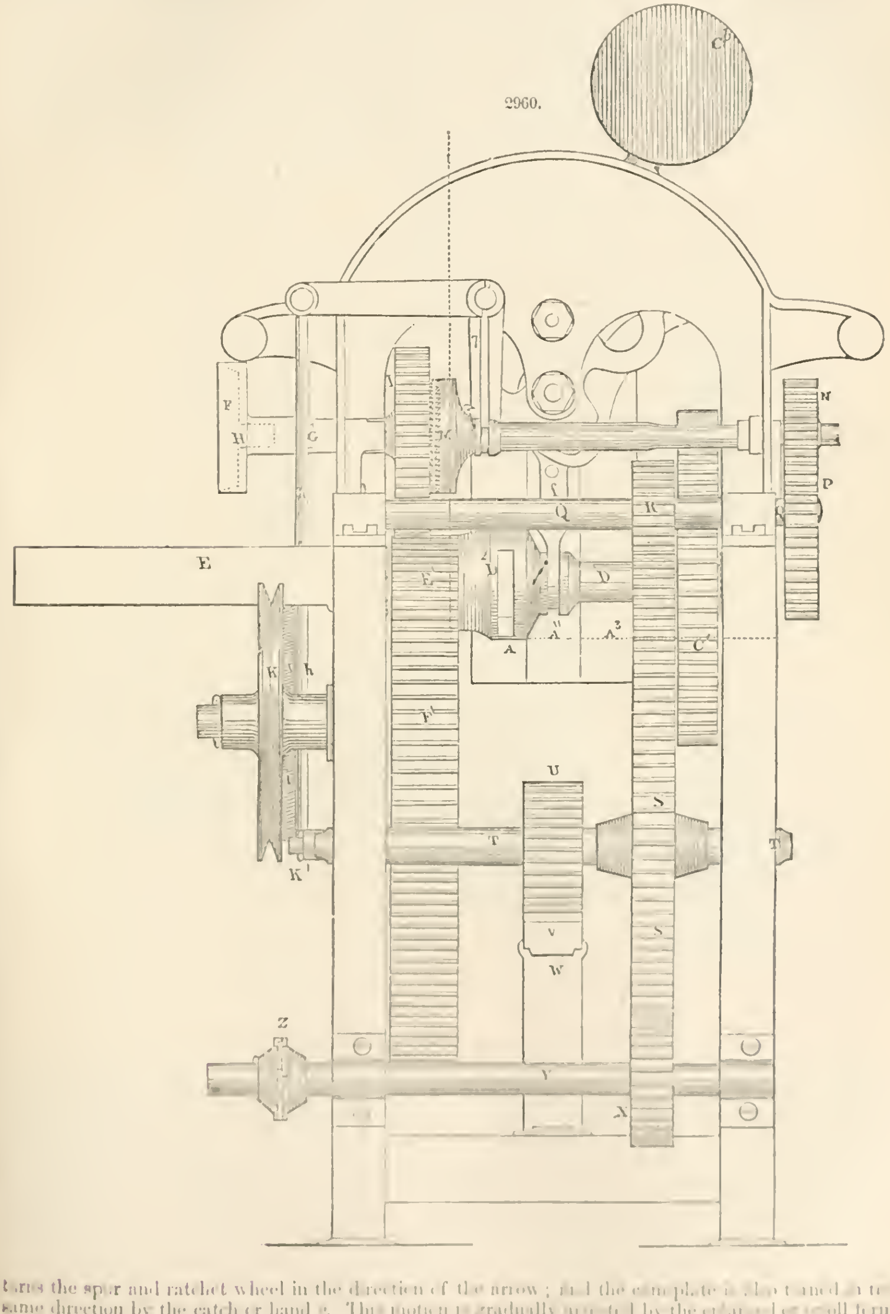
2957.



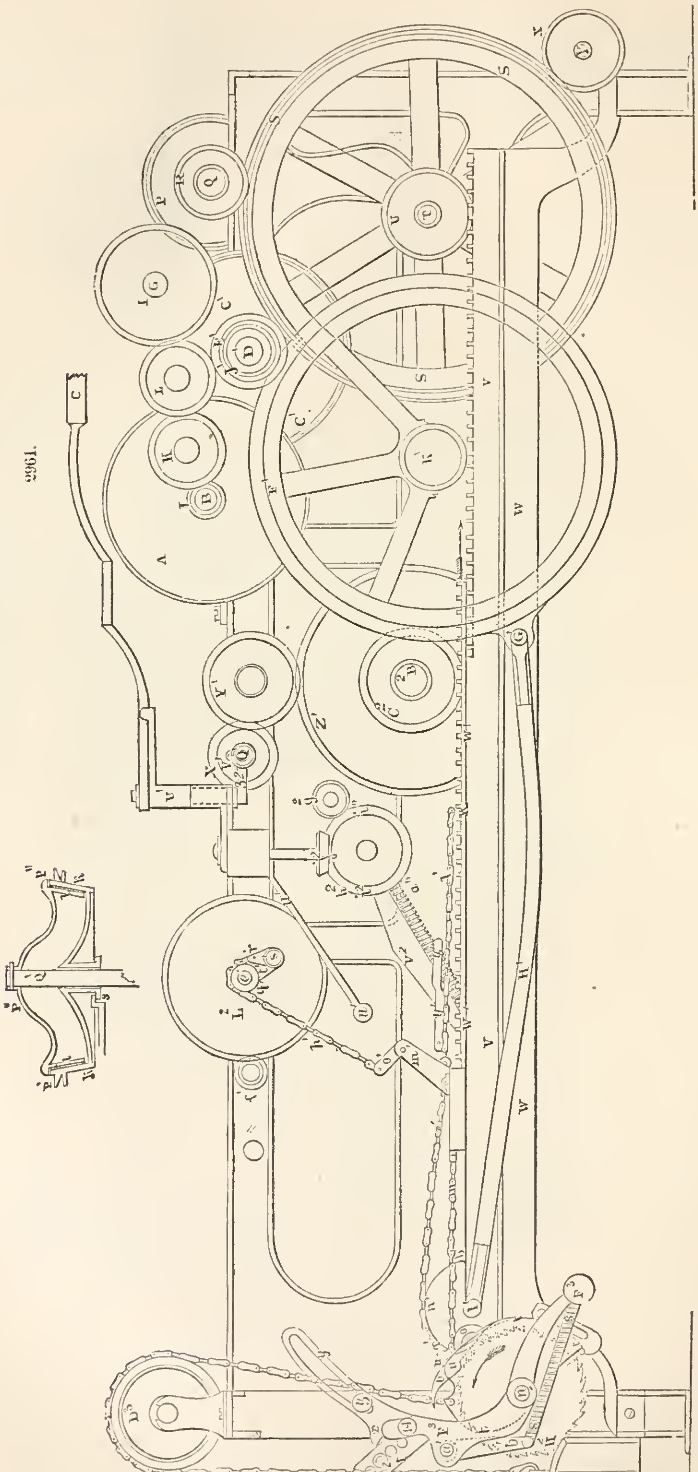
2959.

by the side of the ratchet-wheel, there is a cam-plate *t*, that also turns freely on the shaft, and which is carried in one direction by the ratchet-wheel, when the catch or hand *v*, which is jointed to the cam-plate, takes into the teeth of the ratchet, the two turning independently of each other in the reverse direction, or in the same direction when the catch or hand is lifted out of the teeth. When the rack is drawn by the momentum of the spindle in the direction of the arrow, the chain *m* attached thereto

2960.



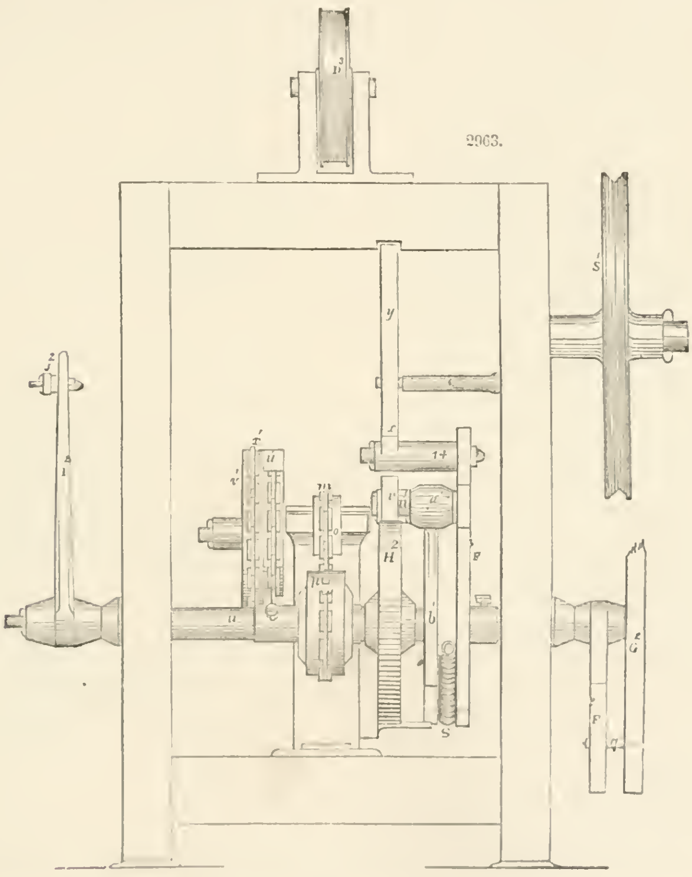
turns the spur and ratchet wheel in the direction of the arrow; and the cam-plate is also turned in the same direction by the catch or hand *v*. This motion is gradually arrested by the enlarged or scroll form of the cam-plate, which forces out a friction arm *b'*, one end of which is jointed at *a'* to an arm of a lever F^3, attached to the rock-shaft *n*, the other arm of this lever being connected with the friction *b'* by a helical spring *s*. It will therefore be perceived that as the friction arm is forced out by the cam



2961.

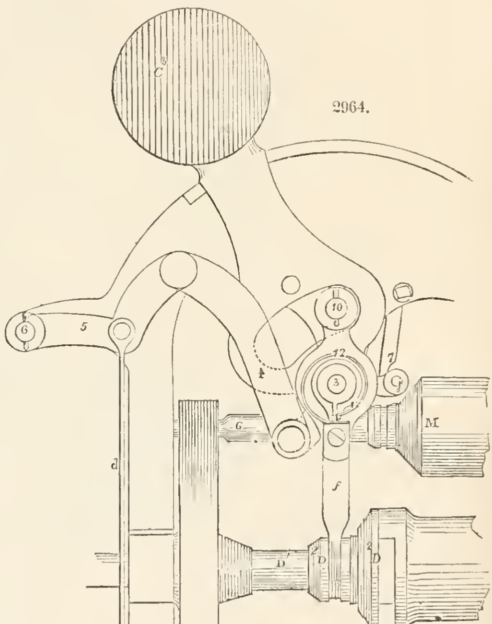
2962.

plate, the tension of the spring increases the friction of the brake on the periphery of the cam-plate, which gradually arrests the motion of the parts in connection with the rack W, and of necessity the spindles. When these parts are arrested the rock-shaft n is turned in the opposite direction, and carries with it the cam-plates, ratchet-wheels, and spur-wheel by the pressure of the brake, and of necessity reverses the motion of the rack and spindles to uncoil the threads from the spindles. At the end of this motion the catch v of the cam-plate is liberated from the ratchet-wheel H^2, by a spur x, of a lever y, jointed at 14, by the arm F^3, of the rock-shaft n, the spur being forced on to the back end of the catch by the rotation of the rock-shaft; the lever y having a slot in it which turns and slides on a permanent rod z. This reversed motion of the rock-shaft n is effected by a crank motion in the following manner, viz.: The pinion D, on the second fast pulley A, commences motion by the train of wheels B, C, and R^2, to the wheel Q^2, in the direction of the arrow, and this wheel carries a crank-pin h', that works in a slot h^2, of a connecting-rod O^2, jointed to a curved arm K^2, that vibrates on a fixed stud-pin 15, and this arm has a slot in it which works a slide e', for the purpose of graduating the backing-off motion and to this slide is jointed another connecting-rod J^2, the other end of which is jointed to the



2963.

arm I^2, of the rock-shaft n. At the time that the driving-belt is shifted to the second fast pulley A', which takes place whilst the momentum of the spindle prepares the parts for the backing-off motion, the crank-pin h' is at h^3, a little above a line passing from the centre of the wheel to the junction of the connecting rod O^2, and the arm K^2, so that the crank pin in this wheel can move around to the position represented in Fig. 2957 before it begins to draw the connecting rod to give time for completing the preparation of the parts for backing-off. In rotating from h to h^4, the crank pin carries the connecting-rod the required distance to give the required backing-off motion to the spindles to uncoil the thread, and at the same time depresses the faller to guide the threads to the cops preparatory to winding on by means of the coping rail or former G^2, one end of which is connected by a slot with a wrist q, on an arm F^2, of the rock-shaft n, the elevation of which, by the backing off motion of the rock shaft n, depresses the faller. So soon as the connecting rod O^2 has been carried to the point h^4 by the crank-pin, which is the extent of the backing-off motion, the catch-lever U^2 takes hold of the pin 13, on the arm K^2, and there holds all the parts of the backing-off operation until released towards the end of the running motion of the carriage, the liberation of the parts being then effected by means of a pin l', on the arm L, on the shaft K, of the wheel F, which runs in a carriage. So long as the backing-off apparatus is held by the catch-lever U^2, the crank-pin h' can revolve freely, the slot in the connecting-rod O^2 admitting of this. When the backing-off apparatus is liberated it falls back to the position indicated in the drawings by the weight of the coping-rail and the other parts attached to the rock-shaft; and to prevent jar this return motion of the parts is eased off by the connecting-rod O^2 coming against the crank-pin h, at the point h^3, the power required to turn this train of wheels in the reverse direction being sufficient to ease off and gradually arrest the moving parts without jar. This return motion of the backing-off apparatus at the same time arrests the second fast pulley A, and the train of wheels in connection with it by means of a brake j', connected by the arm T^2, and link S^2, with the arm K^2, of the backing-off apparatus, and the train of wheels and the connection of the brake are so regulated as to stop the crank pin h' at the point h^3, where it is required to be when the second series of motions is commenced. The link S^2, and the connecting-rod J^2, are provided with adjusting-screws for the proper adjustment of all these parts. As the backing-off motion must be gradually decreased as the cop is formed and increased in length, the vibrating motion of the rock-shaft is gradually shortened by means of the slide e', in the arm K^2, to which the connecting-rod J^2 is jointed. For this purpose the slide is attached to a chain d, which passes over the upper end of the arm, and is gradually wound up on the arbor e'', of a cog-wheel L^2, that geers into a pinion L', of a ratchet-wheel N^2, which receives motion from the arm K^2, of the backing-off apparatus by a hand or catch M^2, jointed thereto at z'. It will be evident that as the slide is drawn up by the chain towards the axis of motion of the arm K^2, the motion of the connecting-rod J^2 will be diminished, and with it the motion of the backing-off apparatus. This completes the second series of motions, and the mule is then in a condition to commence the third series.



2964.

When the clutch D^2, at the end of the backing-off motion, clutches the pinion E′, it begins to turn, which communicates motion to the cog-wheel F on the shaft K, or to the periphery of this wheel at G is jointed a connecting-rod at H; the other end of which at I is jointed to a horizontal sliding-rack V, that runs on ways W that carries by means of the pinion U the train of wheels that communicate motion to the carriage. The wheel F is carried but part of a revolution (nearly one-half) in one direction by its connection with the second driving-pulley A when the clutch D^2 is closed, which gives by the crank motion, in consequence of the connection above pointed out, the peculiar running-in motion to the carriage, as pointed out in the description of the general characteristics of this invention; and as the carriage approaches the end of its running-in motion, the pinion E is unclutched by the reversed action of the shipper-lever C^3; this reversed motion of the shipper and its appendages being effected by the pin e on the arm L of the shaft K of the wheel F′, this pin e being on the side of the shaft K opposite to the pin a which first ships it. The unclutching the pinion E leaves the wheel F free to be turned back by the reversed motion of the rack V by the train of wheels which runs out the carriage in the first series of motions.

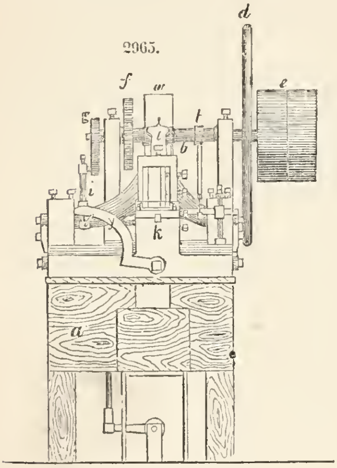
As the carriage is run in by the means just described, the spindles must be turned to wind up the threads which have been spun during the first series of motions, and this is effected by means of the top sliding-rack W, by which the backing-off motion is given, and which is placed on top of the main rack V; the connection of this rack W with the spindles by means of the friction-clutch having been described, it is only necessary to the manner in which the winding-on motion is communicated to it by the main rack V, and the manner in which this motion is varied and regulated to correspond with the varying size of the cops as they are formed. To the upper rack W, and near one end of it, is jointed a lever m, to the short arm of which is attached a chain l', which thence passes around a pulley k that turns on a stud-pin projecting from the side of the main rack V, the other end of the said chain being attached to the smallest diameter of a scroll-cam n' connected with the end of the main rack V. From this arrangement it will be obvious that if the cam n be prevented from turning on its axis, the motion of the main rack V will carry the top rack in the same direction, and with the same varying velocity, which would give to the spindles a winding-on motion, corresponding to the running-in motion of the carriage, such as would be required if the cops were to be formed cylindrical and did not vary in diameter; but such is not the case, as clearly pointed out in the general description. To give the varying motions required, and fully pointed out above, the scroll-cam n' is attached to and turns with a wheel v' on the stud-pin I on the main rack V, and to this wheel at w is attached a chain x', which, after passing around a portion of the circumference thereof is attached by a link y' to a slide z'' that travels on a screw a'' that turns in the arm V^2 of a rock-frame V^3, the lower end of the said arm being jointed to another arm of equal length W^2 that vibrates on the stud-pin I, on which turn the wheel v' and the cam n, so that when the slide z'' is at the lower end of the arm V^2, the end of the chain x', which is attached to the slide during the movements of the main rack, will not communicate motion to the wheel v and cam n, hence the motions of the two racks V and W will correspond and give to the spindles the motion required for winding the threads on the naked spindles, and as the base of the cops is increased in diameter, the slide z'' is drawn up towards the axis of motion of the arm V^2 to decrease the motion of that end of the chain x' attached to it, which will cause the wheel and cam to turn on their axis, and thus give out the chain l', thereby giving to the top rack W', and consequently to the spindles, a gradually reduced motion relatively to the main rack to correspond with the increased diameter of the base of the cops. The motion required is given to the slide z'' by the vibrations of the rock-frame V^3, the screw a'' that operates the slide being connected by a train of cog-wheels b'' c' z' h' i' j' with a horizontal ratchet-wheel l'' which turns freely by the rocking motion of the frame V^3 in one direction, and which therefore does not turn the screw, but which is prevented from turning in the opposite direction, during the running motion of the carriage, by a catch or pawl r'' to turn the said screw. Whenever the tension of the threads in winding on is too great it bears down the counter-faller, (not represented in the drawings,) the arm of which in motion of the carriage strikes an arm S' of what is termed a butterfly, that turns on a stud-pin q'', on which the catch or hand r'' of the ratchet-wheel l^3 also turns, and with which it is connected by a spring w^2, Fig. 2956, and throws it into the teeth of the ratchet-wheel; the wheel being thus held, the further vibration of the rock-frame turns the screw and carries up the slide to reduce the motion of the spindle, and on the return motion of the carriage the hand or catch r'' is thrown out of the teeth of the ratchet-wheel by the arm of the counter-faller, which then comes in contact with another arm t^2 of the butterfly, the end of which extends lower down than the arm S^2, and low enough to be struck by the arm of the counter-faller when it is not under the action of the tension of the threads. The catch or hand then remains out until the tension of the threads again requires the motion of the spindles to be reduced. The butterfly is connected with a hand-latch lever m^2 that turns on a stud-pin n^2, by which the attendant can throw the butterfly in and out of play. So soon as the base of the cops have been formed the scroll form of the cam n' gives the regular varying motions to the spindles to wind the cone of the cops, as fully pointed out in the general description.

It has been stated that in finishing the cops the threads are wound on harder at the point of the cops; this is effected in the following manner: On the shaft e'' which regulates the backing-off motion, as described above, there is a hub q' from which projects a crank-arm t', to the pin S' of which is jointed, by a link r', a chain p', the other end of which is jointed by a link O' to a long arm of the lever m', which forms the connection between the top rack W and the chain l', which forms the connection between the top and the main racks. This shaft, as heretofore described, is connected with the ratchet-wheel N^2, which is operated by the catch or hands M^2 of the lever K^2 of the backing-off apparatus, and the chain p' is of such length that it is wound up by the rotation of the shaft until towards the completion of the cops, at which time it is drawn sufficiently tight to strike against a permanent arm u' towards the end of the winding-on motion, which causes the lever m' to turn on its axis, and by its connection to draw up the chain l, and hence to increase the velocity of the rack W, and therefore the rotation of the spindles, which winds the threads on tighter. This operation gradually increases to the completion of the cops.

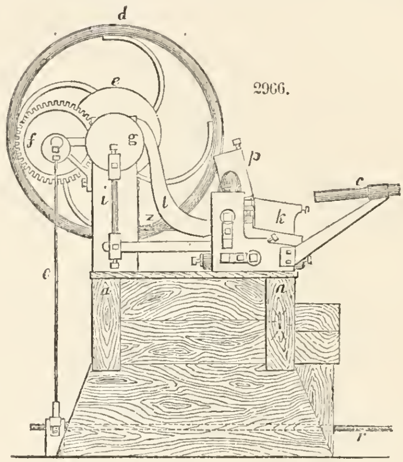
On this same shaft e'' is placed the coping-cam Y^2, the periphery of which acts on the lever X^2, to which the coping-rail or former G^2 is jointed at r', in a manner well known to those who are acquainted with the construction of self-acting mules, and which therefore needs not to be described. This completes the whole series of motions; but it will be obvious that when one set of cops have been completed the parts employed in giving the progressive movements, such as the shaft e'' that rotates the coping or forming-cam Y^2, winds the chain which carries the slide c' of the backing-off apparatus, and the arm t' that winds the chain p' to increase the tension of the threads in finishing the points of the cop, and also the ratchet-wheel l^2 which governs the motion of the slide z'' on the arm V^2, by which the winding-on motion of the spindles is regulated to form the base of the cops, are to be turned back by hand to their original position by the attendant, preparatory to commencing a new set of cops.

I have thus described the general plan of my invention, and the manner of constructing and using the same; but before pointing out what I claim as my invention, I wish it to be distinctly understood that I do not limit myself to the precise form and construction of the various parts employed, or to the precise arrangement described, as I consider all mechanical equivalents as within the limits of my invention. What I claim, therefore, as my invention, and desire to secure by Letters Patent, is, 1st. The disconnecting of the mechanism employed in running out the carriage and turning the draw-rollers from the mechanism which gives the whirling or spinning motion to the spindles when the driving power is shifted from these the first series of motions to enable the spindles to continue their motion by inertia, independent of the other motions, by means of the clutch box or its equivalent, which forms the connection between the three movements, constituting the first series of motions, whereby the momentum of the spindles can be employed for preparing the parts for the backing-off motion, substantially as described. 2d. The method of preparing the parts for the backing-off motion by means of the momentum of the spindles, by connecting them with the backing-off apparatus by means of the friction clutch or any equivalent therefor, substantially as described. 3d. The backing-off apparatus, consisting of the combination of the top sliding-rack, which communicates motion to the spindles; the rocking-frame with a cam and spring brake, and other appendages, and the connecting-rod operated by the crank a'' substantially as described. 4th. The method of decreasing the backing-off motion to correspond with the increased length of the cops, by means of the slide in the intermediate arm of the connecting-rod, (between the two sections of the connecting-rod,) by means of which the rocking motion of the rock-shaft is gradually decreased, substantially as described, to avoid any sudden strain or jar upon the threads. 5th. The method of communicating the winding-on motion to the spindles from the main rack, which runs in the carriage by combining the said main rack with the top sliding-rack, by means of a chain and scroll-cam, or their equivalents; by means of which combination, in connection with the form of the cam, the motions of the spindles so correspond with that of the carriage as to wind the threads on the conical form of the cops, as described. 6th. The method of varying the winding-on motion of the spindles to form the base of the cops, by means of the slide and chain which vary the motions of the wheel that is attached to and which rotates the scroll-cam, substantially as described, whether the slide be operated by the vibration of the arm on which it slides, or by any other means substantially as herein described. 7th. The method of regulating the motion of the slide that varies the motion of the scroll-cam of the winding-on motion, by means of what is termed the butterfly and its appendages, when this is acted upon by the counter-faller, operated by the tension of the threads, substantially as described. And 8th. The method of winding on the threads tighter at the points of the cops when finishing them, by means of the apparatus which gives to the top sliding-rack an increased motion towards the end of the operation; the said apparatus consisting of a chain, which is connected with a chain that forms the connection between the main and top racks, and which is gradually wound up and strikes against an arm towards the end of the operations of the mule to shorten the connection between the two racks, and thus increase the winding-on motion of the spindles, as described.

NAIL-MACHINE. The manufacture of cut nails is entirely an American invention, and was born



2965.



2966.

in our country, and has advanced, within its bosom, through all the various stages of infancy to manhood; and no doubt we shall soon be able, by receiving proper encouragement, to render them superior to wrought nails in every particular.

The nail-machine now extensively in use in this country for all sizes of cut-nails is exhibited in the following figures, and is the machine in operation at Z. B. Crooker's Nail Works, in Brooklyn, L. I.

Fig. 2965 represents the front elevation of the machine.

Figs. 2966 and 2967 side elevations.

Fig. 2968 side and end elevations, showing the method of turning the nail-plate.

Fig. 2969 a general plan of the machine.

a a, frame of the machine; *b*, main-shaft for carrying the cams, driven by a belt over the pulley *e*, and provided with a fly-wheel *d*; *c*, guide which consists of a metal tube through which passes the nail-rod, holding by means of pincers the nail-plate A, Fig 2967. and enlarged view A, Fig. 2968.

2967.

In order to give the wedge-shape required in the brad or cut-nail, the cutter is set oblique to the direction of the nail-plate, which is reversed after each cut, by which means each and every nail has a uniform taper. The reversing of the nail-plate is effected by means of a rocking-shaft *r*, which receives its motion from the shaft through a geering *f*, and crank, producing an alternating motion to the segments *v*, Figs. 2967 and 2968, which is communicated to the guide-tube *c*, by a belt and pulley, the nail-plate being fed to the cutter by means of a weight *m*, as shown in Figs. 2967 and 2968, the nail-rod with its attached plate vibrating freely within the guide-tube *c*.

The cutter, having the width of a nail-plate, is adjusted by screws to the cutting-block *p*; the nail-plate A, lying between guides, rests on the iron block *k*, and bearing by the action of the weight *m* against the face of the cutter. The vibratory movement of the latter is effected by means of the crooked lever *l*, worked by an eccentric on the main-shaft—the cutter-block *p*, forming the short arm of this lever, has a short circular movement about their common centre. The lever *b*, cutter-block *p*, and the axle arms or trunnions upon which they work being all cast in one piece, are shown in Figs. 2965, 2966, 2967, 2969.

y, Fig. 2965, shows the lever of the heading-die, which is worked by a crank-pin and rod *i*, attached to a wheel *q*, on the main-shaft.

To prevent the nail falling from its place before the completion of the

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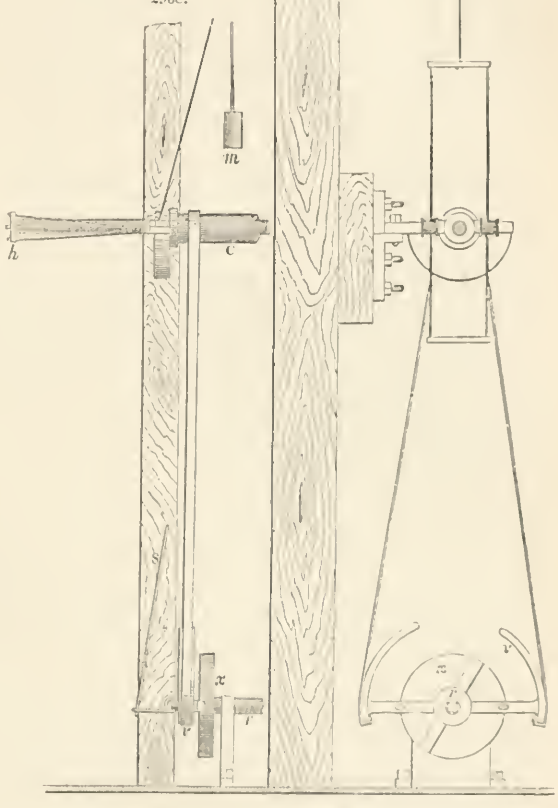

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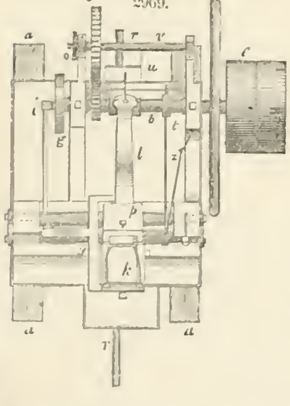
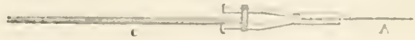


2968a.



stroke, a small pair of nippers, operated by means of a cam *t* on the main-shaft, are placed below and in front of the cutter-block; these are worked by the rods *z*.

The working of the machine is as follows:

The nail plate rests against the frame of the cutter, the lever *l* resting on the point of the cam or eccentric; as the latter revolves, the lever *l* falls, lifting the edge of the cutter above the cutting block, and also above the nail plate; the latter, by the action of the weight *m*, is thrown forward under the cutter to a stop the width of the required nail; at this point, by the revolution of the eccentric, the lever *l* is raised, which lowers the edge of the cutter, shearing off a wedge-shaped strip of metal, having the length of the width of the nail-plate; this is seized at the same instant by the nippers below the cutter, and immediately after the rod *i*, by the action of its crank, raises the lever *y*, of the heading die, and the nail is completed at a stroke. As the complete nail drops from the opening nippers the nail plate is advanced under the cutting-shears for another nail.

The action of this machine is very perfect, and is suited for all dimensions of cut nails; the machine of course being heavier and larger to suit the different sizes. See SPIKES.

NEEDLES. The making of needles, although largely carried on at Birmingham and a few other towns, is mainly conducted at Redditch in Worcestershire. We should surprise many a reader were we to enumerate all the processes incident to the manufacture of a needle, giving to each the technical name applied to it in the factory. The number would amount to somewhere about thirty; but it will be more in accordance with our object to dispense with such an enumeration, and to present the details of manufacture in certain groups, without adhering to a strictly technical arrangement.

First, then, for the *material*. It is scarcely necessary to say that needles are made of steel, and that the steel is brought into the state of fine wire before it can assume the form of needles. The needle-makers are not wire-drawers: they do not prepare their own wire, but purchase it, in sizes varying with the kind of needles which they are about to make, from Sheffield or Birmingham, or some similar town. We will suppose, therefore, that the wire is brought to the needle factory, and is deposited in a store-room. This room is kept warmed by hot air to an equable temperature, in order that the steel may be preserved free from damp or other sources of injury. Around the walls are wooden bars or racks, on which are hung the hoops of wire. Each hoop contains, on an average, about twelve or fourteen pounds of wire, the length varying according to the diameter. Perhaps it may be convenient to take some particular size of needle, and make it our standard of comparison during the details of the process. The usual sizes of sewing needles are from No. 1, of which twenty-two thicknesses make an inch, to No. 12, of which there are a hundred to an inch. Supposing that the manufacturer is about to make sewing needles of that size which is known to sempstresses as No. 6—then the coil of wire is about two feet in diameter; it weighs about thirteen pounds; the length of wire is about a mile and a quarter; and it will produce forty or fifty thousand needles. The manufacturer has a gage, consisting of a small piece of steel, perforated at the edge with eighteen or twenty small slits, all of different sizes, and each having a particular number attached to it. By this gage the diameter of every coil of wire is tested, and by the number every diameter of wire is known.

A coil of wire, when about to be operated on, is carried to the cutting-shop, where it is cut into pieces equal to the length of two of the needles about to be made. Fixed up against the wall of the shop is a ponderous pair of shears with the blades uppermost. The workman takes probably a hundred wires at once, grasps them between his hands, rests them against a gage to determine the length to which they are to be cut, places them between the blades of the shears, and cuts them by pressing with his body or thigh against one of the handles of the shears. The coil is thus reduced to twenty or thirty thousand pieces, each about three inches long; and as each piece had formed a portion of a curve two feet in diameter, it is easy to see that it must necessarily deviate somewhat from the straight line. This straightness must be rigorously given to the wire before the needle-making is commenced; and the mode by which it is effected is one of the most remarkable in the whole manufacture. In the first place, the wires are annealed. There are provided a number of iron rings, each from three or four to six or seven inches in diameter, and a quarter or half an inch in thickness. Two of these rings are placed upright on their edges, at a little distance apart; and within them are placed many thousands of wires, which are kept in a group by resting on the interior edges of the two rings. In this state they are placed on a shelf in a small furnace, and there kept till red-hot. On being taken out, at a glowing heat, they are placed on an iron plate, the wires being horizontal, and the rings in which they are inserted being vertical. The process of "rubbing" (the technical name for the straightening to which we allude) then commences. The workman takes a long piece of iron or steel, perhaps an inch in width, and, inserting it between the two rings, rubs the needles backwards and forwards, causing each needle to roll over its own axis, and also over and under those by which it is surrounded. The noise emitted by this process is just that of filing: but no filing takes place; for the rubber is smooth, and the sound arises from the rolling of one wire against another. The rationale of the process is this:—the action of one wire on another brings them all to a perfectly straight form, because any convexity or curvature in one wire would be pressed out by the close contact of the adjoining ones.

Our needles have now assumed the form of perfectly straight pieces of wire, say a little more than three inches in length, blunt at both ends, and dulled at the surface by exposure to the fire. Each of these pieces is to make two needles, the two ends constituting the points; and both points are made before the piece of wire is divided into two. The pointing immediately succeeds the rubbing, and consists in grinding down each end of the wire till it is perfectly sharp. This is the part of needle making which has attracted more attention than all the rest put together. The surprising manipulation by which the needles are applied to the grindstone; the rapidity with which the grinding is effected; the large earnings of the men; the ruined health and early death which the occupation brings upon them; the efforts which have been made to diminish the hurtfulness of the process; and the resistance with which these efforts have been met—all merit and have received a large measure of attention. Let us first notice the process itself, and then the peculiar circumstances attending it.

Some of the needle-pointers work at their own homes, while some work at the factories; but the process is the same in either case. The pointing-room, generally situated as far away as practicable from the other rooms, contains small grindstones, from about eight inches to twenty inches in diameter, according to the size of needle to be pointed. They rotate vertically, at a height of about two feet from the ground, and with a velocity frequently amounting to two thousand revolutions per minute. The stone is a particular kind of grit adapted for the purpose; but sometimes it flies in pieces, from the centrifugal force engendered by the rapid rotation, and in such cases the results are often fearful. The workman sits on a stool, or horse, a few inches distant from the stone, and bends over it during his work. Over his mouth he wraps a large handkerchief, and, as he can perform his work nearly as well in the dark as in the light, he is sometimes only to be seen by the vivid cone of sparks emanating from the steel while grinding. The vivid light reflected on his pale face, coupled with the consciousness that we are looking at one who will be an old man at thirty, and who is being literally "killed by inches" while at work, renders the processes conducted in this room such as will not soon be forgotten.

The needle-pointer takes fifty or a hundred needles, or rather needle wires, in his hand at once, and holds them in a peculiar manner. He places the fingers and palm of one hand diagonally over those of the other, and grasps the needles between them, all the needles being parallel. The thumb of the left hand comes over the back of the fingers of the right, and the different knuckles and joints are so arranged that every needle can be made to rotate on its own axis by a slight movement of the hand, without any one needle being allowed to roll over the others. He grasps them so that the ends of the wire (one end of each) project a small distance beyond the edge of the hand and fingers, and these ends he applies to the grindstone in the proper position for grinding them down to a point. It will easily be seen that if the wires were held fixedly the ends would merely be bevelled off, in the manner of a graver, and would not give a symmetrical point; but by causing each wire to rotate while actually in contact with the grindstone, the pointer works equally on all sides of the wire, and brings the point in the axis of the wire. At intervals of every few seconds he adjusts the needles to a proper position, against a stone or plate, and dips their ends in a little trough of liquid between him and the grindstone. Each wire sends out its own stream of sparks, which ascends diagonally in a direction opposite to that at which the workman is placed. So rapid are his movements that he will point seventy or a hundred needles, forming one hand-grasp, in half a minute—thus getting through ten thousand in an hour!

The circumstance which renders this operation so very destructive to health is, that the particles of steel, separated from the body of the wire by the friction of the stone, float in the air for a time, and are then inhaled by the workman; and the same remarks apply to this destructive occupation as to fork-grinding.

The reader will bear in mind that the state of our embryo needle is simply that of a piece of dull straight wire, about three inches long, (supposing 6's to be the size,) and pointed at both ends. The next process is one of a series by which two eyes or holes are pierced through the wire, near the centre of its length, to form the eyes of the two needles which are to be fashioned from the piece of wire. A number of very curious operations are connected with this process, involving mechanical and manipulative arrangements of great nicety. Those who are learned in the qualities of needles—as that they will not "cut in the eye," &c.—will be prepared to expect that much delicate workmanship is involved in the production of the eyes, and they will not be in error in so supposing. Most of the improvements which have from time to time been introduced in needle-making relate more or less to the production of the eye. In the commoner kinds of needles many processes are omitted which are essential to the production of the finer qualities, but it will show the whole nature of the operations better for us to take the case of those which involve all the various processes.

After being examined when the pointer has done his portion of the work to them, (an examination which is undergone after every single process throughout the manufacture,) the wires are taken to the stamping-shop, where the first germ of an eye is given to each half of every wire. The stamping machine consists of a heavy block of stone, supporting on its upper surface a bed of iron; and on this bed is placed the under half of a die or stamp. Above this is suspended a hammer, weighing about thirty pounds, which has on its lower surface the other half of the die or impress. The hammer is governed by a lever moved by the foot, so that it can be brought down exactly upon the iron bed. The form of the die or stamp may be best explained by stating the work which it is to perform. It is to produce the gutter, or channel, in which the eye of a needle is situated, and which is to guide the thread in the process of "threading a needle."

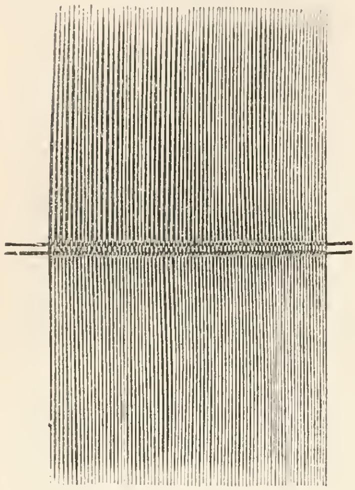
But besides the two channels or gutters, the stampers make a perforation partly through the needle, as a means of marking exactly where the eye is to be. The device on the two halves of the die is consequently a raised one, since it is to produce depressions in the wire. The workman, holding in his hand several wires, drops one at a time on the bed-iron of the machine, adjusts it to the die, brings down the upper die upon it by the action of the foot, and allows it to fall into a little dish when done. This he does with such rapidity that one stamper can stamp four thousand wires, equivalent to eight thousand needles, in an hour, although he has to adjust each needle separately to the die.

To this process succeeds another, in which the eye of the needle is pierced through. This is effected by boys, each of whom works at a small hand-press, and the operation is at once a minute and ingenious one. The boy takes up a number of needles or wires, and spreads them out like a fan. He lays them flat on a small iron bed or slab, holding one end of each wire in his left hand, and bringing the middle of the wire to the middle of the press. To the upper arm of the press are affixed two hardened steel points or cutters, being in size and shape exactly corresponding with the eyes which they are to form. Both of these points are to pass through each wire, very nearly together, and at a small distance on each side of the exact centre of the wire. The wire being placed beneath the points, the press is moved by hand, the points descend, and two little bits of steel are cut out of the wire, thereby forming the eyes for two needles. As each wire becomes thus pierced, the boy shifts the fanlike array of wires until another one comes under the piercers, and so on throughout. The press has to be worked by the right hand for piercing each wire; and the head of the boy is held down pretty closely to his work, in order that he may see to eye the needles properly! Were not the wires previously prepared by the stamper, it would be impossible thus to guide the piercers to the proper point; but this being effected, patience, good eyesight, and a steady hand effect the rest.

There are several processes about this stage which are effected by boys. Some of these little laborers take the needles when they have been eyed, and proceed to spit them; that is, to pass a wire through the eye of every needle. Two pieces of fine wire perhaps three or four inches in length, are prepared, the diameter corresponding exactly with the size of the needle-eye. These two pieces of wire are held in the right hand, parallel, and at a distance apart equal to the distance between the two eyes in each needle wire. The pierced needles, being held in the left hand, are successively threaded upon the two pieces of smaller wire, till, by the time the whole is filled, the assemblage has something the appearance of a fine toothed comb, as shown in Fig. 2970. A workman then files down the bur or protuberances left on the side of the eye by the stamping.

It must be borne in mind that throughout all these operations the needles are double; that is, that the piece of wire, three inches in length, which is to produce two needles an inch and a half long each is still whole and undivided, the two eyes being nearly close together in the centre, and the two points being at the ends. Now, however, the separation is to take place. The filer, after he has brought down the protuberances on each wire, but before he has laid the comb of wires out of his hand bends and works the comb between his hands in a peculiar way, until he has broken the comb into two halves, each half spitted by one of the fine wires. The needles have arrived at something like their destined shape and size: for they are of the proper length, and have eyes and points. In Fig. 2971 we can trace the wire through the processes of change hitherto undergone.

2970.



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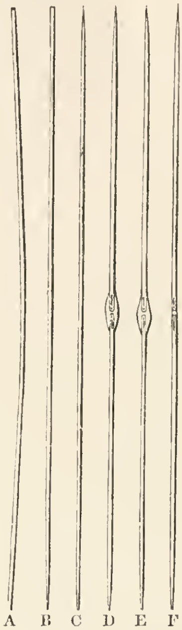

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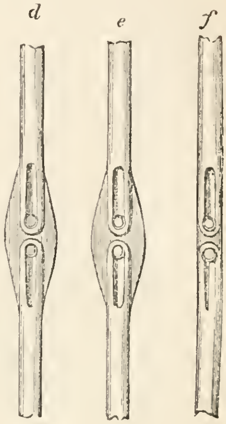


In Fig. 2971, A is the wire for two needles; B the same, pointed at one end; C pointed at both ends; D the stamped impress for the eyes; E the eyes pierced; F the needles just before separation · *def*, Fig. 2972, enlargements of D E F.

But although we have now little bits of steel, which might by courtesy be called needles, they have very many processes to undergo before they are deemed finished, especially if, in accordance with our previous supposition, they are of the finer quality. There are very many workshops which we have yet to glance through, the first of which is that of the soft-straightener. The filer and his two spitters (who together get ready about four thousand needles in an hour) are very likely to bend in a slight degree the needles under operation; and, indeed, so are likewise the stampers and the eye-makers. To restore the straightness of the wire is the office of the soft-straightener, who is frequently a female.

The soft-straightener is seated in front of a bench, near the front edge of which is placed a small steel plate. On this plate the needles are placed, parallel or nearly so; the straightener employed is a steel bar, from a foot to half a yard long, an inch or two in width, and perhaps a quarter of an inch thick. It is turned upwards a little at the two ends, so as to be somewhat convex at the lower surface, and is held by both hands at the two ends. By a curious management of this instrument, the soft-straightener separates each individual needle from the group of which it forms a part, and rolls it over two or three times with the lower surface of the instrument, pressing it against the iron plate, and thus working out any curvatures or irregularities which may have been given to it by the previous operations. So quickly is this done that three thousand needles can be thus straightened in an hour by one person.

The needles are by this time pointed, eyed, and straightened; but before they can be brought to that beautifully finished state with which we are all familiar, it is necessary that they should be hardened and tempered by a peculiar application of heat. After being examined, to see that the preceding processes are fitly performed, the needles are taken to a shop provided with ovens or furnaces. They are laid down on a bench, and by means of two trowel-like instruments, spread in regular thick layers on narrow plates or trays of iron. In this way they are placed on a shelf or grating in a heated furnace When the proper degree of heating has been effected, the door is opened, and the needles are shifted from the iron tray into a sort of colander or perforated vessel immersed in cold water or oil. When they are quite cooled, the hardening is completed; and if it has been effected in water, the needles are simply dried; but if in oil, they are well washed in an alkaline liquor to free them from the oil. Then ensues the tempering processes. The needles are placed on an iron plate, heated from beneath, and moved about with two little trowels until every needle has been gradually brought to a certain desired temperature.

Notwithstanding the soft-straightening which the needles underwent after they were pointed and eyed, they have become slightly distorted in shape by the action of the heat in the processes just described, and to rectify this they undergo the operation of hammer-straightening. A number of females are seen seated at a long bench, each with a tiny hammer, giving a number of light blows to the nee dles; the needles being placed on a small steel block with a very smooth upper surface. This is rather a tedious part of the manufacture, the workwoman not being able to straighten more than five hundred needles in an hour, a degree of quickness much less than that which we have had hitherto to notice.

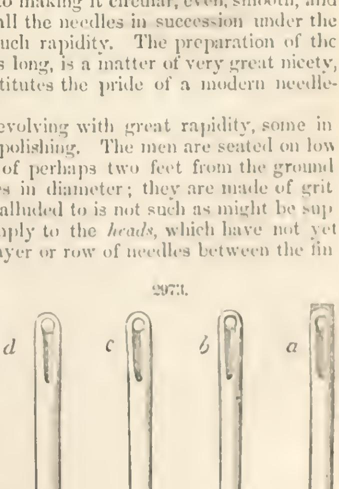
We leave the tinkling hammers, and follow the needles to the only part of the manufacture which involves apparatus other than of a very small size. This is the scouring process, performed by machines, looking like mangles, or, perhaps more correctly, like marble polishing-machines—a square slab or rubber working to and fro on a long bed, stone, or bench. The object of this process is to rub the needles one against another for a very long period, till the surfaces of all have become perfectly smooth, clean, and true. This is effected in a curious manner. A strip of very thick canvas is laid out open on a bench, and on this a large heap of needles, amounting to perhaps twenty or thirty thousand, is laid, all the needles being parallel one with another, and with the length of the cloth. The needles are then slightly coated with a mixture of emery and oil, and tied up tightly in the canvas, the whole forming a compact roll about two feet long and two inches in thickness. Twenty-four rolls of needles being thus prepared, comprising probably six hundred thousand needles in all, they are placed under the rubbers of the scouring-machines, two rolls to each machine. A steam-engine or a water-wheel then gives to the rubbers, by connected mechanism, a reciprocating or backward and forward motion, pressing heavily on the rolls of needles, and causing all the needles of each bundle to roll one over another. By this action an intense degree of friction is exerted among the needles, whereby each one is rubbed smooth by those which surround it. For eight hours uninterruptedly this rubbing or scouring is carried on; after which the needles are taken out, washed in suds, placed in new pieces of canvas, touched with a new portion of emery and oil, and subjected to another eight hours' friction. Again and again is this repeated, insomuch that for the very finest needles the process is performed five or six times over, each time during eight hours' continuance.

The needles are examined after being scoured, and are placed in a small tin tray, where, by shaking and vibrating in a curious manner, they are all brought into parallel arrangement. From thence they are removed into flat paper trays, in long rows or heaps, and passed on to the "header," generally a little girl, whose office is to turn all the heads one way and all the points the other. This is one among the many simple but curious processes involved in this very curious manufacture, which surprise us by the rapidity and neatness of execution. The girl sits with her face towards the window, and has the needles ranged in a row or layer before her, the needles being parallel with the window. She draws out laterally to the right those which have their eyes on the right hand, into one heap; and to the left those which have their eyes in that direction, in another.

About this time too the needles are examined one by one, to remove those which have been broken or injured in the long process of scouring; for it sometimes happens that as many as eight or ten thousand out of fifty thousand are spoiled during this operation. Most ladies are conversant with the merits of "drilled-eyed needles," warranted "not to cut the thread." These are produced by a modern improvement, whereby the eye, produced by the stamping and piercing processes before described, is drilled with a very fine instrument, by which its margin becomes as perfectly smooth and brilliant as any other part of the needle. To effect this the needle is first "blued," that is, the head is heated so as to give it the proper temper for working. Then the eye is counter-sunk, which consists in bevelling off the eye by means of a kind of triangular drill, so that there may be no sharp edge between the eye itself and the cylindrical shaft of the needle. Next comes the drilling. Seated at a long bench are a number of men and boys, with small drills working horizontally with great rapidity. The workman takes up a few needles between the finger and thumb of his left hand, spreads them out like a fan with the eyes uppermost, brings them one at a time opposite the point of the drill, governs the handle or lever of the drill with his right hand, and drills the eye, which is equivalent to making it circular, even, smooth, and polished. He shifts the thumb and finger round, so as to bring all the needles in succession under the action of the drill; and he thus gets through his work with much rapidity. The preparation of the drills, which are small wires of polished steel three or four inches long, is a matter of very great nicety, and on it depends much of that beauty of production which constitutes the pride of a modern needle-manufacturer.

The needles are next applied to the edges of little wheels revolving with great rapidity, some intended for what is termed "grinding" the needles, and some for polishing. The men are seated on low stools, each in front of a revolving wheel, which is at a height of perhaps two feet from the ground. The grinding-wheels are very small, not above five or six inches in diameter; they are made of grit stone, and are attached to a horizontal axis. The grinding here alluded to is not such as might be supposed, relating to the *points* of the needles, but has reference simply to the *heads*, which have not yet had a rounded form given to them. The workman takes up a layer or row of needles between the fingers and thumbs of the two hands, and applies the heads to the stones in such a manner as to grind down any small asperities on the surface. As the small grindstones are revolving three thousand times in a minute, it is plain that the steel may soon be sufficiently worn away by a slight contact with the periphery of the stone.

2973.



The grinders and the polishers sit near together, so that the latter take up the series of operations as soon as the former have finished. The polishing-wheels consist of wood coated with buff leather, whose surface is slightly touched with polishing-paste. Against these wheels the polishers hold the needles, applying every part of the cylindrical surface in succession; first holding them by the pointed end, and then by the eye end. About a thousand in an hour can thus be polished by each man; and when they leave his hands the needles are finished. A magnified representation of the eye in different states will assist these details. *a*, Fig. 2973, represents a needle with the eye and head rough; *b*, the head filed and formed; *c*, the eye countersunk; *d* represents a needle drilled and finished.

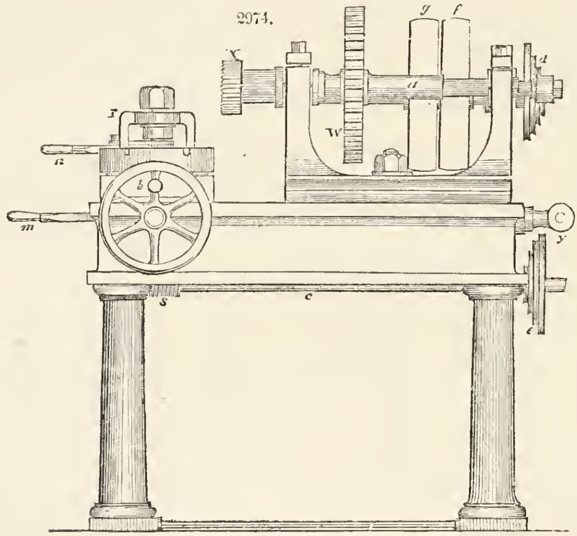
NICKEL. A white metal, ductile, malleable, attracted by the magnet, and which, like iron, may be rendered magnetic. Its specific gravity when hammered is about 9. It is rather more fusible than pure iron; is not altered by exposure to air and moisture at common temperatures, but is slowly oxidized at a red heat. It is found in all meteoric iron; but its principal ore is a copper-colored mineral found in Westphalia, and called *kupfernickel*, nickel being a term of detraction used by the German miners, who expected from the color of the ore to find that it contained copper. The salifiable oxide of nickel consists of 30 nickel + 8 oxygen. Its salts are mostly of a grass-green color, and the ammoniacal solution of its oxide is deep blue, like that of copper. See METALS AND ALLOYS.

NONAGON. A figure of nine angles and nine sides. The angle at the centre of a nonagon is 40°, the angle subtended by its sides 140°, and its area when the side is 1 = 6·1818242, consequently the square of the side × 6·1818242 will give the area of the figure.

NORMAL. A term sometimes used for perpendicular. In the geometry of curve lines, the normal to a curve at any point is a straight line perpendicular to the tangent at that point, and included between the curve and the axis of the abscissa.

NUT-CUTTING MACHINE—By A. MILNE, Glasgow. This is a very convenient tool in works

2974.



where the chief business is the construction of the more finished quality of machinery. In these the nuts are usually dressed to correspond with the other parts of the work. It is not commonly employed by millwrights, although its use would often be a material saving of time in the fitting-shop, and especially in out-door work, in reducing the nuts, and consequently the number of keys required, to a few definite sizes.

Fig. 2974 is a side elevation. Fig. 2975 an end elevation. Fig. 2976 a general plan of the machine.

a is the main-spindle, having a spur-wheel *w*, and the cutter *x*, keyed on it.

k, the driving-shaft, carrying fast and loose pulleys, and having the pinion *p* keyed on it, and which geers into the wheel *w*.

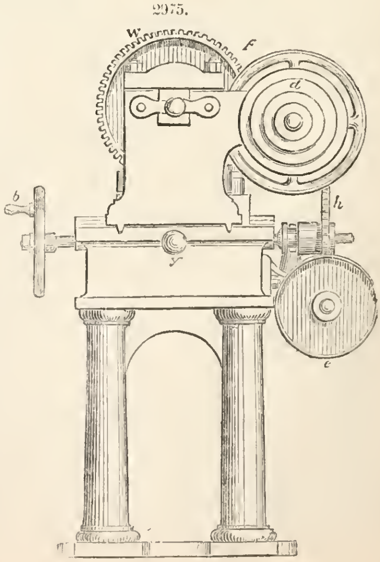
r, the nut-holder: the nuts are screwed on a pin which is tightened by a nut on the under side, seen in Fig. 2974, by a counter-nut; different sizes of these mandrel-pins or screws are of course required for different sizes of nuts.

b, a hand-wheel, upon the end of a slide-lever for carrying the nut across the end of the cutter.

c, a shaft carrying a set of grooved pulleys, connected by a cord, with a corresponding set on the shaft *k*.

s, an endless screw on the shaft *c*, and working into the wheel *h*, on the slide-screw, to render the machine self-acting.

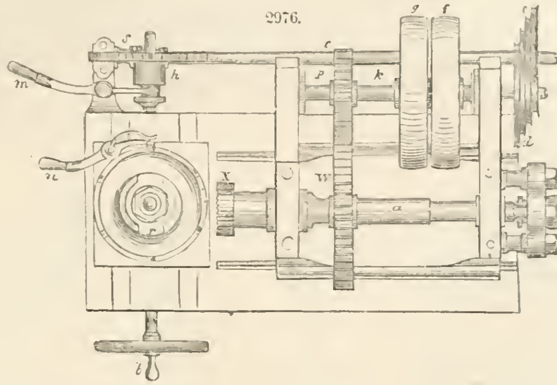
2975.



m, a handle to disengage the self-acting feed when desired. The upper part of the slide on which the nuts are fixed turns round, and is held in the position required by the handle *n*, the end of which is pressed, by a spring, into notches on the rim of the table. See Fig. 2976.

y, a screw for moving forward the head carrying the cutter, so as to adjust it to the size of nut to be cut. This operation is accomplished by hand.

2976.



OCTAGON. In geometry, a plane figure contained by eight sides, and consequently having eight angles. When the sides and angles are equal, it is a *regular* octagon. If a denote the side of a regular octagon, the area is $a^2 \times 2 \tan. 67\frac{1}{2}° = a^2 \times 4{\cdot}828427$.

OCTOHEDRON. In geometry, one of the five regular solids, or Platonic bodies, contained under eight equal and equilateral triangles. Let

$A =$ the linear edge or side,
$B =$ the whole surface,
$C =$ the solid content,
$R =$ radius of circumscribed sphere,
$r =$ radius of inscribed sphere; then

$$A = r\sqrt{6} = R\sqrt{2} = \sqrt{(\tfrac{1}{6}B\sqrt{3})} = \sqrt[3]{\tfrac{3}{2}C\sqrt{2}},$$
$$B = 12\,r^2\sqrt{3} = 4\,R^2\sqrt{3} = 2\,A^2\sqrt{3},$$
$$C = 4\,r^3\sqrt{3} = \tfrac{4}{3}R^3 = \tfrac{1}{3}A^3\sqrt{2},$$
$$R = r\sqrt{3} = \tfrac{1}{2}A\sqrt{2} = \tfrac{1}{2}\sqrt{B\sqrt{\tfrac{1}{3}}} = \sqrt[3]{\tfrac{3}{4}C},$$
$$r = \tfrac{1}{3}R\sqrt{3} = \tfrac{1}{6}A\sqrt{6} = \tfrac{1}{6}\sqrt{(B\sqrt{3})}.$$

ODOMETER. An instrument attached to the wheel of a carriage, by which the distance passed over is measured.

OILS. The term oil is applied to two dissimilar and distinct organic products, which are usually called *fixed* oils and *volatile* oils. The fixed or fat oils are either of vegetable or animal origin; they are compounds of carbon, hydrogen, and oxygen; the relative proportions vary but little in the several species. The following analyses of olive and spermaceti oil may be assumed as types of the rest:

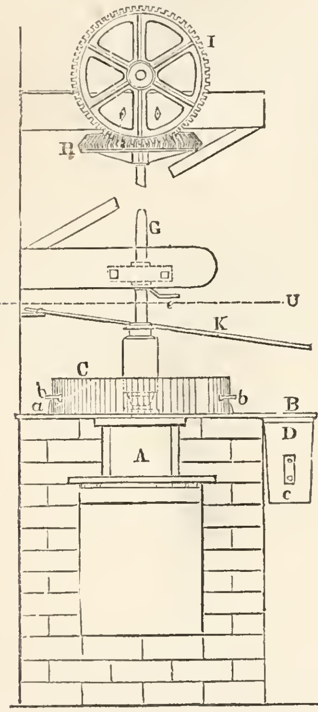
	Olive oil.	Spermaceti oil.
Carbon	772	780
Hydrogen	133	118
Oxygen	95	102
	1000	1000

The *fixed oils* abound in the fruit and seed of certain plants; they are lighter than water, unctuous, and insipid, or nearly so; some of these require a low temperature for their congelation, such as linseed oil; others, such as olive oil, concrete at a temperature higher than the freezing point of water; some are solid at common temperatures, such as cocoa nut oil. Some of these oils when exposed to air absorb oxygen, and gradually harden, forming a kind of varnish; these are called *drying oils*, and are the basis of paints, such as linseed oil; others become rancid, as almond oil. All these oils, like the different kinds of fat, consist of two proximate principles, called *stearine* and *elaine*; the former is the fatty portion, which first concretes on cooling the oil, and from which the elaine, or oily portion, may be separated by pressure. These oils cannot be volatilized without decomposition. At a red heat they are resolved into volatile and gaseous products, among which carburetted hydrogen, in several of its forms, predominates; hence the use of these oils, when volatilized and burned by the aid of a wick, as sources of artificial light. The action of the alkali on the fat oils is highly important, as forming soap.

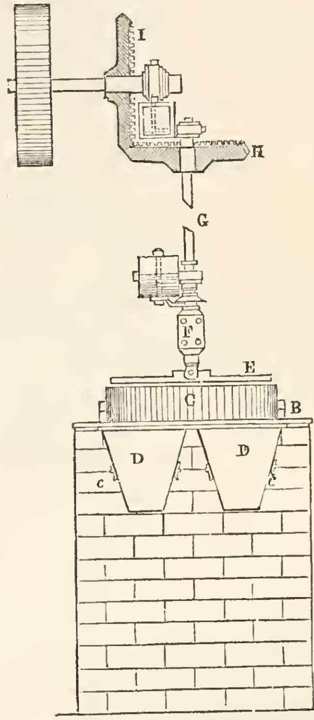
The *volatile oils* are generally obtained by distilling the vegetables which afford them with water; they fluctuate in density a little on either side of water: they are sparingly soluble in water, forming the perfumed or medicated waters, such as rose and peppermint water; they are mostly soluble in alcohol, forming essences. A few of them, such as oil of turpentine, of lemon peel, of copaiva balsam, &c., are hydro-carbons, that is, consist of carbon and hydrogen only; the greater number, however, contain oxygen as one of their ultimate elements. They are chiefly used in medicine and in perfumery, and a few of them are extensively employed in the arts as vehicles for colors, and in the manufacture of varnishes; this is especially the case with oil of turpentine.

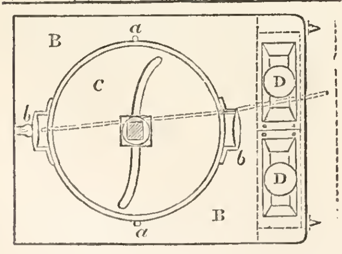
Linseed, rape-seed, poppy-seed, and other oleiferous seeds were formerly treated for the extraction of their oil, by pounding in hard wooden mortars with pestles shod with iron, set in motion by cams driven by a shaft turned with horse or water power; then the triturated seed was put into woollen bags which were wrapped up in hair-cloths, and squeezed between upright wedges in press-boxes by the impulsion of vertical rams driven also by a cam mechanism. In the best mills upon the old construction, the cakes obtained by this first wedge-pressure were thrown upon the bed of an edge-mill, ground anew, and subjected to a second pressure, aided by heat now as in the first case. These mortars and press-boxes constitute what are called Dutch mills. They are still in very general use, and are by many persons supposed to be preferable to the hydraulic presses.

2977.



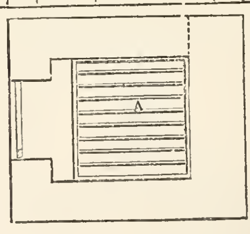
2979.





2978.

2980.



In extracting oil from seeds two processes are required—1st, *trituration;* 2d, *expression;* and the steps are as follows:

1. Bruising under revolving heavy-edge mill-stones, in a circular bed or trough of iron, bedded on granite.
2. Heating of the bruised seeds, by the heat either of a naked fire or of steam.
3. First pressure or crushing of the seeds, either by wedges, screw, or hydraulic presses.
4. Second crushing of the seed-cakes of the first pressure.
5. Heating the bruised cakes: and 6. A final crushing.

The seeds are now very generally crushed first of all between two iron cylinders revolving in opposite directions, and fed in from a hopper above them; after which they yield more completely to the triturating action of the edge-stones, which are usually hooped round with a massive iron ring. A pair of edge mill-stones of about 7 or 7½ feet in diameter, and 25 or 26 inches thick, weighing from 7 to 8 tons, can crush, in 12 hours, from 2½ to 3 tons of seeds. The edge mill-stones serve not merely to grind the seeds at first, but to triturate the cakes after they have been crushed in the press. Old dry seeds sometimes require to be sprinkled with a little water to make the oil come more freely away; but this practice requires great care.

The apparatus for heating the bruised seeds consists usually of cast iron or copper pans, with stirrers moved by machinery. Figs. 2977, 2978, 2979, and 2980 represent the heaters by naked fire, as mounted in Messrs. Maudsley and Field's seed-crushing mills, on the wedge or Dutch plan.

Fig. 2977 is an elevation or side view of the fireplace of a naked heater.

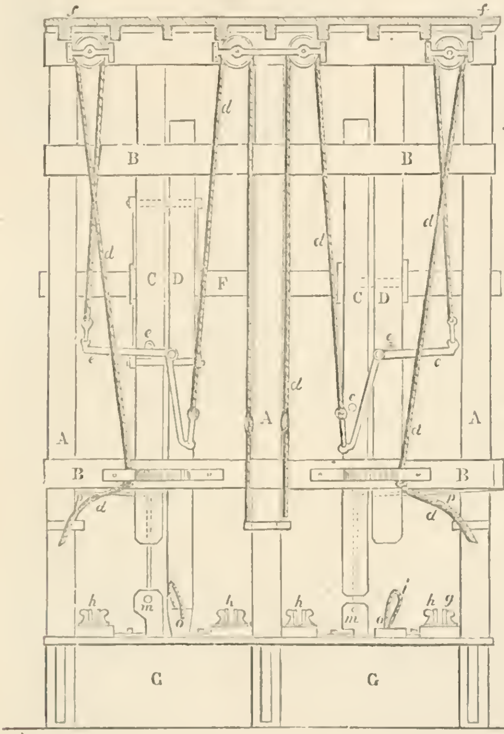
Fig. 2978 is a plan in the line U U of Fig. 2977.

Fig. 2979 is an elevation and section parallel to the line V V of Fig. 2978.

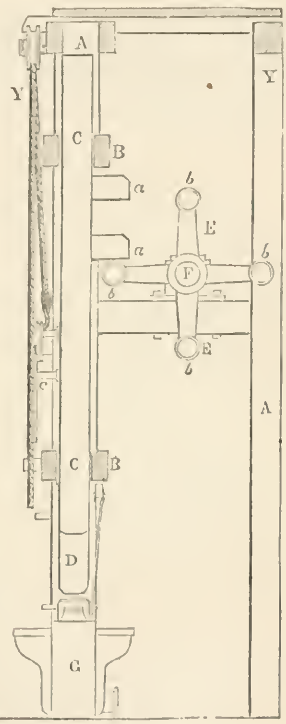
Fig. 2980 is a plan of the furnace, taken above the grate of the fireplace.

A, fireplace shut at top by the cast-iron plate B, called the fire-plate. C, iron ring-pan, resting on the plate B, for holding the seeds, which is kept in its place by the pins or bolts *a*. D, funnels, *britchen*, into which, by pulling the ring-case *c* by the handles *b b*, the seeds are made to fall, from which they pass into bags suspended to the hooks *c*.

2981.



2982.



E, Fig. 2979, the stirrer which prevents the seeds from being burned by continued contact with the hot plate. It is attached by a turning-joint to the collar F, which turns with the shaft G, and slides up and down upon it. H, a bevel-wheel in geer with the bevel-wheel I, and giving motion to the shaft G. K, a lever for lifting up the agitator or stirrer E. *e*, a catch for holding up the lever K, when it has been raised to a proper height.

Fig. 2981, front elevation of the wedge seed-crushing machine, or wedge-press.

Fig. 2982, section, in the line X X of Fig. 2983.

A A, upright guides, or frame-work of wood. B B, side guide-rails. D, driving stamper of wood which presses out the oil; C, spring stamper, or relieving wedge, to permit the bag to be taken out when sufficiently pressed. E is the lifting-shaft having rollers *b b b b*, Fig. 2982, which lift the stampers by the cams *a a*, Fig. 2982. F is the shaft from the power engine, on which the lifters are fixed. G is the cast iron press-box, in which the bags of seed are placed for pressure, laterally by the force of the wedge.

In Figs. 2981 and 2984, *o* is the spring, or relieving wedge. *c*, lighter rail; *d*, lifting rope to ditto, *f f f f*, flooring overhead. *g*, the back iron or end plate, minutely perforated. *h*, the horse-hair bags, (called hairs,) containing the flannel bag charged with seed; *i*, the dam block; *m*, the spring-wedge.

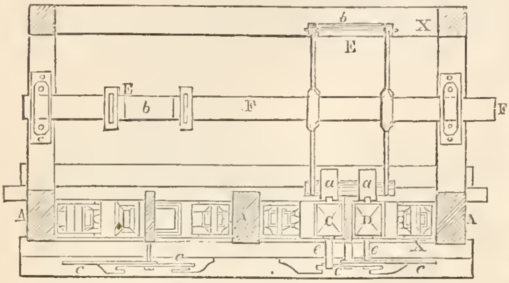
Fig. 2983, A, upright guides; C and D, spring and driving stampers; E, lifting roller; F, lifting shaft; *a a*, cams of stampers.

Fig. 2984, a view of one set of the wedge-boxes, or presses, supposing the front of them to be removed. *o*, driving wedge; *g*, back iron; *h*, hairs; *i*, dam block; *k*, speering or oblique block, between the two stampers; *l* and *n*, ditto; *m*, spring wedge.

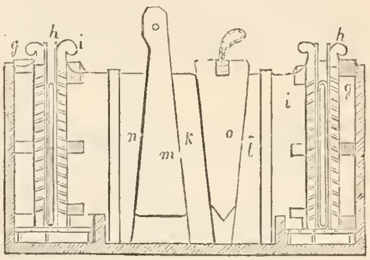
When in the course of a few minutes the bruised seeds are sufficiently heated in the pans, the double door F F is withdrawn, and they are received in the bags below the aperture G. These bags are made of strong twilled woollen cloth, woven on purpose. They are then wrapped in a hair-cloth, lined with leather.

The first pressure requires only a dozen blows of the stamper, after which the pouches are left alone for a few minutes till the oil has had time to flow out; in which interval the workmen prepare fresh bags. The former are then unlocked, by making the stamper fall upon the loosening wedge or key *m*.

2983.



2984.



The weight of the stampers is usually from 500 to 600 pounds; and the height from which they fall upon the wedges is from 16 to 21 inches.

Such a mill as that now described can produce a pressure of from 50 to 75 tons upon each cake of the following dimensions: 8 inches in the broader base, 7 inches in the narrower, 18 inches in the height; altogether nearly 140 square inches in surface, and about $\frac{3}{4}$ of an inch thick.

Adulteration of oils.—M. Heidenreich has found in the application of a few drops of sulphuric acid to a film of oil, upon a glass plate, a means of ascertaining its purity. The glass plate should be laid upon a sheet of white paper, and a drop of the acid let fall on the middle of ten drops of the oil to be tried.

With the *oil of rape-seed* and *turnip-seed*, a greenish-blue ring is gradually formed at a certain distance from the acid, and some yellowish-brown bands proceed from the centre.

With *oil of black mustard*, in double the above quantity, also a bluish-green color.

With *whale* and *cod oil*, a peculiar centrifugal motion, then a red color, increasing gradually in intensity; and after some time it becomes violet on the edges.

With *oil of cameline*, a red color, passing into bright yellow.

Olive-oil, pale yellow, into yellowish green.

Oil of poppies and sweet almonds, canary yellow, passing into an opaque yellow.

Of *linseed*, a brown magma, becoming black.

Of *tallow* or *oleine*, a brown color.

In testing oils, a sample of the oil imagined to be present should be placed alongside of the actual oil, and both be compared in their reactions with the acid. A good way of approximating to the knowledge of an oil is by heating it, when its peculiar odor becomes more sensible.

OIL TEST. The most valuable quality in an oil intended for the lubrication of machinery is *permanent fluidity*. That oil which will for the greatest length of time remain fluid in contact with the iron or brass is, without doubt, the most useful for the purpose. Hence the necessity of including the element of *time* in any experiment on the comparative value of such oils.

Some idea may be formed of the importance of having the means of arriving at correct conclusions on this subject, when we know that in some spinning establishments there are upwards of 50,000 spindles in motion at the rate of 4000 or 5000 revolutions per minute! The slightest defect in the quality of the oil in such a case, by its becoming viscid, tells in the most serious way upon the quantity of fuel consumed in generating the power required to maintain at this high velocity such a multitude of moving parts. The slight increase of fluidity consequent on the rise of temperature, caused by the lighting of the gas in the rooms of a cotton-mill, makes a difference of several horses-power in the duty of the engine of an extensive establishment.

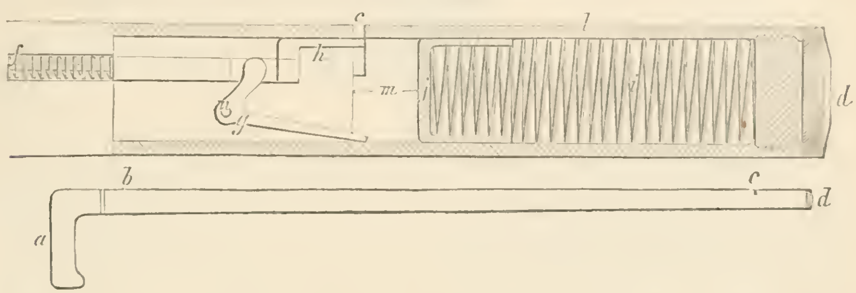
The oil test we have now to describe, and which is an invention of Mr. Nasmyth's, consists of a plate of iron 4 inches wide by 6 feet long, on the upper surface of which six equal-sized grooves are planed. This plate is placed in an inclining position, say 1 inch in 6 feet. The mode of using it is as follows:—Suppose we have six varieties of oil to test, and we are desirous to know which of them will, for the longest time, retain its fluidity when in contact with iron and exposed to the action of the air; all we have to do is to pour out *simultaneously* at the upper end of each inclined groove an equal quantity of each of the oils under examination. This is very conveniently and correctly done by means of a row of small brass tubes. The six oils then make a fair start on their race down hill; some get ahead the first day, and some keep ahead the second and third day, but on the fourth or fifth day the truth begins to come out; the bad oils, whatever good progress they may have made at the outset, come soon to a standstill by their gradual coagulation, while the good oil holds on its course; and at the end of eight or ten days there is no doubt left as to which is the best; it speaks for itself, having distanced its competitors by a long way. Linseed oil, which makes capital progress *the first day*, is set fast after having travelled 18 inches, while second-class sperm beats first-class sperm by 14 inches in nine days, having traversed in that time 5 feet 8 inches down the hill. The following table will show the state of the oil-race after a nine days' run:

Results of Oil Test.

Description of Oil.	First.		Second.		Third.		Fourth.		Fifth.		Sixth.		Seventh.		Eighth.		Ninth.	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
Best sperm oil	2	8½	4	2	4	5¾	4	6	1	6	4	6	4	6½	Stat.			
Common sperm oil..................	1	7	3	9	4	6¾	4	11	5	1½	5	4	5	6½	5	7⅜	5	8
Galiopoli oil	0	10¼	1	2¼	1	6	1	6½	1	7⅝	1	8¾	1	9	1	9¼	1	9½
Lard oil	0	10¼	0	10½	0	10¾	0	10¾	0	11¾	Stat.							
Rape oil	1	2½	1	6¼	1	7	1	7⅛	1	7¼	1	7¼	1	7¼	1	7⅜	Stat.	
Linseed oil	1	5½	1	6	1	6¾	1	6¼	1	6¼	1	6¼	1	6¾	Stat.			

For nice machinery nothing has been found to equal the *best* spermaceti oil, and it is a mistaken economy which applies inferior oil to good machinery.

2984



OMNIBUS CANE. Invented by S. W. Francis of New York, to enable a passenger at the extremity of the stage to pass up his fare to the driver without incommoding others. The cane is a common serviceable stick. Fig. 2984 represents the lower end of the cane; *m* is the receptacle for the coin, here, three cent pieces, which are put in by removing the bottom *d*, and the spring *i* and follower *j*, which, after the insertion of say 40 coin, are replaced. At the upper end of the cane is a small stud *b*, which on being depressed gives a longitudinal motion to the rod or wire *a*, which withdraws *h* from the opening *c*, gaged to the thickness of two coins, which are thrust out by the bell-crank *g*. The small spiral spring, as the stud is relieved, presses *h* against the coin till taken out by the driver.

OPSIOMETER. An instrument for measuring the extent of the limits of distinct vision in different individuals. The principle of M. Lehot's contrivance depends on the appearance presented by a straight line placed very near the eye, in the direction of its axis; and the principle is carried into practice by placing a thread of white silk on a narrow rule covered with black velvet, and furnished with a suitable apparatus for marking the exact points at which the thread begins and ceases to be distinctly seen, when held in a certain position with respect to the eye.

ORDINATE. In geometry, a straight line drawn from any point in a curve perpendicularly to another straight line, which is called the absciss. The absciss and ordinate together are called the *co-ordinates* of the point.

ORDNANCE. CANNON, GREAT GUNS, ARTILLERY. The size of field guns as established in 1827 in the French service, are 8 and 12 pounders, 18 calibres long, and weight of metal 150 times that of the shot. The English field artillery is almost entirely 9 pounders, 17 calibres long, and weight of metal 168 times that of the shot. The Prussian service use 6 and 12 pounders, 18 calibres long, and weight of metal 145 times that of the shot. The common charge is ⅓ of the weight of the ball.

For battery and siege service, as also in the navy, much heavier ordnance is used; from 24 up to 68 pounders. The Dahlgreen guns recently introduced into our navy are very short guns, in shape like a bottle nine-pin, of very large calibre, from 9 to 11 inches. The English 32 pounder is 9 feet long, and weighs 50 cwt.; the 68 pounder is 10 feet 10 inches long, and weighs 112 cwt. The Paixhan gun is intended for the discharge of hollow shot or shell: it is chambered; that is, there is a chamber, for the reception of the charge, of less calibre than the bore of the piece. Howitzers are short pieces, intended to throw shell at an elevation of from 10° to 30°, and are fixed on carriages. Mortars are still shorter pieces fixed to blocks, intended to throw shell at an elevation exceeding 20°, and sometimes even to 60°; they are both chambered ordnance. Howitzers seldom exceed 8 inches in calibre; Mortars are bored up to 13, 15, or even more inches in diameter. See GUNS AND GUNPOWDER.

ORTHOCHRONOGRAPH. This instrument has for its object the ascertaining of correct time. Its property is derived from the intersection of a curvilinear line at two points by the circular transit of a solar ray. The instrument consists of two horizontal circular plates parallel to each other. The upper one *a*, has an aperture for the passage of a solar ray; the lower one *b*, has three pair of semicircular lines, for the purpose of making observations. The lower plate *b*, is supported by a pillar *c*, resting on a tripod, furnished with three adjusting screws *d e f*. The upper plate *a* is raised or lowered by means of a rack *g*, working out of the pillar *c*, by means of a pinion and friction rollers, acted upon by the milled head *h*.

For taking an observation, place the instrument upon any firm support, with the letters N and S as nearly north and south as may be; but rigid accuracy in this respect is by no means essential. By means of a spirit-level and the adjusting screws *d e f*, bring the plate *b* into a horizontal position; then raise or lower the plate *a* until the sun's ray is in contact with the line on which it is intended to make the observation, as at A in the diagram, fig. 2986, or until the ray appears within the double line at at A, fig. 2987. In either case, note the hour, minute, and second, when the ray is at A; leaving the instrument undisturbed, the sun's ray will traverse the plate in the direction of the arrow until it arrives at the point A′, when the time is again to be accurately noted. Add the results of the two observations

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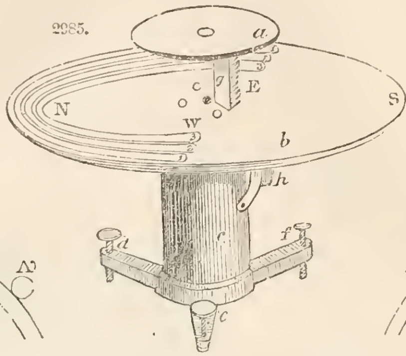

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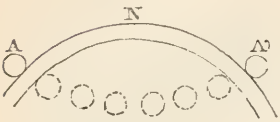

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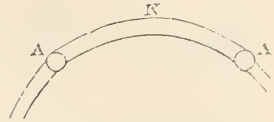
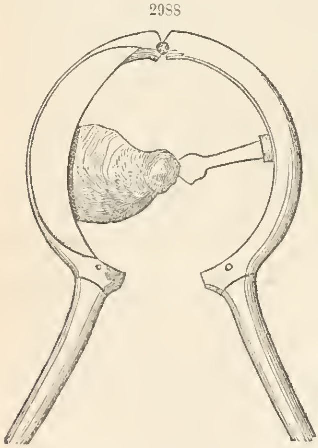


together, and divide by 2; the difference between this result and 12 hours will show the error of the clock as compared with solar time, which being corrected by the necessary equations, (of which very complete tables are given in the descriptive pamphlet which accompanies the instrument,) will give either mean or siderial time, as may be desired.

OSCILLATION, CENTRE OF. The centre of oscillation is that point in a vibrating body into which, if the whole were concentrated and attached to the same axis of motion, it would then vibrate in the same time the body does in its natural state. The centre of oscillation is situated in a right line passing through the centre of gravity, and perpendicular to the axis of motion.

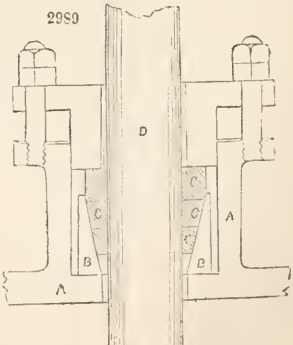
2988



OYSTER-OPENER, Picault's. Amongst the extensive collections of the products of industry, agriculture, and manufactures of 1849, exhibited in Paris, is a peculiar mechanical contrivance for opening oysters, which we have engraved, fig. 2988, to show how judiciously mechanical talent may be exercised in the improvement of articles of an humble class. The instrument, which is the invention of M. Picault, consists of two levers bent semicircularly at one end, and hinged together. In the curved portion of one of these levers is a narrow recess, of a size sufficient to receive the edge of an oyster, as shown; and on the other lever, exactly opposite to this recess, is fixed an oblique knife, which, on drawing the two straight ends or handles of the levers together, enters the joint of the shells, and divides them at once.

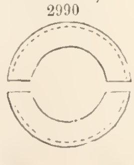
PACKING, METALLIC. Patented by Messrs. Allen & Noyes in 1849. By an examination of the accompanying drawing, its principle will be easily understood. Fig. 2989 A is the cylinder cover, B is a matrix of cast-iron, C C &c., a series of rings, and D a piston-rod. Its application is very simple: the bottom of the inside of the stuffing-box, instead of being curved in the usual way, is turned square with the rod on which the cast-iron matrix is fitted and ground on steam-tight; the diameter of the lower part of the stuffing-box and the inside of the gland is made somewhat larger than the rod; and the stuffing-box the same amount larger than the outside of the matrix; the rings are made of a composition softer than Babbitt's metal, and are cast in two pieces, as shown in fig. 2990. It will be observed, the upper ring in which the gland screws enters the matrix about an eighth of an inch, and the top is left the same diameter as the top of the matrix on the inside.

2989



In its operation, as the matrix is ground on the cylinder cover, and the inside of the rings made the same diameter as the rod, it is kept steam-tight; the rod working through the rings, and being so much the harder metal, keeps perfectly smooth; the rings are kept from being worn by any irregularity of motion, by the play allowed in the stuffing-box for the matrix. In screwing down the gland, which must be done lightly, as the rings are conical and left open, they will all press towards the rod, and in time the upper will take the place of the lower ring. In a stuffing-box of any kind, the great desideratum is to keep it tight, taking care not to cause the packing to scratch the rod, as it always does more or less in using hemp, nor to create an unnecessary amount of friction. This packing effectually accomplishes these, and gives the engineer little or no trouble.

2990



PAPER, MANUFACTURE OF. Till within the last thirty years, the linen and hempen rags from which paper was made, were reduced to the pasty state of comminution requisite for this manufacture by mashing them with water, and setting the mixture to ferment for many days in close vessels, whereby they underwent, in reality, a species of putrefaction. It is easy to see that the organic structure of the fibres would be thus unnecessarily altered, nay, frequently destroyed. The next method employed was to beat the rags into a pulp by stamping-rods, shod with iron, working in strong oak mortars, and moved by water-wheel machinery. So rude and ineffective was the apparatus, that forty pairs of stamps were required to operate a night and a day, in preparing one hundred weight of rags. The pulp or paste was then diffused through water, and made into paper by methods similar to those still practised in the small hand-mills.

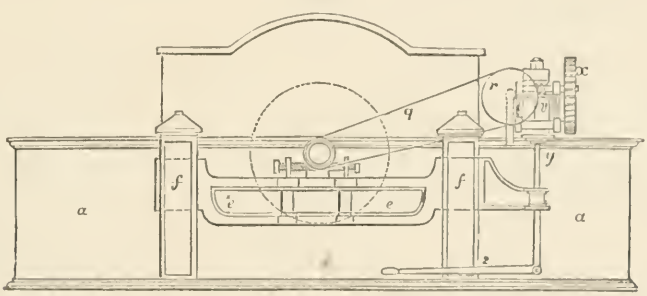
About the middle of the last century, the cylinder or engine mode, as it is called, of comminuting rags into paper pulp, was invented in Holland; which was soon afterwards adopted in France, and at a later period in England.

The first step in the paper manufacture is the sorting of the rags into four or five qualities. At the mill they are sorted again more carefully, and cut into shreds by women. For this purpose a table-frame is covered at top with wire-cloth, containing about nine meshes to the square inch. To this frame a long steel blade is attached in a slanting position, against whose sharp edge the rags are cut into squares or fillets, after having their dust thoroughly shaken out through the wire-cloth. Each piece of rag is thrown into a certain compartment of a box, according to its fineness; seven or eight sorts being distinguished.

The sorted rags are next dusted in a revolving cylinder surrounded with wire-cloth, about six feet long, and four feet in diameter, having spokes about 20 inches long attached at right angles to its axis. These prevent the rags from being carried round with the case, and beat them during its rotation; so that in half an hour, being pretty clean, they are taken out by the side door of the cylinder, and transferred to the engine, to be first washed and next reduced into a pulp. For fine paper, they should be previously boiled for some time in a caustic ley, to cleanse and separate their filaments.

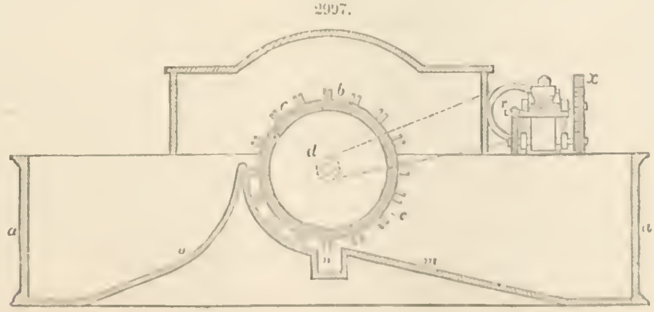
Wrigley's rag-machine is shown in Figs. 2996, 2997, 2998, and 2999. Fig. 2996 is a side elevation; Fig. 2997 a transverse section, taken lengthwise through nearly its middle; Fig. 2998 a plan view of

2996.



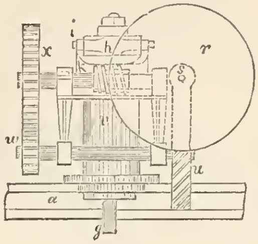
the apparatus detached upon a larger scale; and Fig. 2999 is an elevation. The vessel in which the rags are placed is shown at *a a*, and in about the centre of this vessel the beating or triturating roll *b b* is placed; it is surrounded with the blades or roll-bars *c c*, Fig. 2997. The roll is mounted upon a shaft *d d*, one end of which is placed in a pedestal or bearing on the further side of the chamber *a*, and the other in a bearing upon the arm or level *e e**, Fig. 2996, which is supported by its fulcrum, at the end *e**, in one of the standards *f f*, and at the other end by a pin fixed in the connecting-rod *g g*. At the

2997.



upper end of this connecting-rod there is a cross-piece or head *h*, having turned pivots at each end, upon which are placed small rollers *i i*, resting upon a horizontal cam *k k*, which is made to revolve. The cam *k k*, by means of its gearing, causes the roll *b* first of all to wash the rags a short time, then to be lowered at whatever rate is desired for breaking the fibres; to be maintained at the lowest point for the required number of revolutions for beating; and to be raised and retained, as required, for the final purpose of clearing the pulp. The upper or working edge of this cam is to be shaped exactly according to the action required by the engine-roll; as, for instance, suppose the previous operation of washing to be completed, and the time required for the operation of the rag machine to be three hours, one of which is required for lowering the roll, that, or the first division of the working surface of the cam *k k*, must be so sloped or inclined that, according to the speed at which it is driven, the rollers upon the cross-head shall be exactly that portion of the time descending the incline upon the cam, and consequently lowering the roll upon the plates *n*, Fig. 2997; and if the second hour shall be required for the roll to beat up the rags, the roll revolving all the time in contact with the plates, the second division of the cam *k k* must be so shaped (that is, made level) that the roll shall be allowed to remain, during that period, at its lowest point; and if the third portion of the time, or an hour, be required for raising the roll again, either gradually or interruptedly, then the third division of the cam *k* must be suitably shaped

2999.



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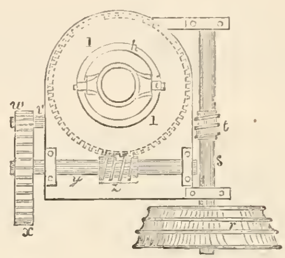

or inclined, so as to cause the cross-head to lift the roll during such interval or space of time; the particular shape of the inclined portions of the cam depending on the manner in which the manufacturer may wish the roll to approach to or recede from the bottom plates during its descent and ascent respectively.

Its mode of connection and operation in the rag-engine is as follows: supposing that the rags intended to be beaten up are placed in the vessel *a*, Fig. 2997, and motion is communicated from a steam-engine or other power, to the further end of the shaft *d*, the roll *b* will thus be caused to revolve, and the rags washed, broken, and beaten up, as they proceed from the front weir *m*, over the bottom plates *n*, and again round by the back weir *o*. There is a small pulley *p*, upon the near end of the shaft *d*, round which a band *q* passes, and also round another pulley *r*, upon the cross-shaft *s*; upon this shaft is a worm *t*, geering into a worm-wheel *u*, fixed upon another shaft *v*, below; upon the reverse end of which is a pinion *w*, geering into a spur-wheel *x*, upon the end of a shaft *y*; and upon the centre of this shaft *y* there is another worm *z*, geering into a horizontal worm-wheel 1, upon which the cam *k k* is fixed. Thus it will be seen that the requisite slow motion is communicated to the cam, which may be made to perform half a revolution in three hours; or it will be evident, that half a revolution of the cam *k k* may be performed in any other time, according to the calculation of the geering employed. The shaft may also be driven by hand, so as to give the required motion to the cam. Supposing, now, at the beginning of the operation, the cross-head bearing the lever and roll to be at the highest point upon the cam *k k*, as its revolution commences, the roll will revolve for a short time on the level surface of the cam, and will then be lowered until the cam *k k* has arrived at that point which governs the time that the roll remains at the lowest point, for the purpose of beating the rags into pulp, and as the cam *k k* continues to revolve, and thus brings the opposite slope upon the third portion of its working surface into action upon the cross-head, the roll will be raised in order to clear the pulp from knots and other imperfections, and thus complete the operation of the engine. In order to raise the cross-head and roll to the height from which it descended without loss of time, or to lift the cross-head entirely from off the cam when requisite, a lever 2, or other suitable contrivance may be attached to the apparatus, also a shaft may be passed across the rag-engine, and both ends of the roll may be raised instead of one only, as above described.

In the paper machine of Messrs Bryan Donkin & Co. in Bermondsey, on Fourdrinier's principle, each machine is capable of making, under the impulsion of any prime mover, all unwatched by a human eye and unguided by a human hand, from 20 to 50 feet in length, by 5 feet broad, of most equable paper in one minute. Of paper of average thickness it turns off 30 feet.

Fig. 3000, 3000^2 is an upright longitudinal section, representing the machine in its most complete state, including the drying steam-cylinders, and the compound channelled rollers of Mr. Wilkes, subsequently to be described in detail. The longer figure shows it all in train, when the paper is to be wound up wet upon the reels E E, which, being movable round the centre *l* of a swing-bar, are presented empty, time about, to receive the tender web. The shorter figure contains the steam or drying cylinders, the points O O of whose frame replace at the points P P the wet-reel frame F F P.

A is the vat, or receiver of pulp from the stuff-chest. B is the knot-strainer of Ibotson, to clear the pulp before passing on to the wire. G is the hog, or agitator in the vat. The arrows show the course of the currents of the pulp in the vat. 1 is the apron, or receiver of the water and pulp which escape through the endless wire, and which are returned by a scoop-wheel into the vat. *b* is the copper lip of the vat, over which the pulp flows to the endless wire, on a leathern apron extending from this lip to about nine inches over the wire, to support the pulp and prevent its escaping. *c c* are the bars which bear up the small tube rollers that support the wire. *d d* are ruler-bars to support the copper rollers over which the wire revolves. K is the breast-roller, round which the endless wire turns. N is the point where the shaking motion is given to the machine. M is the guide-roller, having its pivots movable laterally to adjust the wire and keep it parallel. L is the pulp-roller, or "dandy," to press out water, and to set the paper. *r* is the place of the second, when it is used. H is the first or wet press, or couching rollers; the wire leaves the paper here, which latter is couched upon the endless felt *p*; and the endless wire *o* returns, passing round the lower couch-roller. By Mr. Donkin's happy invention of placing these rollers obliquely, the water runs freely away, which it did not do when their axes were in a vertical line. *e e* are the deckles, which form the edges of the sheet of paper, and prevent the pulp passing away laterally. They regulate the width of the endless sheet. *f f* are the revolving deckle-straps. R is the deckle-guide, or driving-pulley. *g g* are tube-rollers, over which the wire passes, which do not partake of the shaking motion; and *h h* are movable rollers for stretching the wire, or brass carriages for keeping the rollers *g g* in a proper position.

C is the second press, or dry press, to expel the water in a cold state. K K, &c., are the steam-cylinders for drying the endless sheet. *i i* are rollers to convey the paper. *j j* are rollers to conduct the felt, which serves to support the paper, and prevent it wrinkling or becoming cockled. D D are the hexagonal expanding reels for the steam-dried paper web, one only being used at a time, and made to suit different sizes of sheets; *l* is their swing-fulcrum. F F F F is the frame of the machine.

The deckle-straps are worthy of particular notice in this beautiful machine. They are composed of many layers of cotton tape, each one inch broad, and together one-half inch thick, cemented with caoutchouc, so as to be at once perfectly flexible and water-tight.

The upper end of each of the two carriages of the roller L is of a forked shape, and the pivots of the roller are made to turn in the cleft of the forked carriages in such a manner that the roller may be prevented from having any lateral motion, while it possesses a free vibratory motion upwards and downwards; the whole weight of the roller L being borne by the endless web of woven wire.

The greatest difficulty formerly experienced in the paper manufacture upon the continuous system of Fourdrinier, was to remove the moisture from the pulp and condense it with sufficient rapidity, so as to prevent its becoming what is called *water-galled*, and to permit the web to proceed directly to the drying cylinders. Hitherto no invention has answered so well in practice to remove this difficulty as the channelled and perforated pulp-rollers or dandies of Mr. John Wilks, the partner of Mr. Donkin. Suppose one of these rollers (see L, Fig. 3000, and M M, Fig. 3005) is required for a machine which is to make paper 54 inches wide, it must be about 60 inches long, so that its extremities (see Figs. 3001 and 3002) may extend over or beyond each edge of the sheet upon which it is laid. Its diameter may be 7 inches. About 8 grooves, each 1-16th of an inch wide, are made in every inch of the tube; and they are cut to half the thickness of the copper, with a rectangularly shaped tool. A succession of ribs and grooves are thus formed throughout the whole length of the tube. A similar succession is then made across the former, but of 24 in the inch, and on the opposite surface of the metal, which, by a peculiar mode of management, had been prepared for that purpose. As the latter grooves are cut as deep as the former, those on the inside meet those on the outside, crossing each other at right angles, and thereby producing so many square holes; leaving a series of straight copper ribs on the interior surface of the said tube, traversed by another series of ribs coiled round them on the outside, forming a cylindrical sieve made of one piece of metal. The rough edges of all the ribs must be rounded off with a smooth file into a semicircular form.

Figs. 3002 and 3001, A A are portions of the ribbed copper tube. Fig. 3002 shows the exterior, and Fig. 3001 the interior surface; *b b* and *b b* show the plain part at each of the ends, where it is made fast to the brass rings by rivets or screws. C C are the rings with arms, and a centre-piece in each, for fixing the iron pivot or shaft B; one such pivot is fixed by riveting it in each of the centre-pieces of the rings, as shown at *c*, Fig. 3001; so that both the said pieces shall be concentric with the rings, and have one common axis with each other and with the roller. At *a a* a groove is turned in each of the pivots, for the purpose of suspending a weight by a hook, in order to increase the pressure upon the paper, whenever it may be found necessary.

Fig. 3003 is an end view, showing the copper tube and its internal ribs A A, the brass rings C C, arm D, centre-piece E, and pivot B. Fig. 3004 is a section of the said ring, with the arms, &c.

The roller is shown at L, Fig. 3000, as lying upon the surface of the wire web. The relative position of that perforated roller, and the little roller *b* over which it lies, is such that the axis of L is a little to one side of the axis of *b*, and not in the same vertical plane, the latter being about an inch nearer the vat end. Hence, whenever the wire-web is set in progressive motion, it will cause the roller L to revolve upon its surface; and as the paper is progressively made, it will pass onwards with the web under the surface of the roller. Thus the pulpy layer of paper is condensed by compression under the ribbed roller; while it transmits its moisture through the perforations, it becomes sufficiently compact to endure the action of the wet-press rollers H H, and also acquires the appearance of parallel lines, as if made by hand in a laid mould.

Mr. Wilks occasionally employs a second perforated roller in the same machine, which is then placed at the dotted lines *i i*.

The patentee has described in the same specification a most ingenious modification of the said roller, by which he can exhaust the air from a hollowed portion of its periphery, and cause the paper in its passage over the roller to undergo the sucking operation of the partial void, so as to be remarkably condensed; but he has not been called upon to apply this second invention, in consequence of the perfect success which he has experienced in the working of the first.

The following is a more detailed illustration of Mr. Wilks's improved roller:

Fig. 3005 represents two parts of his double-cased exhausting cylinder. This consists of two copper tubes, one nicely lining the other; the inner being punched full of round holes, as at K K, where that tube is shown uncovered; a portion of the inner surface of the same tube is shown at L L. In the figure also, two portions of the outer tube are shown at M M and N N, the former being an external, and the

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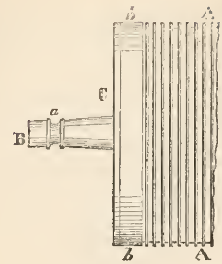

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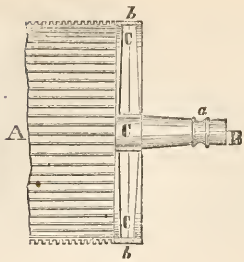

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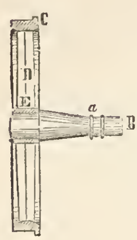

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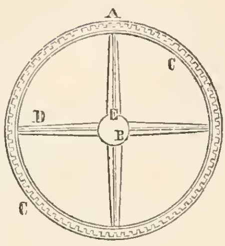

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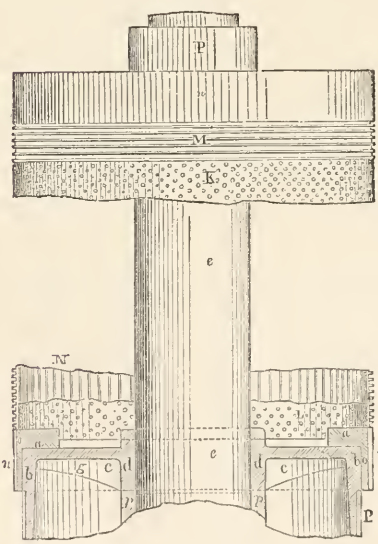

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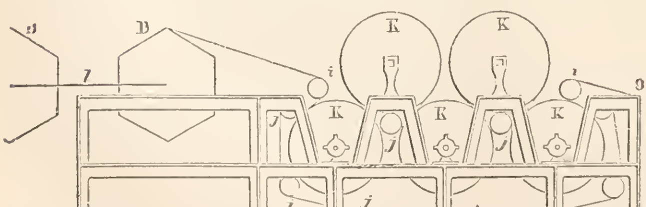
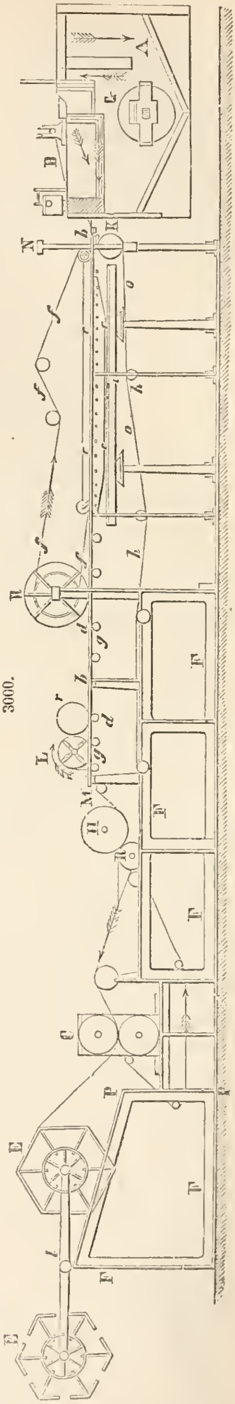


3000.



latter an internal view. Here we see that the external tube is the ribbed perforated one already described; the holes in the inner tube being made in rows to correspond with the grooves in the outer. The holes are so distributed that every hole in one row shall be opposite to the middle of the space left between two holes in the next row, as will appear from inspection of the figure. The diameter of each of the punched holes somewhat exceeds the width of each rib in the inside of the outer cylinder, and every inside groove of this tube coincides with a row of holes in the former, which construction permits the free transudation or percolation of the water out of the pulp. At each end of this double-case cylinder a part is left at N N plain without, and grooved merely in the inside of the outer tube. The smooth surface allows the brass ends to be securely fixed; the outer edge of the brass ring fits tight into the inside of the end of the cylinders.

On the inside of each of these rings there are four pieces which project towards the centre or axis of the cylinder, two of which pieces are shown at *a a*, Fig. 3005, in section. *b b* is a brass ring with four arms *c c c c*, and a boss or centre-piece *d d*. The outer edge of the last-mentioned ring is also turned cylindrical, and of such a diameter as to fit the interior of the former ring *o o*. The two rings are securely held together by four screws. *e e* is the hollow iron axle or shaft upon which the cylinder revolves. Its outside is made truly cylindrical, so as to fit the circular holes in the bosses *d d* of the rings and arms at each end of the cylinder. Hence, if the hollow shaft be so fixed that it will not turn, the perforated cylinder is capable of having a rotatory motion given to it round that shaft. This motion is had recourse to when the vacuum apparatus is employed. But otherwise the cylinder is made fast to the hollow axle by means of two screw-clamps. To one end of the cylinder, as at *p*, a toothed wheel is attached for communicating a rotatory motion to it, so that its surface motion shall be the same as that of the paper web; otherwise a rubbing motion might ensue, which would wear and injure both.

The paper stuff or pulp is allowed to flow from the vat A, Fig. 3000, on to the surface of the endless wire-web, as this is moving along. The lines *o o*, Fig. 3000, show the course of the motion of the web, which operates as a sieve, separating to a certain degree the water from the pulp, yet leaving the latter in a wet state till it arrives at the first pair of pressing-rollers H H, between which the web with its sheet of paper is squeezed. Thick paper, in passing through these rollers, was formerly often injured by becoming water-galled, from the greater retention of water in certain places than in others. But Messrs. Donkin's cylinder, as above described, has facilitated vastly the discharge of the water, and enabled the manufacturer to turn off a perfectly uniform smooth paper.

In Fig. 3000, immediately below the perforated cylinder, there is a wooden water-trough. Along one side of the trough a copper pipe is laid, of the same length as the cylinder, and parallel to it; the distance between them being about one-fourth of an inch. The side of the pipe facing the cylinder is perforated with a line of small holes, which transmit a great many jets of water against the surface of the cylinder, in order to wash it and keep it clean during the whole continuance of the process.

The principle adopted by John Dickinson for making paper, is different from that of Fourdrinier. It consists in causing a polished hollow brass cylinder, perforated with holes or slits, and covered with wire-cloth, to revolve over and just in contact with the prepared pulp; so that by connecting the cylinder with a vessel exhausted of its air, the film of pulp, which adheres to the cylinder during its rotation, becomes gently pressed, whereby the paper is supposed to be rendered drier, and of more uniform thickness, than upon the horizontal hand-moulds or travelling wire-cloth of Fourdrinier. When subjected merely to agitation, the water is sucked inwards through the cylindric cage, leaving the textile filaments so completely interwoven as, if felted among each other, that they will not separate without breaking, and when dry they will form a sheet of paper of a strength and quality relative to the nature and preparation of the pulp. The roll of paper thus formed upon the hollow cylinder is turned off continuously upon a second solid one covered with felt, upon which it is condensed by the pressure of a third revolving cylinder, and is thence delivered to the drying rollers.

Mr. Ibotson, of Poyle, paper manufacturer, obtained a patent, see B, Fig. 3000, which has proved very successful for a peculiar construction of a sieve or strainer. Instead of wire meshes, he uses a series of bars of gun metal, laid in the bottom of a box very closely together, so that the upper surfaces or the flat sides may be in the same plane, the edge of each bar being parallel with its neighbor, leaving parallel slits between them of from about 1-70th to 1-100th of an inch in width, according to the fineness or coarseness of the paper stuff to be strained. As this stuff is known to consist of an assemblage of very fine flexible fibres of hemp, flax, cotton, &c., mixed with water; and as, even in the pulp of which the best paper is made, the length of the said fibres considerably exceeds the diameter of the meshes of which common strainers are formed, consequently the longest and most useful fibres were formerly lost to the paper manufacturer. Mr. Ibotson's improved sieve is employed to strain the paper stuff previously to its being used in the machine above described, (see its place at B in the vat.) When the strainer is at work, a quick vertical and lateral jogging motion is given to it, by machinery similar to the jogging screens of corn mills.

Since the lateral shaking motion of the wire web in the Fourdrinier machine, as originally made, was injurious to the fabric of the paper, by bringing its fibres more closely together breadthwise than lengthwise, thus tending to produce long ribs or thick streaks in its substance, it was proposed to give a rapid up-and-down movement to the travelling web of pulp; and this has been introduced into Mr. Donkin's machines.

Mr. Dickinson obtained a patent for a method of uniting face to face two sheets of pulp by means of machinery, in order to produce paper of extraordinary thickness. Two vats are to be supplied with paper stuff as usual; in which two hollow barrels or drums are made to revolve upon axles driven by any first mover; an endless felt is conducted by guide rollers, and brought into contact with the drums; the first drum gives off the sheet of paper pulp from its periphery to the felt which, passing over a pressing roller is conducted by the felt to that part of a second drum which is in contact with another pressing roller. A similar sheet of paper pulp is now given off from the second drum, and is brought into contact with the former by the pressure of its own roller. The two sheets of paper pulp thus united are carried forwards by the felt over a guide-roller, and onwards to a pair of pressing-rollers where, by contact, the moist surface of the pulp are made to adhere, and to constitute one double thick sheet of paper, which, after passing over the surfaces of hollow drums, heated by steam, becomes dry and compact. The rotatory movements of the two pulp-lifting drums must obviously be simultaneous, but that of the pressing-rollers should be a little faster, because the sheets extend by the pressure, and they should be drawn forwards as fast as they are delivered, otherwise creases would be formed. Upon this invention is founded Mr. Dickinson's ingenious method of making safety-paper for post-office stamps, by introducing silk fibres, &c., between the two laminæ.

The following contrivance of the same manufacturer is a peculiarly elegant mechanical arrangement, and consists in causing the diluted paper pulp to pass between longitudinal apertures, about the hundred-and-fifteenth part of an inch wide, upon the surface of a revolving cylinder.

The pulp being dilated to a consistency suitable for the paper machine, is delivered into a vat, of which the level is regulated by a waste-pipe, so as to keep it nearly full. From this vat there is no other outlet for the pulp except through the wire-work periphery of the revolving cylinder, and thence out of each of its ends into troughs placed alongside, from which it is conducted to the machine destined to convert it into a paper web.

The revolving cylinder is constructed somewhat like a squirrel cage, of circular rods, or an endless spiral wire, strengthened by transverse metallic bars, and so formed that the spaces between the rings are sufficient to allow the slender fibres of the pulp to pass through, but are narrow enough to intercept the knots and other coarse impurities, which must of course remain and accumulate in the vat. The spaces between the wires of the squirrel cage may vary from the interval above stated, which is intended for the finest paper, to double the distance for the coarser kinds.

It has been stated that the pulp enters the revolving cylinders solely through the intervals of the wires in the circumference of the cylinder; these wires or rods are about three-eighths of an inch broad without, and two-eighths within, so that the circular slits diverge internally. The rods are one-quarter of an inch thick, and are riveted to the transverse bars in each quadrant of their revolution, as well as at their ends to the necks of the cylinder.

During the rotation of the cylinder its interstices would soon get clogged with the pulp, were not a contrivance introduced for creating a continual vertical agitation in the inside of the cylinder. This is effected by the up-and-down motion of an interior agitator or plunger, nearly long enough to reach from the one end of the cylinder to the other, made of stout copper, and hollow, but water-tight. A metal bar passes through it, to whose projecting arm at each end a strong link is fixed; by these two links it is hung to two levers, in such a way that when the levers move up and down they raise and depress the agitator, but they can never make it strike the sides of the cylinder. Being heavier than its own bulk of water, the agitator, after being lifted by the levers, sinks suddenly afterwards by its weight alone.

The agitator's range of up-and-down movement should be about one inch and a quarter, and the number of its vibrations about 80 or 100 per minute; the flow of the pulp through the apertures is suddenly checked in its descent and promoted in its ascent, with the effect of counteracting obstructions between the ribs of the cylinder.

The sieve-cylinder has a toothed wheel fixed upon the tubular part of one of its ends, which works between two metal flanches made fast to the wooden side of the vat, for the purpose of keeping the pulp away from the wheel; and it is made to revolve by a pinion fixed on a spindle, which, going across the vat, is secured by two plummer-blocks on the outside of the troughs, and has a rotatory motion given to it by an outside rigger or pulley, by means of a strap from the driving-shaft, at the rate of 40 or 50 revolutions per minute. This spindle has also two double eccentrics fixed upon it, immediately under the levers, so that in every revolution it lifts those levers twice, and at the same time lifts the agitator.

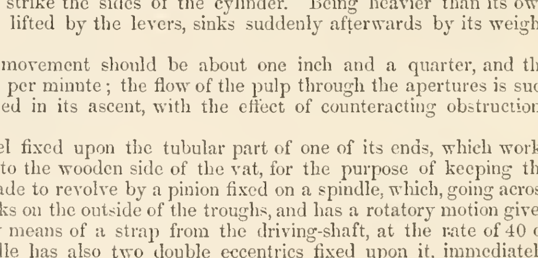
The diameter of the sieve-cylinder is not very material, but 14 inches have been found a convenient size; its length must be regulated according to the magnitude of the machine which it is destined to supply with pulp.

Metal flanches are firmly fixed to the sides of the vat, with a water-tight joint, and form the bearings in which the cylinder works.

Mr. Dickinson obtained a patent in 1840 for a new mode of sizing paper continuously, in an air-tight vessel, (partly exhausted of air,) by unwinding a scroll of dried paper from a reel, and conducting it through heated size; then, after pressing out the superfluous size, winding the paper on to another reel.

A longitudinal section of the apparatus employed for this purpose is represented in Fig. 3006, where *a* is the air-tight vessel; *b*, the reel upon which the paper to be sized is wound; whence it proceeds beneath the guide-roller *c*, and through the warm size to another guide-roller *d*. It thence ascends between the press-rolls *c f*, (by whose revolution the paper is drawn from the reel *b*,) and is wound upon the reel *g*. A float *h* is suspended from the cross-bar *i* of the vessel *a*, for the purpose of diminishing the surface of size exposed to evaporation; and beneath the bottom of the vessel is an inclosed space *j*, into which steam or hot water is introduced for maintaining the temperature of the size.

3006.



PAPER MACHINES, *regulation of.* It is found in practice to be difficult to regulate the motion of the Foudrinier, and other machines, in common use, for the manufacture of endless paper. When the flow of pulp upon any machine is uniform, an acceleration of its motion will make the paper *thin*, whilst a retardation will make it *thick*. Hence it is of the utmost importance, in order to make paper of even weight and thickness, that when the flow of the pulp is uniform, the machine shall move uniformly at the same speed. But if, by any contrivance, the flow of the pulp could be augmented, or checked, just in the same proportion as the machine moves slower or faster, it is evident that the necessary relation between its speed, and the quantity of pulp thrown on, might be effected and maintained. Consequently, two modes of obtaining the requisite uniformity in the thickness and weight of the endless sheet of paper suggest themselves.

I. To regulate the speed of the motor driving the machine.

II. To regulate the flow of pulp upon the machine.

The attention of constructors has usually been directed chiefly to the first method; and hence we find the machine-wheels of paper-mills are very frequently *tub-wheels*, wasting a large amount of water, but nevertheless selected and used on account of the regularity of their motion. With this object also it is almost invariably the practice here to employ an independent wheel to drive the paper machine alone.

Some attempts have recently been made in this country to regulate endless paper machines by the second method, and accordingly "*pulp regulators*" have been applied with considerable success in several important mills.

It being, in fact, a desideratum to procure some unobjectionable means of effecting the regulation referred to, we have translated from J. B. Viollet's *Journal des Usines* an account of a mechanical contrivance devised in France for this object.

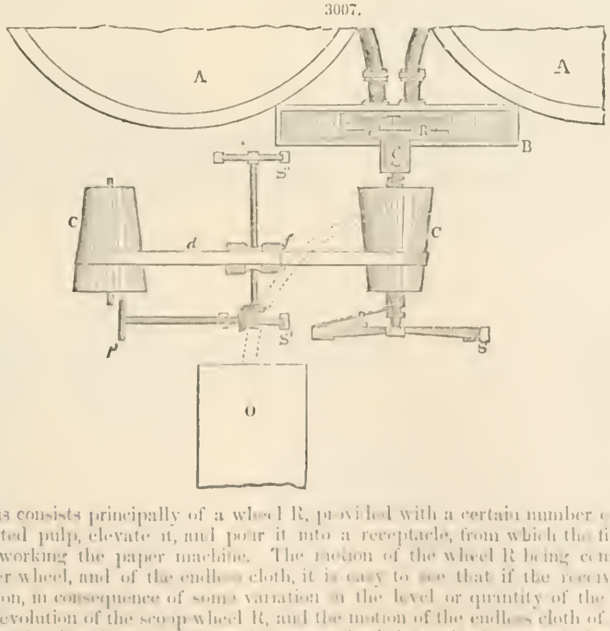
Regulator for feeding machines making endless paper, by Messrs. Sandford and Varrall, *mechanical engineers of Paris.*—Whatever care may be taken to render uniform the speed of the motors which drive endless paper machines, and notwithstanding we usually establish for each of these machines a separate water-wheel, constructed of iron, in the best provided works, it has long been impossible to obtain a regularity of motion, and a harmony between the movement of the endless cloth and the feeding on of the pulp, so that the paper may possess uniformly the same thickness.

From this resulted a serious imperfection, consisting of a marked inequality between the different parts of the long band of paper, and consequently, between the sheets into which it is cut. We conceived that this inequality was not only a fault, but also that it exposed the manufacturers to disputes not arising from any fault on their part.

In fact, to cause the velocity of the machines, and consequently, the strength of the paper to vary, it was enough that the resistances opposed by the materials were not constant, or that the stream of water happened to be disturbed.

It is to avoid these difficulties and inconveniences that Sandford and Varrall have invented the apparatus represented in Figs. 3007, 3008, 3009, 3010, 3011, and 3012.

3007.



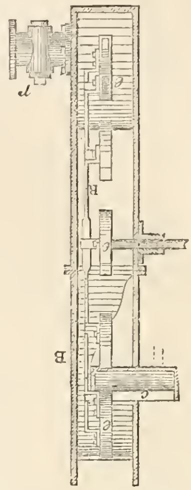
This apparatus consists principally of a wheel R, provided with a certain number of scoops *c*, which take up the diluted pulp, elevate it, and pour it into a receptacle, from which the filter *e* conducts it into the vat for working the paper machine. The motion of the wheel R being connected both with that of the water wheel, and of the endless cloth, it is easy to see that if the receiver accelerates, or retards its motion, in consequence of some variation in the level or quantity of the water above, the rapidity of the revolution of the scoop wheel R, and the motion of the endless cloth of the machine, will each feel a proportional variation. But as the scoop-wheel for each of its revolutions pours the same quantity of pulp into the filter *e* of the machine, it is evident that the feeding on of the pulp will augment, or diminish proportionally to the velocity of translation of the endless cloth, and that, consequently, the strength of the paper ought to be constant, so long as we do not change the ratio between the quantity of pulp furnished and the distance moved in a given time by the metallic cloth.

This principle established, the following are the details of the ingenious apparatus of Sandford and Varrall.

R, as we have said, is the regulating wheel, provided with scoops *e e e*; this wheel is confined in a drum B, which the pulp enters from the reservoirs A A by the large stop-cocks *r r*, kept entirely open, so as to maintain sensibly in the drum B the same level as in the reservoirs A A. It is of little importance, moreover, if this level be not rigorously equal, nor even if it varies notably in the reservoirs A A; for, provided the pulp arrives in sufficient quantity, and we must take care that it be always so, each of the scoops, every time they issue from the pulp, only withdraws the same quantity of material.

3008.

3010.

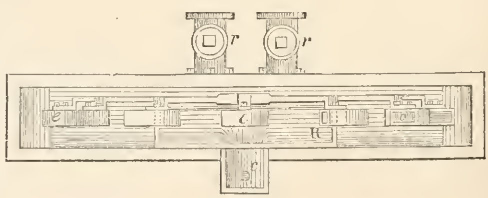


We easily conceive how advantageous is this property of the apparatus, since, notwithstanding all the variations of level of the liquid pulp in the reservoir, or *stuff-chest*, it assures regularity in feeding on the pulp—a regularity which would often be compromised if made dependent solely on this level.

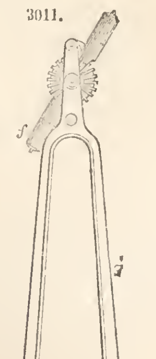
It is necessary that the relation which exists between the number of revolutions of the scoop-wheel R and the velocity of the endless cloth may be varied, when we wish to alter the strength of the paper.

To obtain this effect, Sandford and Varrall have controlled the scoop-wheel R by the two parallel cones C and C′, which carry the belt *d*: the cone C′ receiving its motion from the lateral shaft established alongside the paper machine, and on which is all the geering which moves the endless cloth, and the other movable parts of the machine.

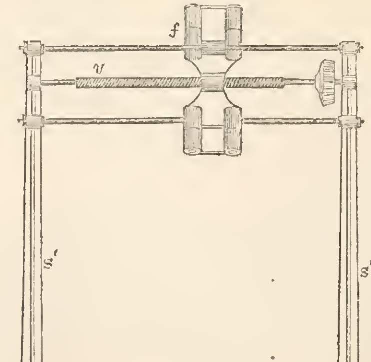
3009.



3011.



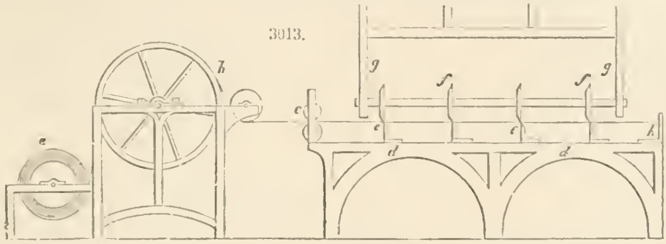
3012.



It is sufficient to move the belt laterally, (along the cones,) in order to retard or accelerate the rotation of the scoop-wheel, without altering the angular velocity of the other movable parts, and thus, consequently, to change the relation in question, and of course the thickness of the paper made.

PAPER CUTTING. The following machine for cutting paper was contrived by J. Dickinson, of Nash Mill. The paper is wound upon a cylindrical roller *a*, Fig. 3013, mounted upon an axle, supported in an iron frame or standard. From this roller the paper in its breadth is extended over a conducting drum *b*, also mounted upon an axle turning in the frame or standard, and after passing under a small guide-roller, it proceeds through a pair of drawing or feeding rollers *c*, which carry it into the cutting machine.

Upon a table *a d*, firmly fixed to the floor of the building, there is a series of chisel-edged knives *e e e*, placed at such distances apart as the dimensions of the cut sheets of paper are intended to be. These knives are made fast to the table, and against them a series of circular cutters *f f f*, mounted in a swinging frame *g g*, are intended to act. The length of paper being brought along the table over the edges of the knives, up to a stop *h*, the cutters are then swung forwards, and by passing over the paper against the stationary knives, the length of paper becomes cut into three separate sheets.



The frame *g g*, which carries the circular cutters *f f f*, hangs upon a very elevated axle, in order that its pendulous swing may move the cutters as nearly in a horizontal line as possible; and it is made to vibrate to and fro by an eccentric or crank, fixed upon a horizontal rotary shaft extending over the drum *b*, considerably above it, which may be driven by any convenient machinery.

The workmen draw the paper from between the rollers *c*, and bring it up to the stop *h*, in the intervals between the passing to and fro of the swing-cutters.

The following very ingenious apparatus for cutting the paper web transversely into any desired lengths, was made the subject of a patent by Mr. E. N. Fourdrinier, in June, 1831, and has since been performing its duty well in many establishments.

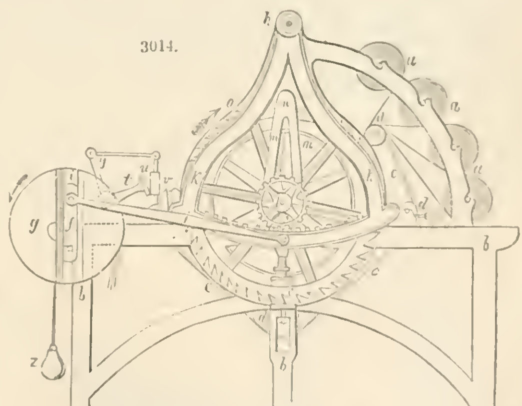
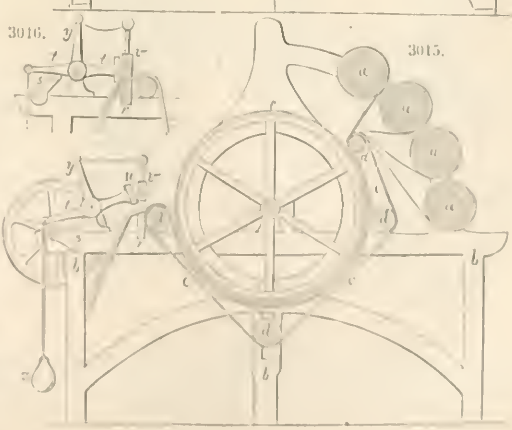


Fig. 3014 is an elevation, taken upon one side of the machine; and Fig. 3015 is a longitudinal section. *a a a a* are four reels, each covered with one continuous sheet of paper; which reels are supported upon bearings in the framework *b b b*. *c c c* is an endless web of felt cloth passed over the rollers *d d d d*, which is kept in close contact with the under side of the drum *e e*, seen best in Fig. 3016.

The several parallel layers of paper to be cut, being passed between the drum *e* and the endless felt *c*, will be drawn off their respective reels and fed into the machine, whenever the driving-band is slid from the loose to the fast pulley upon the end of the main shaft *f*. But since the progressive advance of the paper-webs must be arrested during the time of making the cross-cut through it, the following apparatus becomes necessary. A disk *g*, which carries the pin or stud of a crank *i*, is made fast to the end of the driving-shaft *f*. This pin is set in an adjustable sliding-piece, which may be confined by a screw within the bevelled graduated groove, upon the face of the disk *g*, at variable distances from the axis, whereby the eccentricity of the stud *i*, and of course the throw of the crank, may be considerably varied. The crank-stud *i* is connected by its rod *j* to the swinging curvilinear rack *k*, which takes into the toothed wheel *l* that turns freely



upon the axle of the feed drum *e e*. From that wheel the arms *m m* rise, and bear one or more pallets *n*, which work in the teeth of the great ratchet-wheel *o o*, mounted upon the shaft of the drum *e*.

The crank-plate *g* being driven round in the direction of its arrow, will communicate a see-saw movement to the toothed arc *k*, next to the toothed wheel *l* in geering with it, and an oscillatory motion to the arms *m m*, as also to their surmounting pall *n*.

In its swing to the left hand, the catch of the pall will slide over the slope of the teeth of the ratchet-wheel *o*; but in its return to the right hand it will lay hold of these teeth and pull them, with their attached drum, round a part of a revolution. The layers of paper in close contact with the under half of the drum will be thus drawn forward at intervals, from the reels, by the friction between its surface and the endless felt, and in lengths corresponding to the arc of vibration of the pall. The knife for cutting these lengths transversely is brought into action at the time when the swing arc is making its inactive stroke, viz., when it is sliding to the left over the slopes of the ratchet-teeth *o*. The extent of this vibration varies according to the distance of the crank-stud *i* from the centre *f*, of the plate *g*, because that distance regulates the extent of the oscillations of the curvilinear rack, and that of the rotation of the drum *e*, by which the paper is fed forwards to the knife apparatus. The proper length of its several layers being by the above-described mechanism carried forward over the bed *r* of the cutting-knife or shears *r v*, whose under blade *r* is fixed, the wiper *s*, in its revolution with the shaft *f*, lifts the tail of the lever *t*, consequently depresses the transverse movable blade *v*, (as shown in Fig. 3015,) and slides the slanting blades across each other obliquely, like a pair of scissors, so as to cause a clean cut across the plies of paper. But just before the shears begin to operate, the transverse board *u* descends to press the paper with its edge, and hold it fast upon the bed *r*. During the action of the upper blade *v* against the under *r*, the fall-board *u* is suspended by a cord passing across pulleys from the arm *y* of the bell-crank lever *t t*. Whenever the lifter cam *s* has passed away from the tail of the bell-crank *t*, the weight *z*, hung upon it, will cause the blade *v*, and the pinching-board *u*, to be moved up out of the way of the next length of paper, which is regularly brought forward by the rotation of the drum *e*, as above described. The upper blade of the shears is not set parallel to the shaft of the drum, but obliquely to it, and is, moreover, somewhat curved, so as to close its edge progressively upon that of the fixed blade. The blade *v* may also be set between two guide-pieces, and have the necessary motion given to it by levers.

PARALLEL MOTIONS. The following figures exhibit a variety of forms of parallel motions, such as are employed to maintain the rectilineal direction of the piston-rod of a steam-engine, under the constantly varying angular direction of the beam. Contrivances of this kind are required in other circumstances of the conversion of rotatory and alternating angular motion into rectilineal motion, and the converse: but the absolute necessity there is of guiding the path of piston in the steam-engine, has called forth more attention to the principles and mechanism of parallel motions than would otherwise, in all probability, have been awarded to the subject for other purposes. In the first place, the principle may be briefly indicated.

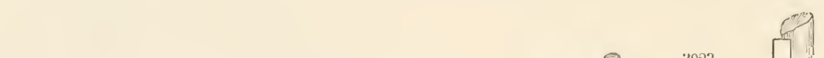


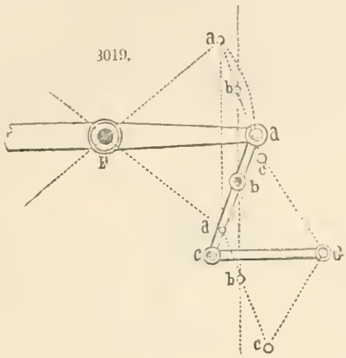
Fig. 3016. Given A B D a right angle: it can be demonstrated that if the end A of the right line A D descend from A to B along the line A B, while the end D moves along the line B D produced, a point C in the middle of the line will describe the circle C G. Hence, if a beam A D has one end sliding in a groove at D, and is connected or jointed at the middle C in a guide B C of half its length, this guide also moving on a joint at B, then in every position of the beam the point C will describe the circle C G, and the point A of the beam will move in a straight line.

Fig. 3017. In practice, it may be more convenient to have the end D of the beam fixed to the end

of a movable bar, as D N, of some feet in length, than to slide in a groove; for, though the arc described by the end D will deviate a little from a straight line, yet the error produced thereby will be so very small that it can have no bad effect, or even be discovered in practice.

In the steam-engine there are various modes adopted by means of jointed rods, &c., different from that described above, for causing the piston-rod, attached to the end of the beam, to move in a straight line, which, although not mathematically correct, are still so very near the truth as to answer the purpose wanted exceedingly well; such a system of jointed rods is generally termed by engineers a *parallel motion.*

3019.



3018.

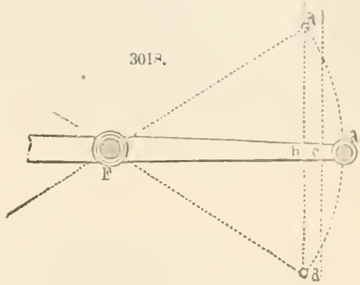
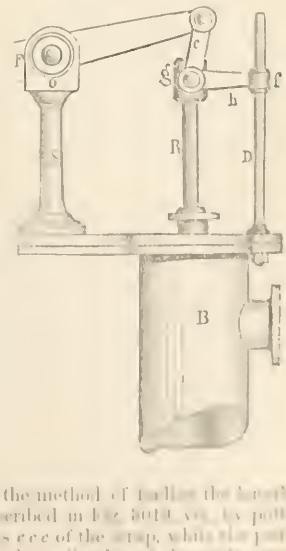


Fig. 3018. In the beam *a* F, which is shown in its three positions, viz., at the middle and the two extremities of the stroke, the versed sine *a b* of the arc formed by the extremity of the beam, is termed the vibration, and a piston-rod attached to the beam is made to move in a line bisecting this vibration; thus, if a piston-rod were attached to the beam *a* F, *c d* is the line in which the rod ought to move.

Fig. 3019 is a general mode of finding the length of the radius-rod G *c*, and shows the principle upon which parallel motions formed by jointed rods are founded; *a* F is the beam, *a c* a strap, one end of which is attached to the beam, and the piston-rod is attached somewhere about the middle, as at *b*; the beam is then put in its three positions, and while the point *b* to which the piston-rod is fixed is kept in the straight line, bisecting the vibration, the positions of the lower end *c* of the strap are carefully marked, as at *c c c*; then the centre G of the circle passing through these points will be the point to which the radius-rod G *c*, connected to the strap at *c*, should be fixed, and the radius of the circle will be the length of the rod. If the point *b* be taken exactly in the middle of the strap, the length of the radius-rod G *c* will be equal to the portion of the beam *a* F.

3021.



3020.

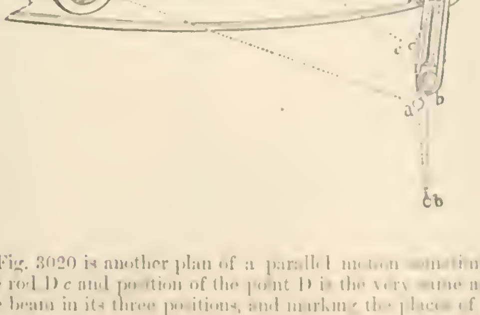


Fig. 3020 is another plan of a parallel motion sometimes used: the method of finding the length of the rod D *c* and position of the point D is the very same as that described in Fig. 3019, viz., by putting the beam in its three positions, and marking the places of the points *c c c* of the strap, while the point *b* to which the piston-rod is fixed is kept in the same straight line: the radius D *c* of the circle passing through the points *c c c* will be the length of the radius-rod, and the centre of the same circle the point to which it should be fixed.

Fig. 3021 is a method of causing the piston rod to describe a straight line, often adopted in steam-pumps: the lever F has the centre of motion at *o* in the up-standard *s*, fixed upon the cover of the pump D is a cylindrical rod, also fixed to the top of the pump, and set quite parallel to the pump-rod R; *g* is a cross-head attached to the top of the pump-rod, having a projecting arm *h* terminating in a socket *f* which moves on the rod D; the lever F is connected to the cross-head *g* by two straps, one of which is shown at *c*; upon moving the lever F it will be quite clear that the piston-rod R must move parallel to D.

Fig. 3022 is a drawing of a walking-beam for a twelve-horse engine, with parallel motion attached The point B to which the inner strap is fixed, is very often taken exactly in the centre, betwixt A and *c* and when that is the case, the length of the radius-rods is equal to the same distance, or, in other words, equal to the fourth part of the whole length of beam.

When the inner strap is suspended from any other point than in the middle of the distance A *c*, the position of the centre and length of the rod *c f* would be found as described in Fig. 3019: keeping the point *a* to which the piston-rod is attached always in the same straight line in which it ought to move, and carefully marking the points assumed by the lower end of the strap *f*.

The point *b* to which the air-pump rod is fixed should be exactly in the middle of the strap, when the beam is divided into four equal parts, which will also insure a parallel motion for the bucket of the air-pump.

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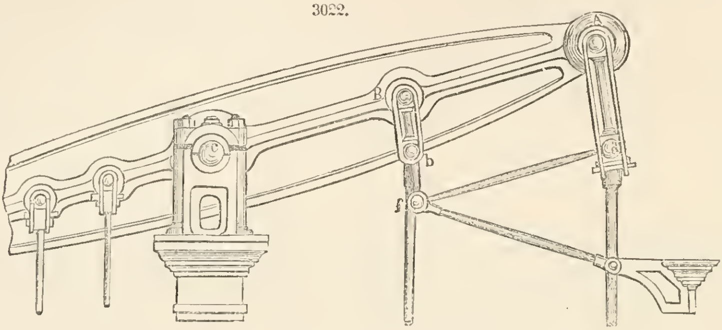
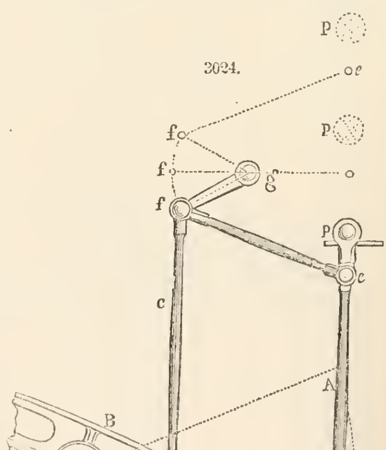


Fig. 3023 is a mode of causing the piston-rod to describe a straight line by the use of the two friction-wheels W W confined betwixt the guides G G; this plan is often used in small engines, when the crank to which the connecting-rod P is attached is immediately above the cylinder.

Fig. 3024 is a plan of parallel motion usually employed in marine engines; the manner of finding the length and position of the radius-rod *g* is precisely the same as in Fig. 3019; this motion is, in fact, the common parallel motion modified to suit the circumstances in which it is placed. The length of the radius-bar *e f* is easily found in practice, by supposing the piston-rod to move in a right line, and finding three points through which a point in the side-rod A, assumed at pleasure, would pass, in the highest, middle, and lowest positions of the piston-rod; then a circular arc passing through these points will give the radius and centre sought; and the point *e* assumed in the side-rod will be the point of connection of the radius-bar.

3024.



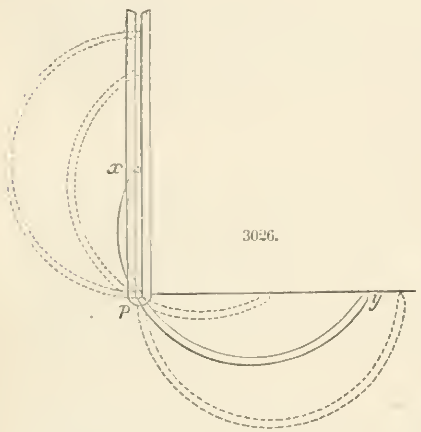
Now, in order that the point P of connection of the side-rod and piston-rod may describe a right line, the point *f* must describe an arc of curvature sufficient to neutralize the curvature which would be transmitted to it by the travel of the side-lever; to determine this arc *f f f*, it is only necessary to describe from the middle point of the stroke, taken in the straight line *e e e*, a right line *e g f* equal in length to the length of the radius-bar, and perpendicular to it; also the highest position of the radius-bar forming the same angle with *e g f* that the radius-bar forms with that line in its lowest position; then the three points *f f f* being thus found, a circular arc drawn through them will determine the fixed centre *g*, and the length of the parallel bar *g f*.

The length of the side-bar *c* from *f* to its connection with the side-lever, must of course be equal in length to the side-rod A, from *e* to the point also of its connection with the side-lever. These rods will remain during the working of the engine parallel to each other, and consequently the radius-rod will continue parallel to the axis of the side-lever in all positions of the stroke. It must, however, be remarked, that the parallelism is not absolutely correct, but is true only within certain though narrow limits, giving an approximation sufficiently near for common practice.

Fig. 3025 shows a form of parallel motion sometimes adopted in land-engines of the smaller class. It is susceptible of great accuracy, and admits of several modifications.

In this figure A is the cylinder of the engine, B the beam, supported on a rocking-bar having a movable centre at D. The radius-bar has its fixed centre at *a* attached to the framing of the engine, and is centred to the beam at a point *c* equidistant from the main centre *f* and the point of attachment to the piston-rod. Now, the radius-rod being equal to half the radius of the beam, and the radius-bar having a fixed centre at *a*, the point *c* of the beam must of necessity describe the arc *c c c* during each stroke of the piston. Now, in describing this arc it is plain that the main centre *f* of the beam must describe simultaneously an arc about the centre D upon which it is carried. But the radius *f* D being great in comparison to radii *f c* and *a c*, the motion of the main centre may be supposed, without sensible error, to be in a right line, as if it were free to slide in a horizontal groove. But the centre *f* being constrained to move horizontally through a given space during a stroke of the piston, the end *a* of the beam will travel horizontally through an equal space in the same direction, and will therefore, instead of describing an arc about the centre *f*, describe the chord *a a a* of that arc, parallel to the chord of the arc *c c c*, which is the thing wanted.

This motion and its modifications are founded on the principle that if the arc of a semicircle be made to slide against a fixed point *p*, Fig. 3026, while one of its extremities *x* is constrained to move in a straight line *x p*, the other extremity *y* will describe another straight line *p y* at right angles to the first.



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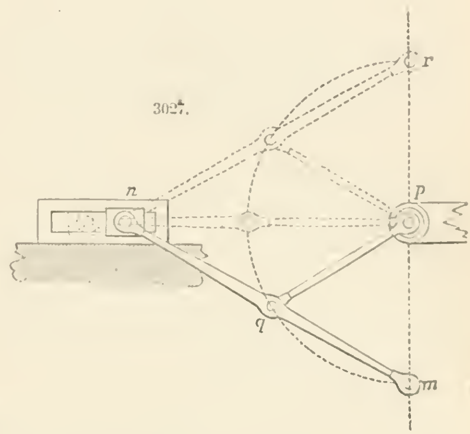


3027.

To exhibit this principle in a practicable form, let *m n* be a rigid bar, having the end *n* guided in a horizontal groove, in which it can slide freely, as represented in Fig. 3027; and let *p q* be also a rigid bar jointed to the former at *q*, and having a fixed centre at *p*. Let this bar be half the length of the bar *m n*, and let *m q* = *n q*; it is then evident, from the principle stated above, that, as the groove at *n* and the fixed centre at *q* control the motion of the bar *m n*, the end *m* is constrained to move in a straight line *m p r* at right angles to *p n*, which is the condition to be fulfilled.

In Fig. 3025, instead of the slot at *n* the main centre is allowed to traverse a small arc, which, deviating very little from a right line, fulfils the condition with considerable exactness. The same principle may be applied in various ways.

PARAMETER. In geometry, a constant straight line, belonging to each of the three conic sections—otherwise called the *latus rectum*. In the parabola, the parameter is a third proportional to the absciss and its corresponding ordinate; in the ellipse and hyperbola, the parameter of a diameter is a third proportional to that diameter and its conjugate. The term is also used in a general sense, to denote the constant quantity which enters into the equation of a curve.

PENDULUM. If any heavy body, suspended by an inflexible rod from a fixed point, be drawn aside from the vertical position, and then let fall, it will descend in the arc of a circle of which the point of suspension is the centre. On reaching the vertical position it will have acquired a velocity equal to that which it would have acquired by falling vertically through the versed sine of the arc it has described, in consequence of which it will continue to move in the same arc until the whole velocity is destroyed; and if no other force than gravity acted, this would take place when the body reached a height on the opposite side of the vertical equal to the height from which it fell. Having reached this height it would again descend, and so continue to vibrate forever; but in consequence of the friction of the axis, and the resistance of the air, each successive excursion will be diminished, and the body soon be brought to rest in the vertical position. A body thus suspended, and caused to vibrate, is called a *pendulum*; and the passage from the greatest distance from the vertical on the one side to the greatest distance on the other is called an oscillation.

In order to investigate the circumstances of the motion, the body must be regarded as a gravitating point, and the inflexible rod as devoid of weight. This is denominated the *simple pendulum*, and the problem to be resolved is to determine the motion of a point constrained to move in a circular arc by virtue of the accelerating force of terrestrial gravity.

According to the theory of falling bodies, (See GRAVITY,) the time t in which a body falls through the space s, by the accelerating force of gravity, is given by the equation $t = \sqrt{\frac{2s}{g}}$. Let $2s = l$; then $t = \sqrt{\frac{l}{g}}$. But the time T, of the oscillation of a pendulum whose length is l, is $T = \pi\sqrt{\frac{l}{g}}$; therefore $T : t :: \pi : 1$; consequently the time of the oscillation of a pendulum is to the time that a heavy body would fall freely by the force of gravity through half its length, as the circumference of a circle to its diameter.

If we suppose the time to be expressed in seconds, and make $T = 1$, we shall have $g = \pi^2 l$. Captain Kater found the length of the simple pendulum at London to be 39·13929 inches, and we know that $\pi^2 = 9{\cdot}8696$; therefore $g = 9{\cdot}8696 \times 39{\cdot}139 = 386{\cdot}29$ inches, or $g = 32{\cdot}2$ feet. It follows, therefore, that the space through which a body falls freely at London in a second of time is 16·1 feet.

Compound pendulum.—The simple pendulum, as above defined, is only a theoretical abstraction, for the oscillating body can neither be so small that it may be regarded as a mathematical point, nor can the rod be entirely devoid of weight. When the body has a sensible magnitude, and the suspending-rod a sensible magnitude and weight as they must have in all actual constructions, the apparatus is called a *compound pendulum;* and instead of being supported by a single point it is supported by an axis, or by a series of points situated in the same straight line. According to this definition, any heavy body oscillating about an axis of suspension is a compound pendulum.

In every compound pendulum there is necessarily a certain point at which, if all the matter of the pendulum were collected, the oscillations would be performed in exactly the same time. This point is the centre of oscillation. (See CENTRE OF OSCILLATION.) It is situated in the vertical plane passing through the centre of gravity of the pendulum, and at a distance from the axis of suspension, (the axis being always supposed horizontal,) which is determined by the following formula: Let dm be the element of the mass of the compound pendulum, r its distance from the axis of rotation, and x the distance of the centre of oscillation from the same axis; then

$$x = \int r^2\, dm \div \int r\, dm;$$

that is, the distance of the centre of oscillation from the axis of suspension is equal to the moment of inertia of the oscillating body divided by its moment of rotation. This value of x is the length of the isochronous simple pendulum, and is what is always to be understood by the term *length of a pendulum*

The centre of oscillation possesses a very remarkable property, which was discovered by Huygens; namely, that if the body be suspended from this point, or a horizontal axis passing through it parallel to the former axis of suspension, its oscillations will be performed in the same time as before; in other words, the axis of suspension and oscillation are interchangeable. This property furnishes an easy practical method of determining the centre of oscillation, and thence the length of a compound pendulum.

Applications of the pendulum.—The most important application that has been made of the pendulum is to the measurement of time.

Compensation pendulum.—The value of the pendulum as a regulator of time-pieces depends on the isochronism of its oscillations; which, in its turn, depends on the invariability of the distance between the points of suspension and oscillation. But, as every known substance expands with heat and contracts with cold, the length of the pendulum will vary with every alteration of temperature, and the rate of the clock consequently undergo a corresponding change. To counteract this variation numerous contrivances have been employed. The principle is, however, the same in all; and consists in combining two substances, whose rates of expansion are unequal, in such a manner that the expansion of the one counteracts that of the other, and keeps the centre of oscillation of the compound body always at the same distance from the axis of suspension. A brief description of the two compensation pendulums in most common use—the *mercurial pendulum* and the *gridiron pendulum*—will sufficiently explain the means by which compensation is obtained.

Mercurial pendulum.—This was the invention of Mr. George Graham, a celebrated watchmaker, who subjected it to the test of experiment in the year 1721. The rod of the pendulum is made of steel, and may be either a flat bar or a cylinder. The bob or weight is formed by a cylindrical glass vessel, about 8 inches in length and 2 inches in diameter, which is filled with mercury to the depth of about 6½ inches. The cylinder is supported and embraced by a stirrup, formed also of steel, through the top of which the lower extremity of the rod passes, and to which it is firmly fixed by a nut and screw on the end of the rod. Now the effect of an increase of temperature on this apparatus is evidently as follows: In the first place, the rod expands, and the distance between the axis of suspension and the bottom of the stirrup is increased. In the second place, by the expansion of the mercury in the cylinder, its column is lengthened, and the distance of its centre of gravity from the bottom of the stirrup consequently increased. But, as the expansion of mercury is about sixteen times greater than that of steel, the height of the mercurial column may be so adjusted by trial that the expansion of the rod and stirrup shall be exactly compensated by that of the mercury, and the centre of oscillation of the whole suffer no change. This pendulum is, perhaps, the most perfect of all compensators; but, as its adjustments are attended with considerable difficulty, it is seldom used excepting in astronomical observatories.

Gridiron pendulum.—This was contrived by Mr. Harrison, the inventor of the chronometer. It consists of a frame of nine parallel bars of steel and brass, arranged as follows: The centre rod, of steel, is fixed at the top to a cross-bar connecting the two middle brass rods, but slides freely through the two lower cross-bars, and bears the bob. The remaining rods are fastened to the cross-pieces at both ends, and the uppermost cross-piece is attached to the axis of suspension. It is easy to see that the expansion of the steel rods tends to lengthen the pendulum, while that of the brass rods tends to shorten it; consequently, if the two expansions exactly counteract each other, the length of the pendulum will remain unchanged. The relative lengths of the brass and steel bars are determined by the expansions of the two metals, which are found by experiment to be, in general, nearly as 100 to 61. If, then, the lengths of all the five steel bars added together be 100 inches, the sum of the lengths of the four brass bars ought to be 61 inches. When the compensation is found on trial not to be perfect, an adjustment is made by shifting one or more of the cross-pieces higher on the bars.

Application of the pendulum to the determination of the relative force of gravity at different places.—There are two methods of determining the relative intensity of gravity by means of the pendulum. According to the first, the absolute length of the simple pendulum which makes a certain number of oscillations in a given time is accurately ascertained at each of the places, and the comparative force of gravity is then given by the formula $g' = \frac{l'}{l} g$. According to the other method, an invariable pendulum is swung at the different places, and the number of its oscillations noted at each, when the relative gravity is given by the formula $g' = \frac{N'^2}{N^2} g$. Each of these methods has been followed in the delicate experiments which have been made for the purpose of determining the figure of the earth; but though the results of both appear to be nearly equal in point of accuracy, the latter method, on account of its affording greater facilities in practice, is now generally adopted. See Watchmaking.

PENS, STEEL, *manufacture of.* The manufactory, at Birmingham, of Messrs. Hinks, Wells, & Co., a few years ago consisted of a small house on one side of the street. Now the establishment has become an immense manufactory, giving employment to 561 hands, consuming $2\frac{1}{2}$ tons of steel per week, turning out 35,000 gross of pens weekly, or 1,820,000 gross in a year.

The metal in its crude state.—This consists of the best quality of cast-steel, made from Swedish iron, its granular structure dense and compact. It is in sheets $4\frac{1}{2}$ feet long by 18 inches wide, which sheets are clipped across into lengths from $1\frac{3}{4}$ to $4\frac{1}{2}$ inches wide. These strips are packed into cast metal boxes, and placed on what is technically called a *muffle*, or large stone oven, heated to a white heat; there the process of annealing takes place. After twelve hours of this roasting, the strips are placed in revolving barrels, where, by the friction of metallic particles, the scales caused by the annealing and the rough edges are removed. They are now ready for the rolling-mill. The rollers consist of metal cylinders revolving upon each other. A man and boy attend at each. The first introduces the strip of steel between the opposing surfaces, and the boy pulls it out considerably attenuated. From the first pair of rollers it passes through several others, until it finally assumes the requisite tenuity. Such is the pressure employed, that the steel, in passing through, becomes hotter than it is sometimes convenient for unpractised hands to touch. The strip of steel is now precisely the thickness of a pen, is quite flexible, and has increased in length from 18 inches to $4\frac{1}{2}$ feet.

It is now ready for the "cutting-out room," where the pen first begins to assume a form. Along this room a number of women are seated at benches, cutting out, by the aid of hand-presses, the future pen from the ribbon of steel. This is done with great rapidity, the average product of a good hand being 200 gross, or 28,800, per day of ten hours. Two pens are cut out of the width of the steel—the broad part to form the tube, and the points so cutting into each other as to leave the least possible amount of waste.

From this room the *blanks* are taken to be pierced. The flat blanks are placed separately on a steel die, and, by a half-circular action of a lever turning an upright screw, a fine tool is pressed upon the steel, and forms the delicate centre perforation, and the side slits which give flexibility to the pen.

All this time the metal is soft, bending in the fingers like a piece of lead. It becomes necessary, however, that it should be rendered still softer. The pens are consequently placed in the heated oven, and a second time annealed. Proceeding with these softened pens to the "marking-room;" upon each side and down the middle of the room are arranged a multitude of young women at work, each of whom raises a weight by the action of the foot, and suddenly allows it to fall on the pen. The rapidity of this process is equal to that of cutting out the blanks, each girl marking many thousands of pens in the day. When it leaves the hand of this operator, the back of the pen is stamped either with the name of a retail dealer at home or abroad, a national emblem, &c., according to the fashion.

The next process is the *raising.* Until now the pen is flat; and by being placed in a groove, and a convex tool dropped upon it, forcing it into the groove, it is bent into a tube of the required shape.

Upon the perfection of the slit of course depends the value of the pen. Those who recollect the difficulty experienced in getting a perfect slit in a quill pen, can understand how much less easy it is to prevent the gaping of a metallic substance. The first preparatory process after the pens leave the raising-room, is to return them once more to the muffle, into which they are placed in small iron boxes with lids, and heated to a white heat. They are then drawn out and suddenly thrown into a large tank of oil, where, by the chemical action of the liquid on the steel, the pens attain a brittleness that makes them crumble to pieces when pressed between the fingers. After being cleaned from the oil they are tempered, or brought back to the condition of softness and elasticity which they are henceforth to retain. This is done by placing them in a cylindrical vessel, open at one end and turned over a fire, somewhat after the fashion in which coffee is roasted. The action of the heat gradually changes the color of the pens, first from a dull gray to a pale straw-color, next to a brown or bronze, and then to blue.

Still the pens are rough, and covered with small metallic particles. To remove this roughness, they are placed in large tin cans, with a small quantity of sawdust, &c. These cans lie horizontally on a wooden frame, and are made to revolve by steam power, the pens rubbing against each other, and so cleansing themselves. From this process of *scouring*, they are taken to the "grinding room." Each individual pen of the 262,080,000 which are annually turned out of this establishment undergoes the process of grinding, which employs one-fourth of the entire number of hands engaged in the manufactory. We have previously referred to the difficulty of getting a close slit in a quill pen. The grinding serves the same purpose as the scraping the back of the quill did, as, by weakening a certain part of the metal, the point where the slit is made has a tendency to cohere, and so to form a good pen. The pen is simply caught up by a pair of nippers, and held on a revolving *bob*, and so ground.

The pens are now taken to the "slitting-room." This work is very light, for the pen is simply placed on a press, and the handle being pulled, a sharp steel tool descends, and the pens are perfect. To secure uniformity of quality, the pens are now looked over, by the points being pressed against a small piece of bone placed on the thumb, and they are then thrown into heaps according to their quality of good, bad, or indifferent. They are next varnished with a solution of gum, and are ready for affixing to cards, or boxing, the latter mode of packing being almost universally adopted.

PERCUSSION. The centre of percussion is that point in a body revolving about an axis, at which, if it struck an immovable obstacle, all its motion would be destroyed, or it would not incline either way

When an oscillating body vibrates with a given angular velocity, and strikes an obstacle, the effect of the impact will be the greatest if it be made at the centre of percussion.

For, in this case, the obstacle receives the whole revolving motion of the body; whereas, if the blow be struck in any other point, a part of the motion will be employed in endeavoring to continue the rotation.

If a body revolving on an axis strike an immovable obstacle at the centre of percussion, the point of suspension will not be affected by the stroke.

PERCUSSION-CAP MACHINE, by Richard M. Bouton, of West Troy, New York. Fig. 3028 is a front elevation; Fig. 3029, a right-hand profile elevation; Fig. 3030, four views of the transfer apparatus, full size; Fig. 3031, the star-punch, with its picker, lower die, and thimble, all in section, full size; Fig. 3032, the forming-punch and its die, in section, full size.

This machine consists essentially of two vertical punches, of which one cuts the star or blank, of which the capsule is formed; and the other forms the capsule by compression. These punches are at their upper ends attached each to its respective arm on the same end of a double-headed lever, and consequently both move at the same time; and their operations are combined in effect by mechanism, which transfers the star or blank from its punch to the forming-punch. To enable other practical mechanics to make and use my invention, I will proceed to describe its construction and operation.

A A, &c., is the bed-plate, on which are fixed the frame of the machine and a pedestal, (not shown,) which supports the right-hand end of the branch arbor C C, to which the power is applied.

B B, &c., the frame of the machine, to which most of the working parts are attached.

L L, main lever, or double-headed lever, by which the punches are worked. Its long arm is, by a connecting-rod and crank-pin, connected with the crank of the crank-arbor. *h h* are the short arms or double head, to which are attached

R R′, the two runners which carry the punches. 1 2 3 4 are the guides through which the runners work. These runners may be operated by cams on an arbor passing over their upper ends or through openings or offsets in the middle of their lengths. In this case the main lever and crank-arbor can be dispensed with, and power be applied to the cam-arbor direct.

K K K, bench or shelf, projecting from the frame, on which are the die-beds F and F′. The right-hand half of this bench is elevated higher than the left-hand half of its length, in order that the star-die on this part shall be higher than the forming-die on the left-hand half, and that the groove or way of the director *d d*, &c., which rests on this part, may be on a level with the face of the forming-die V.

F, die-bed of the star-punch. This is a square above the bench, and has a round shank passing down into the bench, to which it is fixed by a screw from below. The star-die U has a round hollow shank passing down into this bed, and is supported by a flanch X, Fig. 3031, at its upper end, resting on the top of the die-bed. Within this shank of the star-die is a conical steel tube or thimble *v v*, Fig. 3031, the lower end of which rests on the director and transfer slide, it reaching up to the cutting part of the star-die. Its internal diameter is exactly equal to the diameter of the star or blank, which, falling from the star-punch through it, is conducted to its proper position on the transfer. The star-punch, with its picker, die, and thimble, are seen in section, full size, in Fig. 3031.

F′, die-bed of the forming-punch. This is round and has a shank passing down through the bench, to which it is fixed by a screw-nut on it below; through the axis of this shank, and of the forming-die, operates the elevator *e*. In a socket in this bed stands

V′, the forming-die; its upper surface is on a level with the way of the director *d* T‴. This die is seen in section, full size, in Fig. 3032, V, as is also

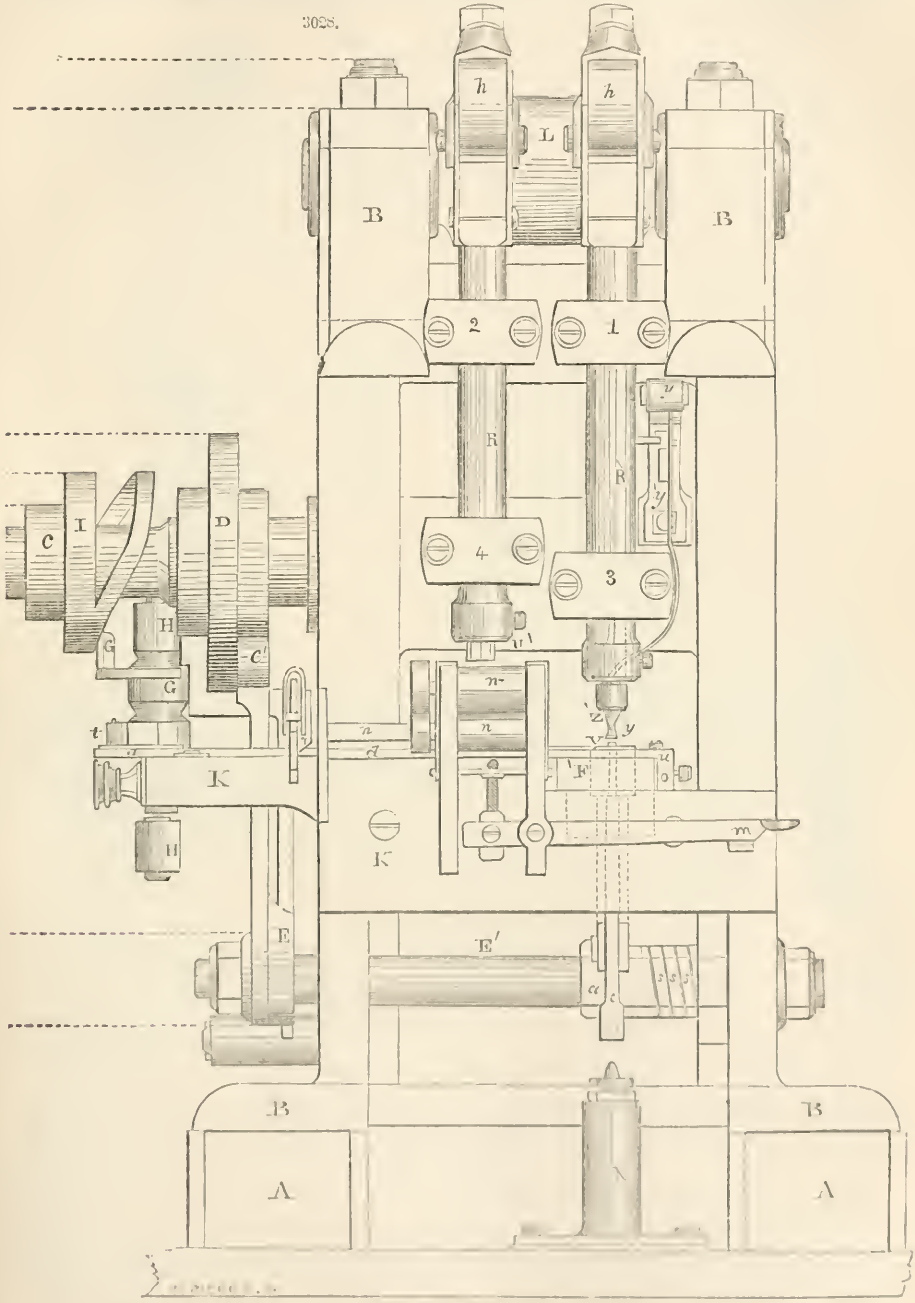
Z Z′, the forming-punch, which is compound, having an outer shell *z*, which planishes the flanch of the capsule, and an internal or centre punch Z′, which forms the inside. This centre punch has a shank passing up through the axis of the shell *z*, and is secured by a cross-key near the bottom, or by a countersunk nut at the upper end. This arrangement, by equalizing the thickness of the several parts, allows a better temper, and consequently insures a more perfect operation and more durability.

T T′ T″, Fig. 3030, three views of the transfer, full size. T, slide, with lower face upward; *b*, the boss in which the pin *i* of the connecting-link *l* works. T′ shows the plate and link in profile, and T″ shows it in working position with the connecting-link *l* attached to it, slides in the way (groove) of the director *d* T‴. The transfer is operated by the lever or arm *t t* applied to the pintle *i*. It will be seen in Figs. 3028 and 3029 that the director *d* T‴, &c., with its transfer, pass through the bed F of the star-die; it passes immediately below the star-die and its thimble, in order that the star may fall from its punch through the thimble upon the transfer slide.

U, Fig. 3031, the star-punch. This punch, with its picker, and the star-die, with its included thimble are shown, full size, in vertical section, where *q* is the picker with its spiral spring above it, and *v v* the thimble. The office of the picker is to prevent the adhesion of the stars to the face of the punch.

C C, crank-arbor, to which the power is applied. On this is the collar and flanch D D, on which is the feed-cam *c*, which operates the feed-lever *f*, and through the double hands P P, works the ratchets *r r* of the feed-rollers. On the opposite face of this collar is the cam *c'* of the elevator lever E E, which, through the rocking-arbor E' and arm *a*, raises the elevator *c*, lifting the capsule out of the forming-die; it is returned by the spiral spring *s s s*, Fig. 3028. N is the anvil on which the elevator rests while a capsule is being pressed; it has an adjusting screw and nut.

3028.

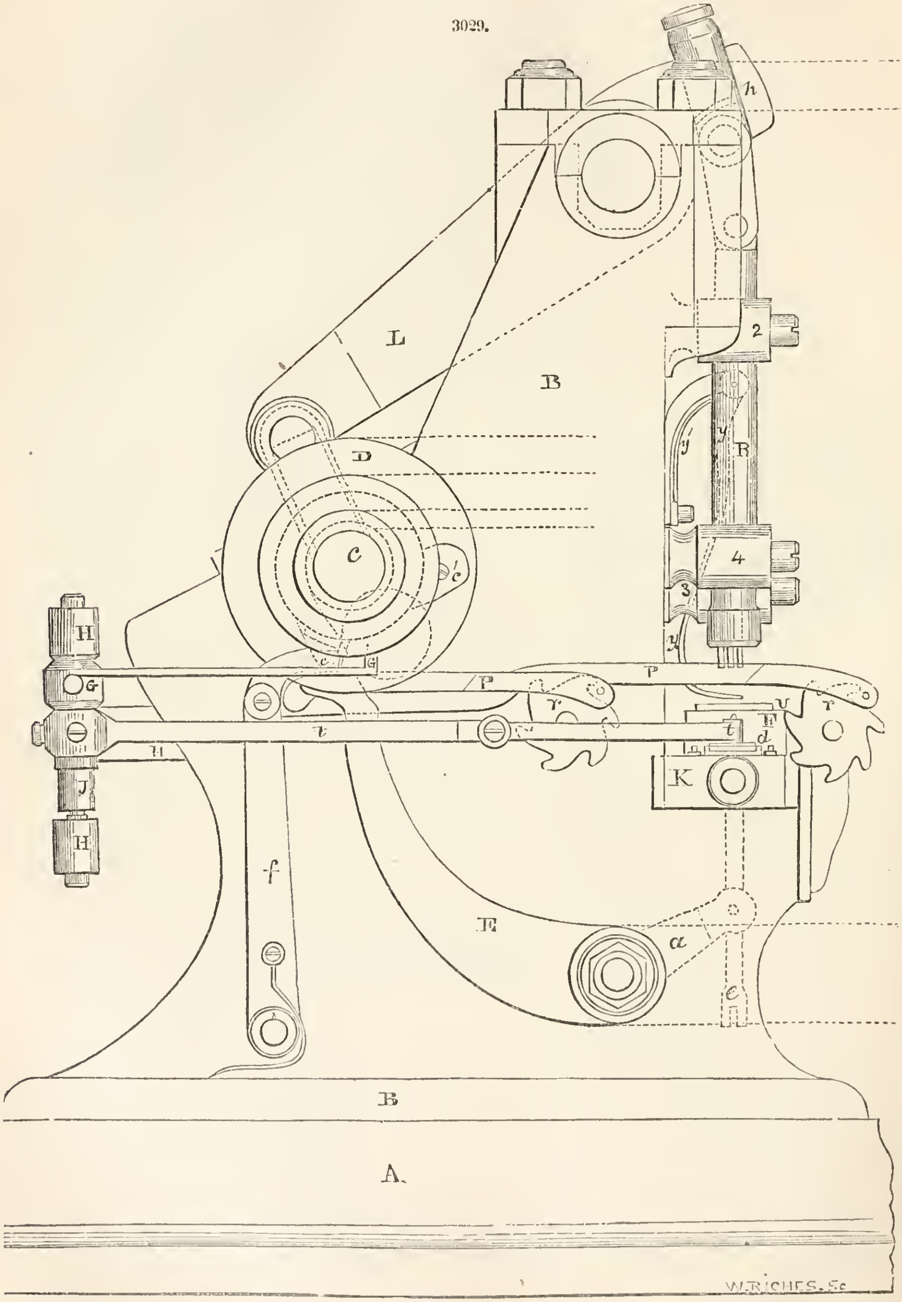


G G, &c., cam lever of the transfer apparatus. It is fast on its axis J J, which works in the bracket H H, &c., and is operated by the cylinder cam I on the crank-arbor, and returned by a spiral spring on the axis J J. The lever *t t* is free on the axis J J, but is constrained to move in concert with G, by means of a spring, which allows it, together with the transfer, to yield to extraordinary resistance, while the cam and fast lever pursue their way thus preventing injury to the machine.

u is the gage, a cap of steel over the head of the forming-die, with semicircular notch in its edge against which the star is driven by the transfer and held concentric with the forming-die until seized by the forming-punch.

y y, the driver, a slender lever suspended by its upper end thrown forward by a spring *y′*; its lower end is bent forward over the face of the forming-die, somewhat in form of a human foot and leg, Fig

3029.

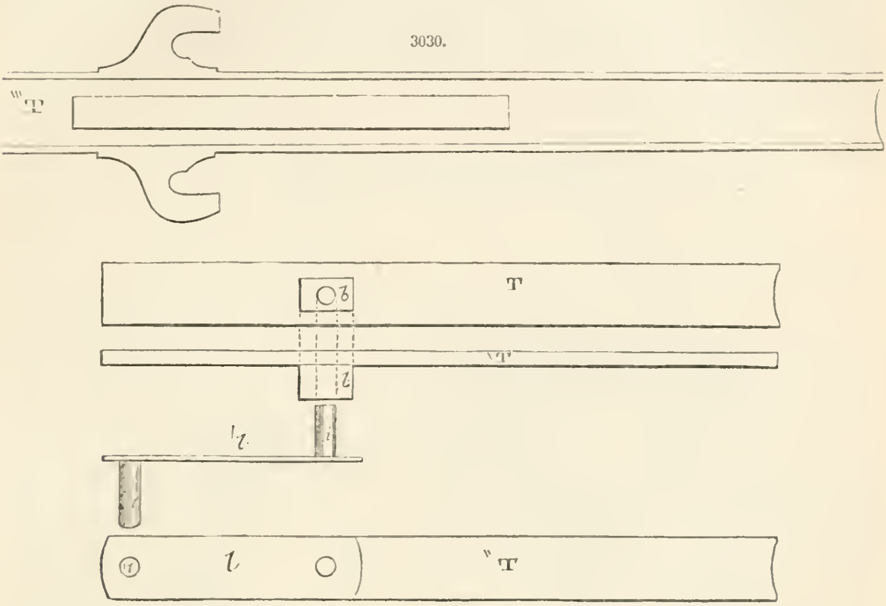


3029. It is operated by a pin in the runner R′ pressing against a tumbler, and holding it behind the punch while a capsule is being formed, and releasing it instantly when the capsule is raised by the elevator above the gage *u*.

n n, feed-rollers. There is a similar pair behind the punch to continue the progress of the ribbon after it has passed the front rollers. *m* is a lever to open and close the feed-rollers. All these parts are attached to a movable plate K, covering the front of the bench K, &c.

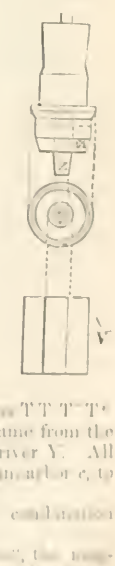
Operation.—The material is cut in ribbons of such width as will admit of two rows of blanks or stars being cut from each lengthwise; but the machine may be so constructed without departing from its principles as to work from ribbons of any width.

3030.



One end of a ribbon being inserted between the feed-rollers *n n*, is by them drawn in, while a row of stars is successively cut near one edge throughout its length. When not enough surface remains for another star or trigger, (not shown,) which has ridden upon its surface, drops off at the end, and by mechanical connections stops the machine. Each star, as soon as cut, is projected by the picker *q* down through the thimble *v v*, Fig. 3031, upon the face of the transfer, which at this instant is holding a previous star against the gage *u* under the forming-punch *z′*; on its return its operating end passes beyond the thimble, which consequently sweeps the star deposited in it off of the transfer into the *way* of the director, and the next stroke of the transfer drives it to the forming-die while another star is being dropped from the star-punch, so that only one star is in the thimble at the same time.

3031. 3032.



While the forming-punch rises out of its die, the elevator *e* raises the capsule after it above the gage, whence the driver *y* kicks it into the mouth of a receiving-tube, (not shown,) which conveys it to the reservoir. The elevator now sinks, the driver retires behind the punch, and all is clear for another star.

The machine is a self operator, and delivers the capsules with a high finish and in a state proper to receive the priming.

I do not claim as my invention punches and dies for making percussion caps, as these have been so employed in various ways; but what I do claim as my invention, and desire to secure by Letters Patent, is the combination and arrangement of the mechanism above described for producing the combined operations herein fully set forth, of feeding the metallic ribbon to the star-die U′, punching the blank from the ribbon, transferring the blank to the forming-die V by the transferring apparatus T T T″ T‴, punching the blank into the forming-die V and forming it into a cap, and discharging the same from the die by the elevator *e*, and kicking the cap in a finished state from the die-bed by the driver Y. All of said operations being performed successively at every revolution of the crank and cam-arbor *c*, to which the propelling power is applied, substantially as above described.

2d. I also claim the transferring apparatus constructed substantially as described, in combination with the punches.

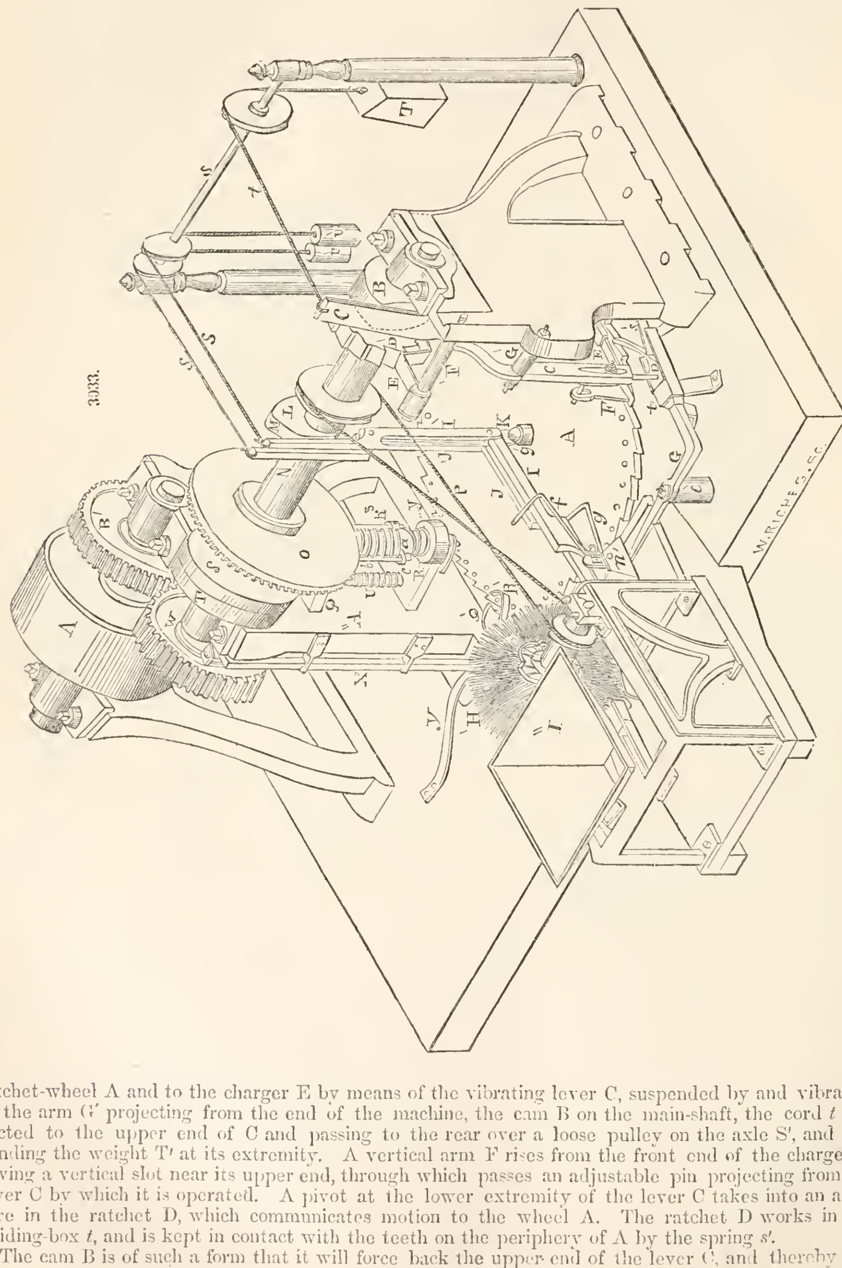
PERCUSSION CAPS, MACHINE FOR CHARGING—M. W. [illegible]'s. In Fig. [illegible], the magazine or hopper, in which the fulminating composition is placed, is supported by the standard *a′* rising from the platform, and projecting over the edge of the horizontal ratchet wheel A, in the series of vertical apertures near the periphery of which the caps are placed to receive their charge

The lower portion of the magazine is funnel-shaped, and opens into a rectangular tube in which the charge E is accurately fitted, and freely slides back and forth.

A circular aperture is formed in the under side of the tube at the distance of an inch or two from the magazine, exactly corresponding in size with the aperture at the bottom of the magazine, and with the aperture in the charge E.

A reciprocating movement being imparted to the charger, the aperture in the same, in passing back and forth under the outlet of the magazine, will receive the charge of composition for a cap and will discharge the same as the charger is drawn back into a cap brought immediately under the aperture, by the movement of the wheel A upon its axis, in the manner hereinafter set forth.

N is the main-shaft, from which all parts of the machine receive motion. Motion is imparted to the



3033.

ratchet-wheel A and to the charger E by means of the vibrating lever C, suspended by and vibrating on the arm G′ projecting from the end of the machine, the cam B on the main-shaft, the cord t connected to the upper end of C and passing to the rear over a loose pulley on the axle S′, and suspending the weight T′ at its extremity. A vertical arm F rises from the front end of the charger E, having a vertical slot near its upper end, through which passes an adjustable pin projecting from the lever C by which it is operated. A pivot at the lower extremity of the lever C takes into an aperture in the ratchet D, which communicates motion to the wheel A. The ratchet D works in the guiding-box t, and is kept in contact with the teeth on the periphery of A by the spring s'.

The cam B is of such a form that it will force back the upper end of the lever C, and thereby will carry forwards the ratchet D and the charger E, and move the periphery of the wheel A the distance of the length of a tooth, and in that position will retain them during one-half of the revolution of the main-shaft. During the other half of the revolution of the main-shaft, the periphery of the cam B ceases to press back the upper end of C, and receding towards the shaft permits the weight T′ to draw forwards the upper end of C and carry back the ratchet D and the charger E. The charger, in passing back to its starting-place, deposits a charge in a cap, as before described. In this manner the metallic caps placed in the series of apertures in the ratchet-wheel A receive their respective charges. The apertures in A correspond in number with the ratchet-teeth on its periphery, and are so arranged that each forward movement of the ratchet D will place one of the apertures in A directly under the aperture in the tube, in which the charger E traverses back and forth, as before described.

The composition is forced into the caps in the following manner: On the opposite side of the wheel A from the magazine two arms project from the standard A″, which arms embrace journals at the ends of a vertical tube R. The tube R serves as a guide and supporter to the shaft of the punch which forces the composition into the caps. The shaft is composed of two cylindrical parts, which rotate with and play freely up and down in the tube R. The respective parts of the shaft are connected to each other and to the tube R. *c c* are arms secured to the inner ends of the respective parts of the shaft, projecting out through vertical slots in the sides of the tube. The extremities of the arms *c c* are connected to each other by the screw bolts or rods *b b*; the blank portion of the bolts play freely in the apertures in the arm *c* through which they pass.

A stiff and powerful helical spring embraces the middle portion of the tube R, the ends of which bear against the arms *c c* within the bolts *b b*. A ring *a* loosely encircles the lower end of tube R; *y* is a helical spring encircling the lower end of the tube between the lower supporting arm and the ring *a*, which, acting against the lower arm *c*, forces up the punch-shaft.

A rotary motion is imparted to the tube R and the punch by means of the bevel-pinion, made fast to the upper end of R, and working into a bevel cog-wheel O on the main-shaft. The punch is of such a shape as to fit accurately into the caps: the wheel A in depth exactly corresponds with the depth of the caps; the wheel A revolves upon a journal *g′* made fast to the platform, and passing up through its centre. The edge of the wheel immediately under the punch passes over and slightly rests upon the surface of a metallic block.

S is a cam on the main-shaft, immediately over the shaft of the punch; the cam S is of such a form that it will press down and have a continuous action upon the punch during about three-fourths of the revolution of the main-shaft. The cam S strikes against the upper end of the punch-shaft, and forces down the same, pressing the punch with great force into a cap, immediately after the cam B has acted on the lever C, the ratchet D, the charger E, and wheel A, as before described; during the time that the punch is pressed upon the composition in a cap, four revolutions, more or less, are imparted to the punch by means of the guiding-tube R, the pinion P, and cog-wheel O, which perfects the solidification of the composition, and gives it the requisite adhesion to the caps.

During the action of the punch the ratchet D and the charger E are drawn back by the lever C and weight T′, and immediately thereafter the form of the cam S allows the spring *y*, on the lower portion of R, to elevate the punch out of the cap, and retain it in an elevated position while the cam B and lever C again operate upon the ratchet D, charger E, and wheel A, as before described. It will be perceived that the pressure exerted upon the upper portion of the punch-shaft is communicated to the lower portion of the same and to the punch through the medium of the spring. The object of this arrangement is to give an elastic bearing of the punch upon the composition in the cap, so that should it explode from any cause the punch can yield and give back, and no injury will be done to the machine or attendant.

The cam T, on the main shaft, is placed immediately over and operates upon the rod U as follows: the cam T is of such a form as to cause the rod U to descend simultaneously with the punch, forcing the gagged under surface of an arm upon the flanch of the cap, which retains the same and prevents the cap from turning while the punch is operating: the cam T also retains the arm upon the flanch of the cap till the punch is elevated, and then allows the retaining arm to be elevated by the spring encircling U, to allow motion to be imparted to the wheel.

The caps are thrown out of the apertures in the wheel A after the operation of charging before described, by the following described arrangement of parts, viz.: A cap horizontal tilting lever is jointed to a fulcrum standard, the extremity of which farthest from its fulcrum joint terminates in an upright punch; the opposite end of it supports the vertical rod X, which passes up through guiding apertures in arms projecting from the standard A″. A spring *y* acts against the under side of the shortest portion of the lever and sustains the rod X. W is a wheel on the main shaft, from the periphery of which projects the tilting-tooth *e*; as the main shaft is revolved the tooth *e* will strike against the top of the rod X and cause it to tilt the lever at the moment when the wheel A is stationary; the tilting of the lever brings the punch against the bottom of a cap, and throws it out of its aperture in the wheel; as the cap is thrown upwards the spring R′ gives it a lateral direction, and conducts it into the funnel Q′ open at the side, to which a tube may be connected to convey the caps to a drawer, or other suitable receptacle.

The metallic caps may be placed in the apertures in the wheel A by hand, or by the arrangement of the following described parts, viz.: I″ is a hopper in which the caps are placed preparatory to their being deposited in the apertures in A by machinery, the caps fall from the vibrating shoe, at the base of the hopper, into an inclined vibrating groove—the tubular portion of the caps passing into the groove, and the flanches resting upon the edges of the groove. The periphery of the rotating brush H′ comes so nearly in contact with the sides of the groove as to prevent the caps from passing the same unless their tubes are inserted in the groove. The inclined groove is [illegible] by a pivot at its lower end, and its upper end slides freely on a supporting bar. The shoe and the inclined groove are vibrated by means of a connection with the ratchet teeth on the axle of the brush H′ by any usual or suitable contrivance. As the groove is vibrated, the caps are carried down the [illegible] portion of the same; the feeding-hand on the front end of the arm I is then placed upon them, and draws them down the groove until the foremost one is caught between the scolloped edged wheels *n n*, located on each side of and projecting into the groove. The concavities in the peripheries of *n n* are arcs corresponding with the tubes of the caps, and embrace nearly their entire circumference when the caps are drawn between them. One of the wheels *n* plays freely on its axis; the points radiating from the other wheel *n* are operated upon by a retaining spring. The spring partially retains the wheel *n*, on which it acts. As the caps are drawn down the groove, should the foremost one strike against a radiating point of the loose wheel *n*, it will revolve the same sufficiently to bring the cap between opposite concavities of both wheels. The elastic feeding-finger, connected to the front end of the arm J, is so operated that it is placed in a cap while it (the cap) is retained between the wheels *n n*, and draws it forwards and deposits it in an aperture in the wheel A. As the cap is drawn from between the wheels *n n* it causes a partial revolution of the wheels; the spring passes over a radiating point in one of the wheels, and, striking on the next point in succession, retains the wheel in the proper position for the reception of another cap.

The feeding-hand on the front end of the arm I has a soft face that rests but slightly upon the flanches of the caps; the front end of the arm I, when the hand is acting upon the caps, rests upon the roller which traverses upon the edges of the groove. The feeding-finger passes through an aperture and is secured to the spring-plate projecting from the under side of the front end of the arm J; it is steadied and kept in a vertical position by passing loosely through the plate projecting from the upper side of the front end of J, and to give additional elasticity to the finger it is inclosed in a helical spring. The arms I and J are jointed to and receive motion from the upright vibrating levers I′ J′; the levers I′ J′ are jointed to and suspended by the curved standard K; the standard K rises from the rear side of the platform, curves forwards over the centre of wheel A, and descends vertically to the top of the axle *g*, to which it is connected. To the upper ends of the levers I′ J′ the cords *s s* are connected, which pass to the rear over loose pulleys on the axle S′, and suspend the weights U′ U′ at their extremities: causing the upper end of I′ to bear against the cam L, and the upper end of J′ to bear against the cam M on the main-shaft.

H is a vertical vibrating-lever, placed in the guiding-box *u′*, and working on a joint-pin passing through the sides of the same.

Angular arms *f* and *g* project from the upper portion of H; the angular extremity of *f* passes to the right over the arms I J, the extremity of *g* passes to the right under the arms I J. G is a horizontal vibrating-lever jointed to the standard *e′*. The end of G, to the right of the standard *e′*, passes immediately in front of the lower cord of the lever H; the opposite end of G turns at right angles to the rear, and is brought directly opposite and in contact with the head of the ratchet D.

When the ratchet D is drawn back by the lever C, it vibrates the lever G, causing it to throw back the upper end of H, and thereby to elevate the front ends of the arms I J by the arm *g* at the moment that the arms I J are elevated. The form and position of the cams L M permit the weights U′ U′ to draw the upper ends of the levers I′ J′ to the rear, and carry the arms I J forwards; the moment the ratchet D is carried forwards again, the arms I J descend, placing the hand *h* upon the flanches of the caps in the groove P′, and the finger *k* in the cap held between the concavities of the wheels *n n*, as before described. As soon as the arms I J descend, the cams L M commence acting upon the levers I′ J′ and arms I J, causing the hand to carry forward the caps in the groove, and the finger to place a cap in an aperture in the wheel A, as before described. The moment after the finger has deposited a cap in an aperture in A, the arms I J are again elevated and carried to the front in the manner before described.

The rotating brush H′ is driven by the band passing around a pulley on the main-shaft N. The rotating brush in the rear portion of the machine acts upon the upper surface of the wheel A near its periphery, for the purpose of removing any of the percussion composition that may chance to be deposited upon the wheel or flanches of the caps. This brush is driven by a band passing around a pulley on the main-shaft.

PERPETUAL MOTION. In mechanics, a machine which, when set in motion, would continue to move forever, or, at least, until destroyed by the friction of its parts, without the aid of any exterior cause. The discovery of the perpetual motion has always been a celebrated problem in mechanics, on which many ingenious, though in general ill-instructed, persons have consumed their time; but all the labor bestowed on it has proved abortive. In fact, the impossibility of its existence has been fully demonstrated from the known laws of matter.

In speaking of the perpetual motion, it is to be understood that from among the forces by which motion may be produced we are to exclude not only air and water, but other natural agents, as heat, atmospheric changes, &c. The only admissible agents are the inertia of matter, and its attractive forces, which may all be considered of the same kind as gravitation.

It is an admitted principle in philosophy that action and reaction are equal, and that, when motion is communicated from one body to another, the first loses just as much as is gained by the second. But every moving body is continually retarded by two passive forces, the resistance of the air and friction. In order, therefore, that motion may be continued without diminution, one of two things is necessary—either that it be maintained by an exterior force, (in which case it would cease to be what we understand by a perpetual motion,) or that the resistance of the air and friction be annihilated, which is physically impossible. The motion cannot be perpetuated till these retarding forces are compensated, and they can only be compensated by an exterior force; for the force communicated to any body cannot be greater than the generating force, and this is only sufficient to continue the same quantity of motion when there is no resistance. To find the perpetual motion is, therefore, a proposition equivalent to this—to find a force (either an attractive force like that of gravitation or magnetism, or an elastic force, that of a spring, for example) greater than itself.

But it may be argued that, by some arrangement or combination of mechanical powers, a force may be gained equal to that which is lost in overcoming friction and atmospheric resistance. This motion at first mention appears plausible, and is, in fact, that by which most spectators have been led astray. It is, however, entirely erroneous; for by no multiplication of forces or powers by mechanical agents can the quantity of motion be increased. Whatever is gained in power is lost in time; the quantity of motion transmitted by the machine remains unaltered.

PERSIAN WHEEL. In mechanics, a contrivance for raising water to some height above the level of a stream. In the rim of a wheel turned by the stream a number of strong pins are fixed, from which buckets are suspended. As the wheel turns, the buckets on one side go down into the stream, where they are filled, and return up full on the other side till they reach the top. Here an obstacle is placed in such a position that the buckets successively strike against it and are overset, and the water emptied into a trough. As the water can never be raised by this means higher than the diameter of the wheel, it is obvious that this rude machine is capable of only a very limited application. Sometimes the wheel is made to raise the water only to the height of the axis. In this case, instead of buckets, the spokes are made hollow, and bent into such a form that when they dip into the water it runs into them, and is thus conveyed to a box on the axle, whence it is emptied into a cistern. Such wheels are in common use on the banks of the Nile, and elsewhere.

PHOTOGRAPHY. Photography, or sun-painting, is divided, according to the methods used to produce the picture, viz.—*Daguerreotype, Calotype, Chrysotype, Cyanotype, Chromatype, Energiatype, Anthotype, and Amphitype.*

The principal instrument used in the Daguerreotype process is the camera obscura, and the images from the lenses are thrown on prepared metal or other surfaces and fixed. The processes for the retention of the picture belong rather to chemical than mechanical science. This art is frequently employed by mechanics and architects in making copies of drawings. See CYCLOPÆDIA OF DRAWING.

PHOTOMETER. An instrument for measuring the intensity of light, or of illumination.

PILE-DRIVER—*Nasmyth's patent steam.* This is a machine of great power, and one destined undoubtedly to take a prominent place among the improvements of the age.

Fig. 3034 is a front elevation of the entire machine, shown in full operation driving a pile.

Fig. 3035 is a corresponding general side elevation.

Fig. 3036 is a general sectional plan of the machine.

Fig. 3037 is a transverse section of the stage or platform, taken on the line 1—2, in Fig. 3036.

Fig. 3038, an enlarged elevation of the steam-chest and safety-valve geer.

Fig. 3039, a section corresponding to the above.

Fig. 3040 is an enlarged section of one of the joints of the flexible steam-pipes, for conveying steam to the hammer-cylinder.

Fig. 3041, a plan corresponding to the above.

Fig. 3042, a sectional elevation of the hammer-cylinder and pile-case with all their appendages. In this view the hammer is supposed to have just effected a blow upon the head of the pile, and the various parts of the valve-geer are represented in the positions they occupy at the commencement of a fresh stroke.

Fig. 3043, a front view of the hammer-cylinder and pile-case, with their various attachments.

Fig. 3044, a sectional elevation of the same parts as are represented in Fig. 3042, with the driving apparatus and valve-geer shown in the positions they occupy when the hammer is about to fall.

Figs. 3045 and 3046, enlarged views of the trigger and parallel motion of the valve-geer detached. These views are drawn to a scale of twice the size of the other figures.

Fig. 3047 is a section of the hammer-block and hammer.

Fig. 3048 is a sectional plan of the pile-case, taken on the line 3—4, in Fig. 3043.

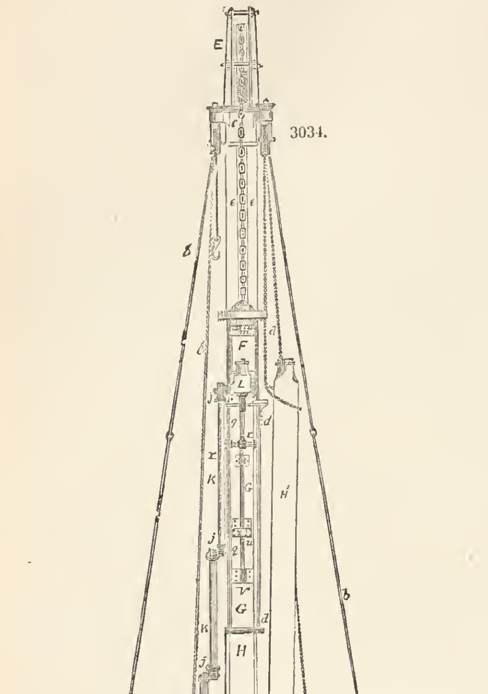
Fig. 3049, a sectional plan of the pile-case and hammer-block, taken on the line 5—6, in Fig. 3042.

General description.—There are two important features of novelty which serve to distinguish the Patent Steam Pile-Driving Engine from all such as had previously been employed for the same purpose. These consist: First, in the direct manner in which the steam is employed as the agent by which the block of iron which strikes the head of the pile is raised to the required height; and, Secondly, in the peculiar mode in which the pile, while being driven into the ground, is employed to support that part of the apparatus which is directly concerned in driving or forcing it into the soil—the apparatus in question being so contrived that, as the pile penetrates into the ground, the superincumbent machinery shall follow down with it until it has reached the required depth.

By the peculiar arrangement referred to under the second head, we secure two most important practical advantages: First, the piles are guided throughout their entire course with the utmost accuracy and precision, so that no one shall twist or swerve in the slightest degree from the general line, or from the position in which it is set at the commencement of the driving process, this object being attained without any sacrifice of power from the friction of bands, or other appliances usually employed for that purpose; and, Secondly, the entire dead weight of the driving apparatus is brought into effective action to second and follow up the blow last inflicted upon the head of the pile. This last peculiarity of action constitutes one of the most important features of the machine, and has contributed very materially to the success which has attended its use. During the brief intervals between the blows, (70 to 80 per minute,) the pile is urged continuously downward by the action of the force here adverted to, so that it may be said to be in a state of constant motion from the commencement to the termination of the driving, and thus the power which would otherwise be wasted in overcoming its inertia is profitably expended in forcing it further into the soil.

The basis or foundation on which the entire machine is erected, consists of a strong wooden stage or platform A A, firmly framed together and strengthened by diagonal timbers, and wrought iron corner pieces, the whole being further secured by the massive cast iron brackets B B, at each end of the platform, in which the locomotive wheels *a a a a* are fitted to work upon rails disposed parallel and close to the line of piling on which the machine is destined to operate. The stage is made of [illegible] sions and weight to give the requisite stability and firmness to the entire structure, and to afford room for the steam-boiler, the workmen, and all that is necessary for the accomplishment of the proposed object. The great vertical guide-pole C C, on which the driving apparatus slides, is securely bolted to one side of the platform, the boiler being situated towards the opposite side, to counterbalance the weight of the former, and to afford an abutment for the diagonal timber supports D D, firmly bound to both by plates of iron and numerous bolts; the entire frame-work of the machine is further secured by the four adjustable tie-rods or stays *b b b b*, attached to the four corners of the stage and to the top of

3034.



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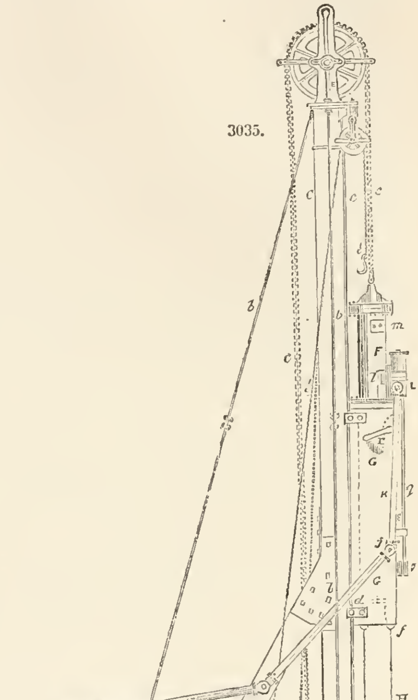
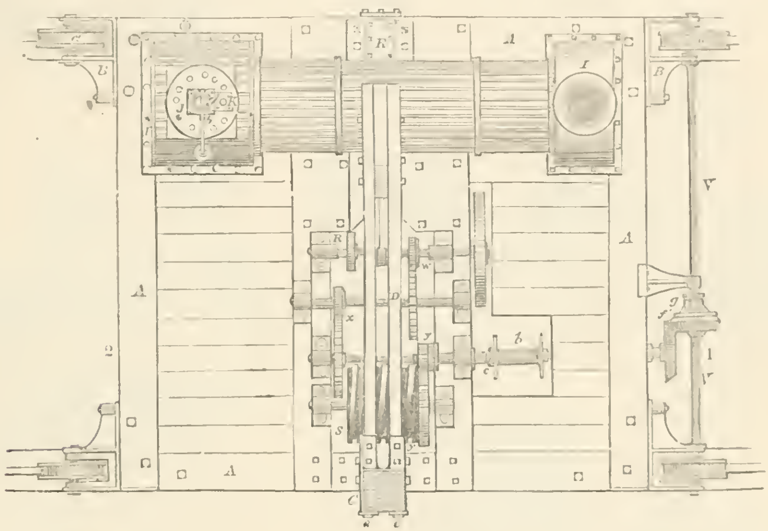


the upright. This latter is surmounted by a cast-iron socket-frame, supporting the brackets E E, which carry a chain-pulley, over which works the great chain *c c*, one end of which is passed round a barrel worked by a small steam-engine, as will be hereafter described, while the other end is attached to, and sustains the weight of, the pile-driving apparatus.

This consists of a steam-cylinder F, with all the necessary appendages of piston, valves, &c., as will be more particularly specified below; the lower flange of the cylinder is firmly bolted to the *pile-case*

G G, which is a species of rectangular box of a square section, constructed of plates of wrought-iron, strongly framed together in the manner indicated in the detail views. The interior surfaces of the pile-case serve to guide the hammer-block in its vertical motion, and it is itself guided along the great upright C C, by the pieces *d d*, which are fitted to embrace the projecting slips of iron *e e*, bolted to the front of the upright throughout its entire length. The lower end of the pile-case is open, to admit the head of the pile, and is furnished with cast-iron jaws or resting-pieces *f f*, (see Figs. 3042 and 3044,) bolted to its interior surfaces; these are so formed as to rest upon the shoulders of the pile H, which, if we suppose the great chain-barrel to be left free to revolve, thus becomes the sole support for the weight of the whole mass of the driving apparatus. By these arrangements it will be seen that as the pile is, by successive steps, forced into the ground by the action of the hammer, (the chain barrel being thrown out of geer with its driving apparatus during the process,) the pile-case with all its appendages, weighing about three tons, is left at perfect liberty to bear upon the shoulders of the pile, and follow down along with it, while at the same time, and by the same means, the pile itself is guided into a strictly vertical and true course.

3036.



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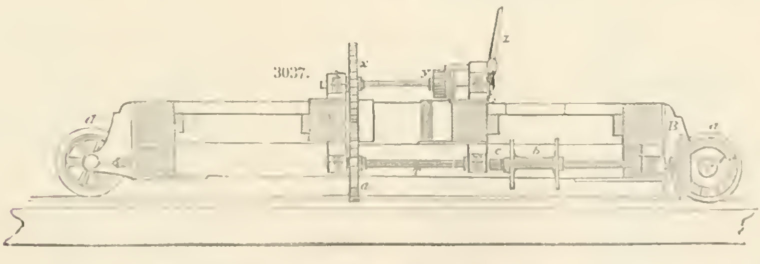

The driving apparatus consists simply of a modification of his steam hammer, the action of the various parts being in all respects identical, though the whole is movable, as above described, instead of being fixed. The steam necessary for its supply is generated in a boiler I, the construction of which is very similar to that of the ordinary locomotive engine boiler. The steam chest J surmounts the fire box, and is made of sufficient height to prevent the influx of water into the steam-pipes, and the entire boiler and steam chest are covered externally with a coating of felt, and with strips of wood to prevent the radiation of heat, and to give greater symmetry of appearance. On the cover of the steam chest (the internal construction of which is fully shown in Fig. 3039,) is cast a small square box *g*, containing suitable bearings for the safety valve, which is loaded by a weight and combination of levers *h h h*, and for the throttle or shut-off valve, commanded by the lever handle and rod *i i*. The steam is conveyed from the boiler to the valve-chest of the driving cylinder, by a flexible steam pipe K K, composed of several lengths of wrought iron tube, connected together by swivel joints of cast iron *j j j*, the construction of which will be fully understood by reference to Figs. 3040 and 3041. This arrangement admits of the steam pipe accommodating itself, without any loss of steam from leakage, to every variety of height or distance at which the driving cylinder may be from the boiler, from the commencement of the process, when the apparatus is sitting aloft upon the shoulders of a tall pile, until it has arrived at its lowest position, when the pile has penetrated the soil to the required depth.

The remaining part of the driving apparatus is identical in the principles of its action, and very similar in the details of its construction to those of the direct action steam-hammer. For fuller informatio on these points, see STEAM-HAMMER.

F is the steam-cylinder, within which the power necessary for raising the hammer to the required elevation (three feet) is generated.

L, the steam-valve chest, bolted to the lower side of the cylinder, within which the valve *k* is fitted to work upon a face cast with the cylinder. The steam, after having accomplished its work, is permitted to escape into the atmosphere by an oblong aperture *l*, formed in the cylinder-face; and, to obviate the risk of accident from the piston rising too high, a number of small round holes *m m* are formed near

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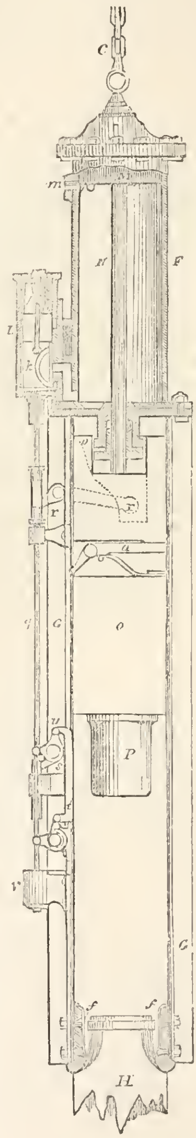

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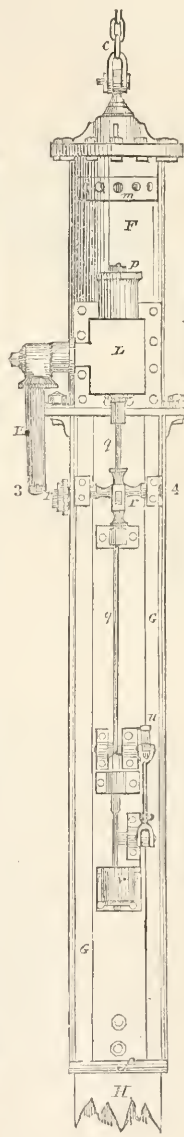

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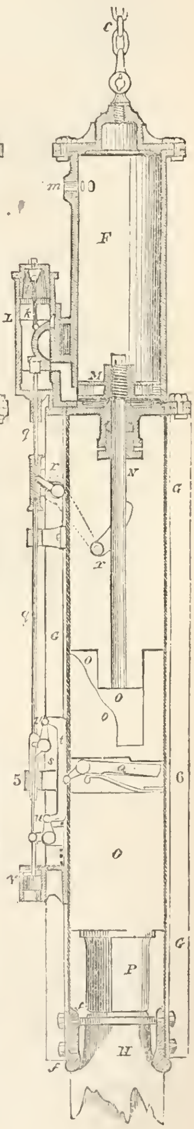

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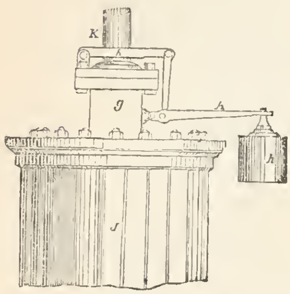

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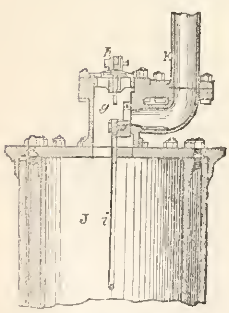

the top of the cylinder, so that the steam may blow out into the air when the piston rises above their edges. It may here be remarked that the efficacy of the blows of the hammer, and the security from damage to the parts of the machinery, are in this case, as in that of the steam forge-hammer, materially augmented by the recoil of the air or steam inclosed above the piston.

M, the piston, formed of wrought-iron, and fitted with a single packing-ring.

N the piston-rod, having a cylindrical boss or enlargement *n*, at its lower extremity, for the purpose of affording means for securing a slightly elastic connection, by hard-wood washers, between the piston-rod and hammer-block.

O, the hammer-block, consisting of a rectangular mass of cast-iron, weighing 30 cwt., adapted to slide freely but without much play, within the pile-case G G. It is furnished with suitable recesses for the securing of the hammer, piston-rod, &c., and for enabling it to rise clear of the cylinder stuffing-box; and at its upper extremity a recess in the form of a species of inclined plane *o' o''*, is provided, for the purpose of acting upon the valve-lever so as to permit the escape of the steam, after it has raised the hammer to a sufficient height.

P, the hammer: a cylindrical block of cast-iron, formed with a slightly concave face, fitted into the hammer-block, and fastened thereto by a wrought-iron key *o*, which at the same time serves to secure the connection of the piston-rod.

Q, the latch-lever working in a recess in the hammer-block, (see Fig. 3049.) The action of this part of the apparatus is fully described in the account of the steam-hammer.

p, a small solid piston working in a cylindrical part of the valve-chest, and attached to the valve by a short connecting-rod. Its under surface is constantly acted upon by the pressure of the steam within the valve-chest, so as to cause the steam-valve to assume the position indicated in Fig. 3042, unless counteracted by a superior force.

q, the valve-spindle, produced downwards and working in suitable bearings, so as to bring it under the action of the trigger at the termination of the stroke.

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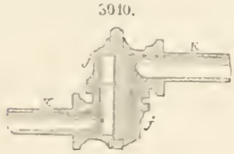

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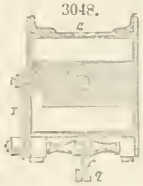

3049.

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r, the valve-lever, working outside of the pile-case, but having a small friction-roller attached to its inner end, and situated so as to come under the action of the inclined plane *o' oo''*.

s, the trigger, the function of which is to keep the steam-valve in such a position as to prevent the admission of steam into the cylinder during the descent of the hammer-block.

t, the parallel bar, against which the latch-lever acts at the termination of the stroke, for the purpose of releasing the valve-spindle from the trigger, in order to allow the steam to be admitted for a fresh stroke.

u u u, the parallel motion bell-cranks and connecting rod of the disengaging apparatus.

v, a buffer-box for the purpose of restricting the travel of the valve to its proper amount, and of deadening the shocks to which it is subjected.

The above enumeration, together with the explanations previously given, will convey a sufficiently clear idea of the construction of the pile driving apparatus, properly so called. We shall now proceed to describe the mechanism by which the pile-case and its appendages are elevated to the top of the great vertical guide-pole, and the means employed to render the whole machine locomotive.

The power requisite for these purposes is supplied by a small horizontal steam engine R, situated opposite to the great upright C, and under the boiler I, from which it derives its supply of steam. The motion of this steam engine is transferred to the axis of the great chain barrel by means of a train of spur geering calculated to increase the power to the required extent. Two broad plates of wrought-iron, extending across the entire platform, and bolted securely to its timbers, afford a sufficiently firm foundation for the engine, and for the bearings of the various shafts in the train of wheels, which consists of three pairs marked *w*, *x*, and *y*, the pinion of the first pair being fixed upon the crank shaft of the engine, and the wheel of the last upon the axis of the chain barrel. The pinion *y* is fitted to slide longitudinally upon its shaft by means of a sunk feather, and is commanded by the lever handle *z* so as to enable the attendant in charge of the machine to throw it out of geer with the wheel upon the chain barrel shaft, when the latter is to be left free to revolve during the driving of the pile. The wheel *x*, upon the third motion shaft, geers with a similar wheel *a'*, fixed upon a cross-shaft T, working in bearings under the platform, and serving to impart motion at once to the small chain barrel *b'* for hoisting the piles, and to the locomotive geer. A clutch, or coupling *c'*, sliding upon the shaft T, enables the attendant to throw the small chain-barrel into geer with the driving apparatus or disengage it at pleasure; the remaining details of this part of the process will be fully understood by reference to Fig. 3034, where a pile H' is shown suspended from the chain d', ready to come under the action of the driving machinery. To adjust the pile-case over the head of the pile at the commencement of the driving, it is of course necessary that one or two men should be raised to the summit of the machine. A rope c' passed over a pulley at the top of the great upright, and wound round the barrel of a winch U, serves to accomplish this object.

The locomotive geer is exceedingly simple, and will be at once understood by referring to Figs. 3036 and 3037. A bevel-wheel f', fixed to the outer end of the shaft T, geers with another of equal diameter working loose upon the shaft V, to which a pair of the locomotive wheels a a are fixed. When it is required to move the platform, with its superincumbent machinery, along the line of rails, a sliding-clutch g' is thrown into geer with the last-mentioned bevel-wheel, and is disengaged when the machine has arrived at the desired position.

Action of the machine.—The pile having been raised by means of the hoisting apparatus, and its point having been set into the proper position, the pile-case G G, with its attached machinery, is lowered down over the head by reversing the small engine R, so that the jaws f f rest upon the shoulders of the pile, which sinks down into the ground by the effect of the superincumbent weight, till it has reached soil sufficiently firm to support it; this is indicated by the chain c c becoming slack. The pinion y is then thrown out of geer, and the steam is admitted into the driving-cylinder F by turning the handle i. The hammer-block O is by this means raised till the inclined plane o' o'', coming in contact with the end of the valve-lever r, causes the valve k to assume the position represented in Fig. 3044. The steam which had served to raise the hammer is thus allowed to blow out into the air, and the hammer descends and discharges its momentum in the form of an energetic blow upon the head of the pile. During the descent of the hammer-block, the steam-valve is retained in its proper position by the action of the trigger s, but by the effect of the concussion upon the head of the pile, the valve-spindle is released from contact with the trigger, and the steam-valve assumes the position indicated in Fig. 3042, in which circumstances the steam is allowed to act freely under the piston, for the purpose of again raising the hammer.

Such is the rapidity with which these various movements and functions of the driving apparatus are accomplished, that the machine may be easily made to perform 80 strokes per minute. Some idea may be formed of the vast efficiency of this system of driving piles, when it is stated that, in ordinary ground, piles of 14 inches square are driven at the rate of upwards of 10 feet per minute!

At the conclusion of the driving of each pile, the action of the hammer is arrested by turning the handle i, which cuts off the supply of steam. The great chain-barrel pinion is then thrown into geer with the wheel on the barrel-shaft, and the small engine R is started, which rapidly raises the apparatus off the head of the pile to the top of the great guide-pole C. In the mean time the locomotive action is applied, and the machine brought opposite the next pile, when the process just described is repeated.

PILE-DRIVING MACHINE—THE AMERICAN STEAM. The following is a description of the American steam pile-driving machine, and the operations for which it is applicable.

The machine consists of two pair of leaders, similar to the common hand machine, placed 6 feet from centre to centre, and firmly bolted to a strong horizontal framing, and supported by two oblique ladders. The frame is 9 feet wide to the outside of the framing, and 28 feet long; it carries at one end a locomotive boiler 11 feet long and 2 ft. 6 in. diameter, calculated to bear 120 lb. per square inch pressure, but generally worked at 80 lb. per square inch, and about 100 strokes per minute. Under the boiler is placed the supply cistern. In the centre of the framing, and on each side of the boiler, is a pair of inclined cylinders 5½ inch bore, with solid pistons working well without packing, and 14 inch stroke, which act on right-angled cranks, and the geering, drums, &c., described in the motions of the machine; the shaft centres are 1' 3" apart, the spur-wheel has 56 and the pinion 19 teeth; bevels 101 and 40 teeth; saw-pulley 1' 9" and 10½ inches diameter. The ram is generally raised from 4 to 5 times a minute, the steam being at 80 lb. per square inch.

For river work the machine is made much more compact, the apparatus is placed on each side and over the boiler, so that the stage is little more than half the length of the machine shown in the engraving, and it is also sometimes made with an apparatus for driving one pile only, consequently requiring smaller power.

In the drawing, Fig. 3050 is a side elevation of the machine; Fig. 3051 elevation in front of leaders, showing saw, &c.; Fig. 3052 a section taken in front of geering, &c.; Fig. 3053 a plan of geering end with leaders and ladders removed, and showing saw in plan; similar letters refer to similar parts in each figure.

Taking up the pile.—The ram A being secured by placing the stop B under it, by means of the small ropes attached to the latter, and passing over the small pulleys C C, to within three feet of the stage. The dogs D are made fast to the pile, Fig. 3052, the rope attached to which passes upwards through the small guide-pulleys and over the outer pulley E, passes downwards and is coiled round the pulley F fixed on the shaft G, which being made to revolve, raises the pile to its place between the leaders, and is then secured by the loose stay H and the iron work H' placed round it for guiding it perpendicularly.

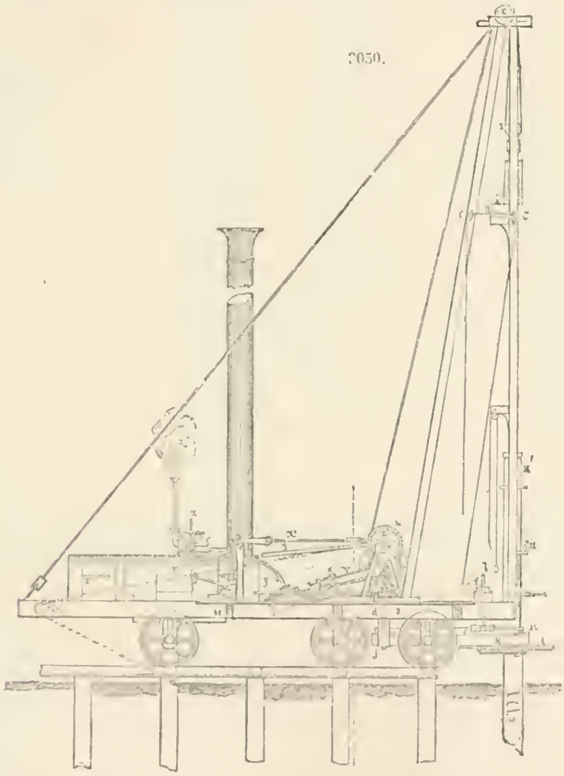
Driving the pile.—The stop B being withdrawn from under the ram A, the ram is raised by a rope, which, being secured to a staple on the top journal, passes down under the pulley J, then upwards over the pulley K, and again downwards to the drum L, upon which the rope is coiled. The drum is placed on the shaft G, which is made to revolve by the spur-wheel N working in the pinion O on the lower shaft P, which shaft revolves by the action of two cranks Q, Figs. 3050 and 3052, placed on each end of the shaft P; the cranks are set at right angles to each other, and are worked by the connecting-rods R attached to the piston-rods, which are furnished with slide parallels, as shown in Fig. 3050. The slide-valves of the piston are worked by the eccentric V on the end of the shaft P. Steam is supplied to the cylinder by the pipe S from the boiler T; the boiler is supplied with water from the cistern M, Fig. 3050, by the pump W, which is worked by the eccentric-rod X fixed on the spur nave at Y, or by the handle at Z; the supply of steam is regulated by the handle *a* acting on a valve in the steam-pipe S. The drum L consists of a fixed and a loose cylinder, the latter revolving by the friction of the former, (fixed,) and is brought into or out of contact by the hand-lever Y, Figs. 3050 and 3053, which has a fulcrum attached to the standard.

The follower *f'* is furnished with a pair of tongs or clippers, which take hold of a staple fixed on the ram and carries it to the top of the frame; then, when the top of the tongs is pressed closer together by coming between the contracted cheeks *e' e'*, the lower part opens and allows the ram to fall.

For working the apparatus, the engine-tender stands at the valve S, and a man at the lever *y* of each machine. For raising the ram the man turns on the steam at the valve S, which sets in motion the apparatus of each machine, coils the rope round the drums, and, at the same time, raises the ram; as soon as the latter reaches the top of the leaders, the ram is detached and descends; at the same moment the engine-tender turns off the steam, and the men at the levers *y* throw the drum out of geer, which allows the clippers and chain to descend again and lay hold of the ram, when the drum is again thrown into geer, the steam turned on, and the ram again raised, and so the operation is continued until the pile is driven.

Drawing a pile.—Chain tackle is secured to the pile and passed over the top pulley to the drum L, and is then drawn by applying the power to turn the drum of the apparatus.

3050.



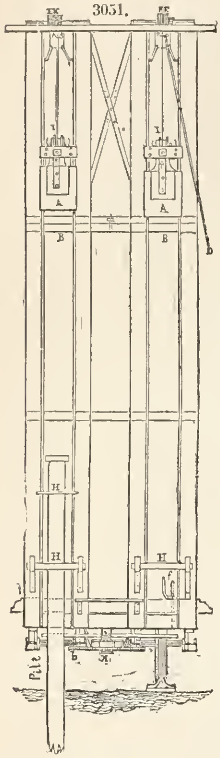
The saw apparatus consists of a circular saw *b*, 4 feet diameter, having teeth set three inches apart, secured to the end of a beam *c*, which beam works on the upright shaft *d* for a centre, and slides laterally on the iron arc *e*; when used, the saw is adjusted to the proper height by the screws *f*, and a bar having a hook in one end, and fitting into a staple in the beam's end, is used to press the saw against the work; the bevel pinion *g* being raised into geer by the foot-lever *h*, Fig. 3053, motion is given to the pulleys *i* and *j* and band *k* which work the saw *b*. The operation of sawing off the end of a pile takes less than a minute.

Progressing motion.—The hook *l* being fastened to a driven pile, and the rope passed over the pulley *m* attached to the side of the frame to the pulley F, round which it is coiled twice and the end held by a man; motion being now given to the drum the machine progresses; this motion is shown by the dotted rope, Fig. 3050. It should be stated that the frame is intended to be supported upon six railway wheels, which run on a temporary rail laid on the top of the piles as they are driven. There is another mode of progressing, but which is not found to answer so well, viz., by means of two sledge beams faced with iron and attached to the under framing; these are placed six feet apart from centre to centre, and pass under the whole length of the machine, and slide on small iron wheels fixed to standards, which are placed loose on the piles.

The plumb bob *t* suspended to a line regulates the pile being driven perpendicularly, and Y is a lever attached to a friction band break passing over the end of the drum, which is only used occasionally.

For the steam machine it requires to work the engine and apparatus for driving two piles at one time, with a ram weighing 16 cwt., the following men: an engine-tender, one man for throwing each apparatus in and out of geer, and one man to attend to each pile, making altogether five men for driving *two* piles For the ordinary machine it requires four men to work the crab-engine for lifting a ram of the same

3051.



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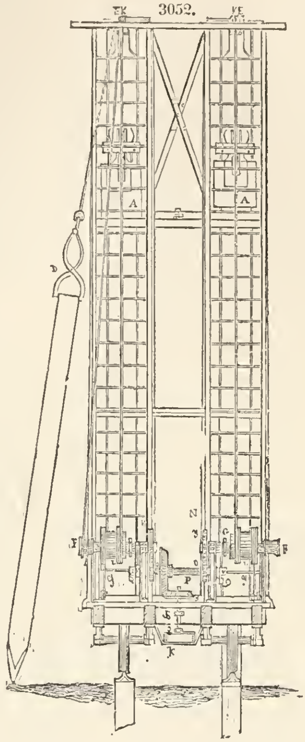

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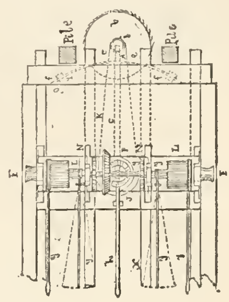
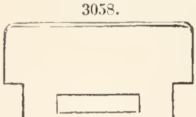


weight, and one man to attend to the driving of the pile, making five men for *each* pile, or 10 men for two piles. With the steam machine the ram is lifted four or five times in a minute, thereby the operation of driving the pile is very short in comparison with the ordinary machine. The cost of the steam machine, with an engine of ten horse-power, tubular boiler and apparatus, is about $3500, and the cost of the ordinary pile-driving machine, with crab-engine, is about $350.

3058.



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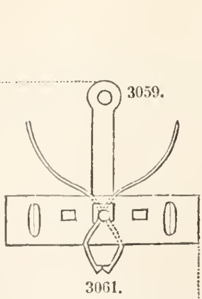

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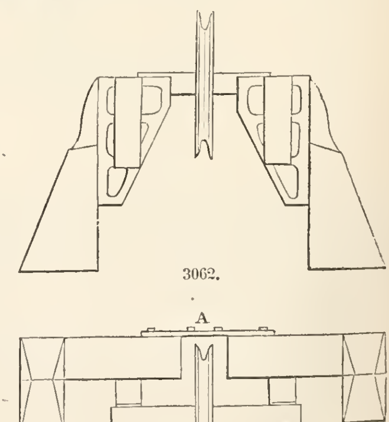
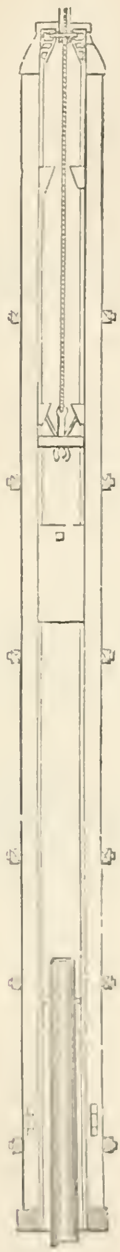


PILING MACHINE. Fig. 3054 represents the side elevation, Fig. 3055 the front elevation, Fig 3056 the plan, and Fig. 3057 a section of a pile-driver used at the construction of the Dry Dock, Brook

3057.



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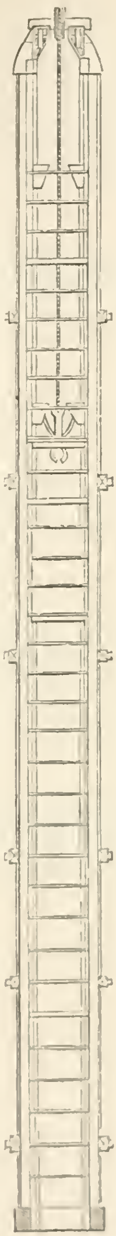

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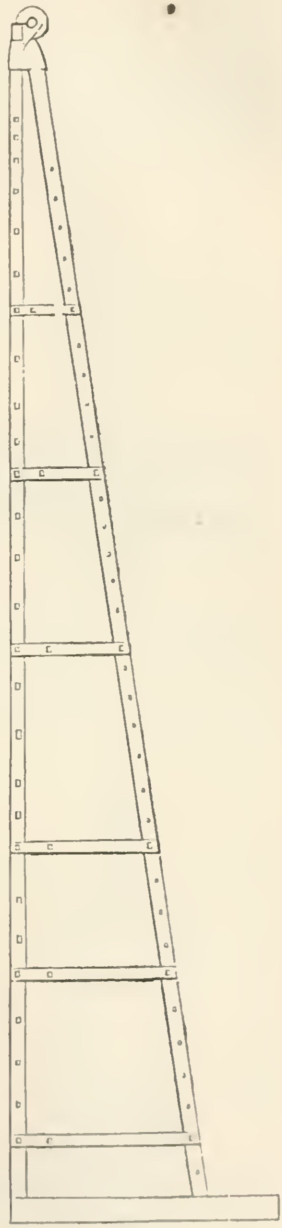

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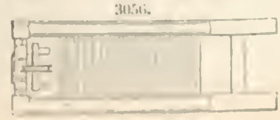
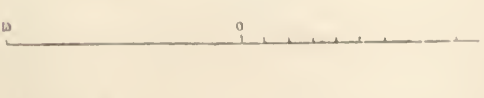




Scale for details.

lyn Navy Yard, drawn to a scale of 8 feet to an inch. Fig. 3085 is a plan of the hammer, weighing 4050 pounds.

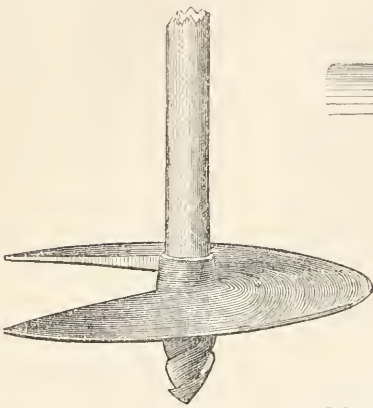
Figs. 3061, 3059, and 3060 are plan, elevation, and section of the nippers.

Fig. 3062, plan and elevation of head-pulley.

These machines were operated by steam ; the fall passing through the leading-blocks to the drum of a steam engine.

PILE, SCREW AND SCREW MOORING. To Alexander Mitchell, Esq., of Belfast, Ireland, the profession is indebted for this discovery, by means of which we are now able to construct permanent foundations in deep water, on shoals of sand, mud, clay, or gravel, or in fact on any bottom, excepting solid rock, and to moor shipping of the largest class with a degree of security never before attained.

3063



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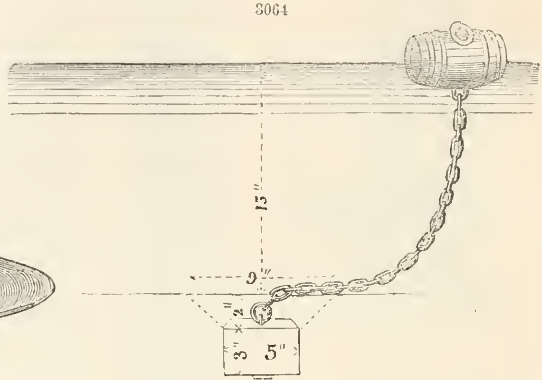
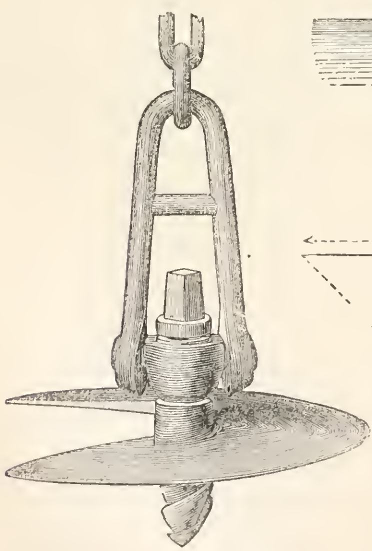
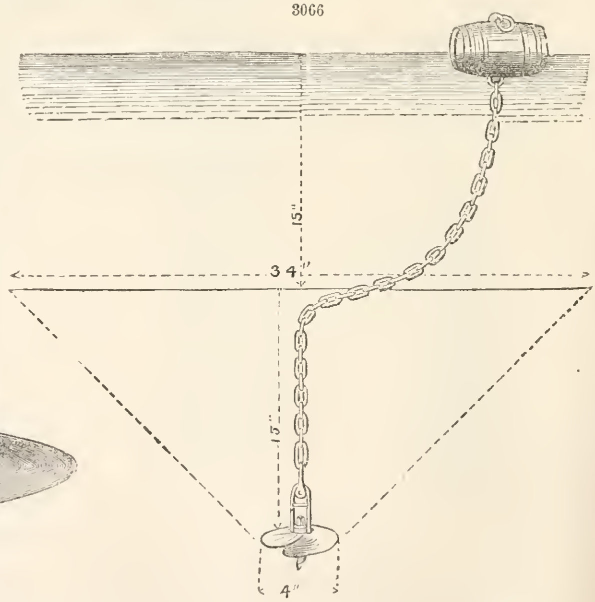


The plan which appeared best adapted for obtaining a firm hold of soft ground or sand, was to insert to a considerable distance beneath the surface a bar of iron, fig. 3063, having at its lower extremity a broad plate, or disk of metal, in a spiral or helical form, on the principle of the screw, in order that it should enter the ground with facility, thrusting aside any obstacles to its descent, without materially disturbing the texture of the strata it passed through, and that it should at the same time offer an extended base, either for resisting downward pressure, or an upward strain.

3065



3066



Whether this broad spiral flange, or "ground-screw," as it may be termed, be applied to the foot of a pile to support a superincumbent weight, or be employed as a mooring to resist an upward strain, its holding power entirely depends upon the area of its disk, the nature of the ground into which it is inserted, and the depth to which it is forced beneath the surface.

The proper area of the screw should, in every case, be determined by the nature of the ground in which it is to be placed, and which must be ascertained by previous experiment. The largest size hitherto used has been 4 feet in diameter; but within certain sizes, prescribed by the facility of manufacturing them, the dimensions may be extended to meet any case, and may be said to be limited only by the power available for forcing them into the ground.

Either the screw-pile or the screw-mooring can be employed in every description of ground, hard rock alone excepted; for its helical form enables it to force its way among stones, and even to thrust aside medium-sized boulders. In ports, harbors, estuaries, and roadsteads, rock is, however, seldom met with, except in detached masses, the ground being usually an accumulation of alluvial deposit, which is well adapted for the reception of such foundations, and is also that in which they are generally most required.

The ground-screw has been already extensively used for several purposes, and its applicability to many others will be evident from a succinct account of its present employment.

The fixed or permanent moorings at present most commonly used are of two kinds—the span-chain mooring, and the sinker, or mooring-block.

The former of these consists of a strong chain of considerable length, stretched along the ground (across the river), and retained by heavy anchors, or mooring blocks, at either end, and to the middle of the ground-chain the buoy-chain is shackled.

The other kind, which is more generally employed, consists of a heavy sinker, to which a strong chain is attached, extending to a buoy shackled at the other end (fig. 3064). This sinker, which is a block of stone or iron, is either laid upon the surface of the ground, or is placed in an excavation prepared for its reception. As a simple, effective, and at the same time an inexpensive mode of holding the buoy-chain down, Mr. Mitchell adopted a modification of the screw-pile, fig 3065, because it offers great facilities for entering the ground, and when arrived at the required depth, it evidently affords greater holding power than any other form.

Every description of earth is more or less adhesive, and the greater its tenacity, the larger must be the portion disturbed, before the mooring can be displaced by any direct force. The mass of ground thus affected, in the case of the screw-mooring, is in the form of a frustrum of a cone, inverted; that is, with its base at the surface, the breadth of the base being in proportion to the tenacity of the ground; this is pressed on by a cylinder of water equal to its diameter, the axis of which is its depth, and the water again bears the weight of a column of air of the diameter of the cylinder.

It is evident, therefore, that if a cast iron screw, of a given area, be forced into the earth to a certain depth, it must afford a firm point of attachment for a buoy-chain in every direction (fig. 3066), and will oppose a powerful resistance, even to a vertical strain, which generally proves fatal to sinker moorings, depending (as they do) chiefly on their specific gravity.

The first trials were upon a comparatively small scale; but their success was so decisive that the merits of the moorings were acknowledged, and their use soon became extended.

The depth to which these moorings have been screwed varies from 8 to 18 feet; the former is deep enough where the soil is of a firm and unyielding description, and the latter depth is found to give sufficient firmness in a very weak bottom. It is evident from its form, that every part of the screw-mooring is so far beneath the surface, as to prevent a vessel from receiving injury from grounding immediately above it, the mooring chain alone protruding from the ground; and it is also obvious that anchors, dropped in the neighborhood, cannot be hooked into or get foul of the chain, one end alone being attached to the ground.

In fixing these moorings in the ports and harbors where they have been used, the persons hitherto engaged in the operation have been generally compelled to avail themselves of any means within their reach, for the construction of a floating stage, or platform, on which the men could execute the work. Barges, lighters, and pontoons have been therefore indifferently employed; those that were without decks being planked over for the purpose. Two such vessels being lashed broadside to each other, with a certain space between them, are securely moored over the spot, and the screw-mooring lowered, with the chain attached to the shackle, from the centre of the stage, to the level of the water, and as it descends to the bottom the lengths of the apparatus for screwing it into the ground are successively attached.

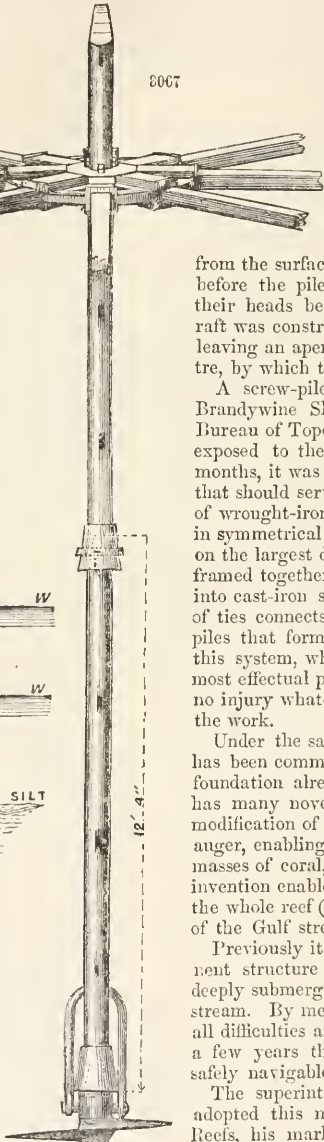
This apparatus, fig. 3067, consists of a strong wrought-iron shaft, in lengths of 10 or 12 feet each, connected with each other by key-joints or couplings, the lower extremity having a square socket to fit the head of the centre pin, or axis, of the mooring. When the centre pin rests on the bottom, a capstan is firmly keyed upon the shaft at a convenient height; the men then shift the capstan bars and apply their power whilst travelling round upon the stage, the capstan being lifted and again fixed as the mooring is screwed down into the ground. The operation is continued until the men can no longer move the shaft round, or until it is considered to have been forced to a sufficient depth.

The most important purpose to which the screw-pile has hitherto been applied, to any considerable extent, is for forming the foundations of lighthouses, beacons, and jetties, in situations where the soil, or sand, is so loose and unstable, as to be incapable of supporting any massive structure, or where the waves have so much power of undermining by their continuous action, or beat so heavily, that the stability of any mass of masonry would be seriously endangered.

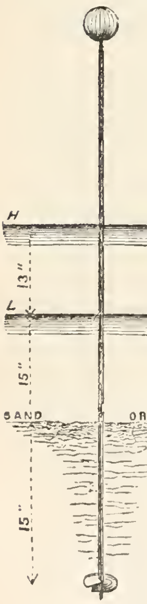
In 1838, Mr. Mitchell and his son laid the foundation of the Maplin Sand Lighthouse. Before determining the length of the piles and the area of the screws to be employed, a careful examination of the ground was made, and it was proposed to use nine malleable-iron piles of 5 inches diameter, and 26 feet in length, with a cast-iron screw of 4 feet diameter, secured to the foot of each. Eight of the piles were placed at the angles of an octagon, and one in the centre; these were put down in nine consecutive days, being screwed into the bank to the depth of 22 feet, leaving 4 feet above the surface. The tide rises on the bank about 16 feet, and seldom leaves the surface dry.

The instrument used in trying the nature of the ground was also employed in testing its holding power. It consisted of a jointed rod 30 feet long, and $1\frac{1}{4}$ inch in diameter, having at its foot a spiral flange of 6 inches diameter. It was moved round by means of cross levers, keyed upon the boring-rod and upon these levers, when the screw was turned to the depth of 27 feet, a few boards were laid, forming a platform sufficiently large to support twelve men. A bar was then driven into the bank at some distance, its top being brought to the same level as that of the boring-rod. Twelve men were then placed upon the platform to ascertain if their weight, together with the apparatus, in all about one ton, sufficed to depress the screw. After some time the men were removed, and the level was again applied, but no sensible depression of the screw could be observed.

3067



3068



The inference from it was, that if a screw of 6 inches in diameter could support one ton, one of 4 feet diameter was capable of supporting at least 64 tons, the comparative area of their surfaces being as the square of their diameters; but this experiment was nothing more than an approximation to the truth, a continuous surface possessing a much greater sustaining power than the same area in detached portions.

In fixing the foundation piles for the Maplin Sand Lighthouse, a raft of 36 feet square was used as a stage, or platform, upon which the men worked, as barges would have been too high from the surface, and "it was necessary to ground the raft itself," before the piles could be screwed down to the required depth, their heads being only a short distance above the bank. The raft was constructed of balks of American timber bolted together, leaving an aperture of two feet in width from one side to the centre, by which the pile was brought to its position.

A screw-pile lighthouse of iron has been constructed on the Brandywine Shoal, in Delaware Bay, under the orders of the Bureau of Topographical Engineers. This work being very much exposed to the action of fields of drift ice during the winter months, it was deemed prudent to protect it by an exterior work that should serve as an ice-fender: this consists of 30 screw-piles of wrought-iron of 5 inches diameter. These 30 piles are placed in symmetrical order, so as to form an oblong hexagon, 75 feet on the largest diameter, and 45 feet on the shorter. The piles are framed together at their heads by ties of 3-inch round iron, keyed into cast-iron sleeves fitted to the pile-heads. A similar system of ties connects the piles at the plane of low water. The nine piles that form the foundation of the lighthouse are inclosed in this system, which has been found, during a series of winters, a most effectual protection against the heaviest drifts of field-ice—no injury whatever having thus far been sustained by any part of the work.

Under the same Bureau, a screw-pile lighthouse of great size has been commenced on the Florida Reefs at Sand Key, and the foundation already completed. This work is quite peculiar, and has many novel features. The principal one is, however, the modification of the form of the screw, into something like a screw auger, enabling the engineer thereby to penetrate through solid masses of coral, of which these reefs are entirely composed. This invention enables the government to erect a chain of lights along the whole reef (upwards of 250 miles long), and right on the edge of the Gulf stream.

Previously it was thought impracticable to locate any permanent structure on these reefs, as in hurricane seasons they are deeply submerged, and exposed to a tremendous sea from the Gulf stream. By means of the screw-pile, as modified for this locality, all difficulties are now surmounted, and it is supposed that within a few years the whole reef will be illuminated, and rendered safely navigable.

The superintendent of the United States Coast Survey has adopted this modified screw-pile to establish, on the Florida Reefs, his marks of triangulation, the old form of tripod being annually washed away, and their replacement attended with a great expense. To the screw is attached a tube of cast-iron 8 feet long; by means of this tube, which takes the place of the ordinary pile, the screw is inserted into the reef 4 or 5 feet deep. A long signal pole, with a cone or ball on top, is then inserted in the iron tube, and will stand erect during the heaviest storms. The number of wrecks on these reefs has greatly diminished since the operations of the Coast Survey were commenced.

Three beacons have been erected by Mitchell & Son for the Dublin Ballast Board, on the Kish Bank, the Arklow Bank, and the Blackwater Bank, which are parts of the same shoal. These have all been put down with the intention of placing lighthouses on their sites, should they appear eventually to suffer no change by the action of the sea. All these beacons are similar in form and principle (fig. 3068) each consisting of a single pile of wrought-iron in two joints, connected by a strong screw-coupling, and measuring, when together, 63 feet in length; their diameter at the surface of the ground is 8 inches, diminishing from thence both up and down.

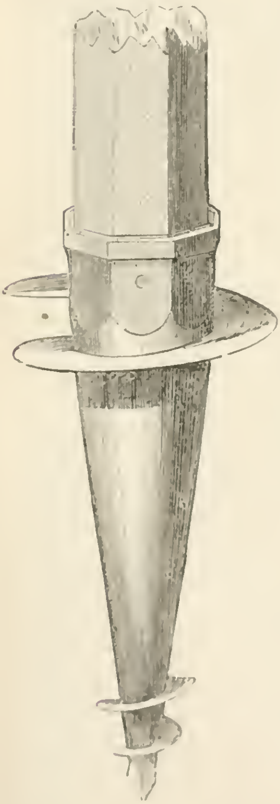
The incompressible nature of the sand offering considerable opposition to the descent of the pile, screws of only 2 feet in diameter were used, and on the top of each pile, when fixed, a ball was placed of 3 feet 6 inches diameter. The screws used for the Blackwater and the Arklow beacons were forged of malleable iron, and turned in the lathe, at great expense; but that will probably never again be necessary, as they can generally be quite as well made of cast-iron, and at much less cost.

One of these beacons was fixed in June, 1843, the other two in the summer of 1846, and are all standing, though two of them diverge considerably from the perpendicular, having been frequently struck by vessels in heavy weather.

The engineer of the Great Portland Breakwater, which the British government have ordered to be constructed as a harbor of refuge for the Channel fleets, has applied the screw-pile in a novel and efficient manner. On the axial line of the breakwater a viaduct of screw-piles is erected, bearing a railway, which extends inland to the quarries, and is prolonged seaward as fast as the growth of the work requires. The stone of which the breakwater is to consist is thus brought direct from the quarry by rail, to the site, and there dumped into the water. The screw-pile viaduct is of course buried up in the mass of the breakwater; but an enormous saving has been effected by this arrangement, when compared with that pursued at the Plymouth Works. An extensive railway viaduct was erected on screw-piles over the fens of Lincolnshire in 1849, by Mr. W. Cubitt, and other similar structures are now in progress.

Messrs. Ransomes and May (of Ipswich, England) have constructed several kinds of cast-iron screw-points, shown in figs. 3069, 3070, 3071, and 3072.

3069



3070

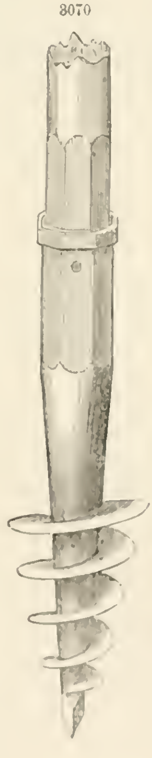


Fig. 3069 shows the largest size, weighing 2 cwt. 3 qrs. 14 lbs., adapted for whole timber piles, which are often so splintered and shattered, and even set on fire, by the rapid blows of the steam pile-driver, when traversing compact ground, and where wrought-iron shoes are generally crushed into the timber even in ordinary ground, with the force of the common pile-engine. The small screw-point opens the way for the conical part, and the larger screw not only draws the pile down, but, when it has penetrated to a sufficient depth, affords an extended base for preventing further depression. Thus several feet of timber must be saved, and the general length of the pile can be reduced, as it will bear a greater weight and offer a more solid base when introduced to a less distance, than when it rests upon the ordinary sharp, wrought-iron pointed shoe.

3071

3072

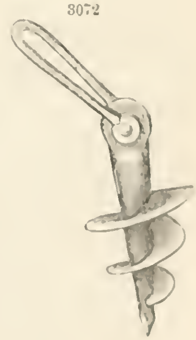


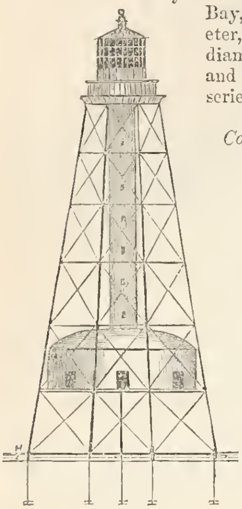
Fig. 3070, weighing 3 qrs. 22 lbs., shows the shape adapted for railway signal posts; and fig. 3071, weighing 2 qrs. 4 lbs., that for the supports for the wires of the electric telegraph. For these purposes the screw-points must be very useful, as independent of the economy of labor in putting them down by merely screwing them into the ground, instead of digging holes to introduce the cross feet, all possibility of injury to the banks would be precluded; whereas at present there is always a liability of causing a slip by disturbing uncertain ground, and admitting water in the sides of cuttings.

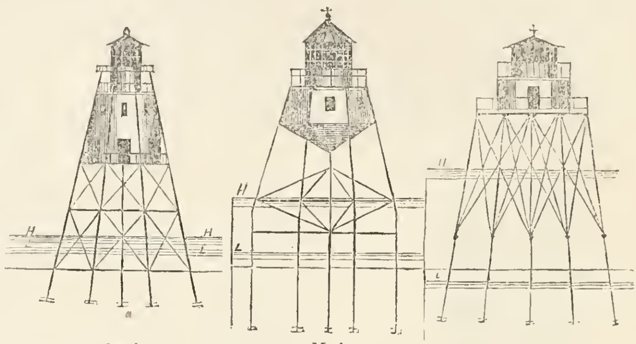
The cast-iron screw socket-points, fig. 3069, have recently been very successfully applied for the supporting posts or columns of timber-sheds and buildings for railway stations and other purposes.

Fig. 3072 shows the applicability to smaller objects, and a tent-pin has been selected as the most familiar example, as it requires to be removed so frequently, and shows the use that may be made of the screw for the standards of fencing, and for an infinite number of agricultural and other purposes.

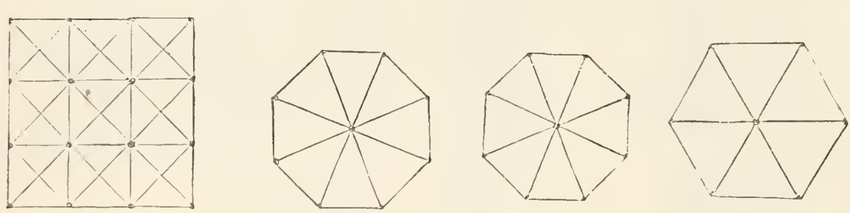
The diagram given below represents four lighthouses that have been erected on the "skeleton frame tower system," with screw-pile foundations. The whole of these structures are drawn to one scale, so that at a glance their comparative magnitudes in elevation and area of foundations are immediately visible. The Brandywine Lighthouse is erected upon the shoal of that name at the mouth of Delaware Bay, and was lighted in 1851. It stands upon nine piles of 5½ inches diameter, tapering from the screw (which is 3 feet diameter) to the top, where the diameter is reduced to 4 inches. The diameter of the foundation is 42 feet, and the height of the superstructure above the shoal is 70 feet. There are two series of tension braces. The keeper's house is entirely of cast-iron, circular

Comparative Magnitude of Lighthouses erected on the Screw-Pile system.
Scale 50 feet to 1 inch.





Coral Reef. Sand. Mud. Sand



Sand Key, 1851. Brandywine, 1849. Maplin, 1840. Fleetwood, 1839.

in form, and consists of two stories. The prevalence of vast fields of ice in the Delaware in winter, rendered it advisable to protect the frame of the tower by surrounding it with a system of thirty 5 inch screw-piles, arranged in the form of a hexagon of 75 by 45 feet, the longer axis of the polygon being parallel to the thread of the current. This ice-breaker has proved perfectly efficient after a trial of seven winters.

The screw-pile lighthouse at Sand Key, constructed by I. W. P. Lewis, is different in design and detail from all that have preceded it. On reference to the diagram, it will be seen that the base is square. It was found while constructing the Brandywine and Carysfoot lighthouses, that there was a want of rigidity in the frame-tower, and that the application of any external force produced a vibratory movement about the central axis of the frame. Secondly, it was observed that in tying all the horizontal framing to a common centre, there was a very unequal distribution of metal and strength—the centre pile bearing 6 or 8 times the load borne by any one of the angle piles. Both these important defects are entirely remedied by adopting the square base. The tower at Sand Key requiring to be of the first class, it was decided to increase the number of piles to 16, and one auxiliary pile in the centre to bear the weight of the staircase. The foundation thus is formed of 17 screw-piles of 8 inches diameter, armed with a modified form of screw 2 feet in diameter. A survey in 1850 by the engineer, enabled him to design a form of screw, similar in principle to a centre-bit auger, which should with a very slow motion cut its way through the coral. This screw was entirely successful; being slowly turned by powerful machinery, it descended through the coral about 2 inches for each revolution.

The screws are bored 12 feet into the reef, and the pile-heads being framed and braced together as shown in the diagram, a perfectly rigid and firm foundation is obtained.

The superstructure of the frame-tower consists of six series of cast-iron tubular columns, framed together with wrought-iron ties at each joint, and braced diagonally on the faces of each tier, as seen in the diagram; the rigidity of such a system of pillars and braces can be easily estimated.

The keeper's house rests on a floor of cast-iron, supported upon cast-iron girders and joists, at the height of 20 feet above the plane of the foundation top; this is higher by 15 feet than the great hurricane tide of 1846, and beyond the reach of any sea that could rise there, the surrounding coral reef forming a perfect breakwater.

The foundation of Sand Key Lighthouse measures 50 feet on the side of the square, and its total height is 132 feet, or 120 feet above high-water level. The site is a small bank of calcareous sand thrown up by the combined effects of wind and tide, to the height of 4 feet above mean high water, and in depth about 2 feet below low-water level.

PIN-MAKING MACHINE. An improved method of making pins, by JOHN J. HOWE, of New Haven, Connecticut. The wire having been properly straightened and placed in a coil upon a suitable reel, and having one of its ends introduced in a proper manner into the machine, is, in successive portions, drawn in and converted into pins, by the action of the machine; each pin so made by the machine consisting of a single piece of metal or wire, the head of the pin being upset or raised, and formed at one end, and the other end being sharpened in a suitable manner, to form the point. The following is a full and exact description thereof, and of the manner of constructing and using the same, reference being had to the accompanying figures.

The individual parts of the machine are marked in the drawings with capital letters, with small letters, and with numbers respectively; and the same marks of reference refer in all cases to the same or similar parts.

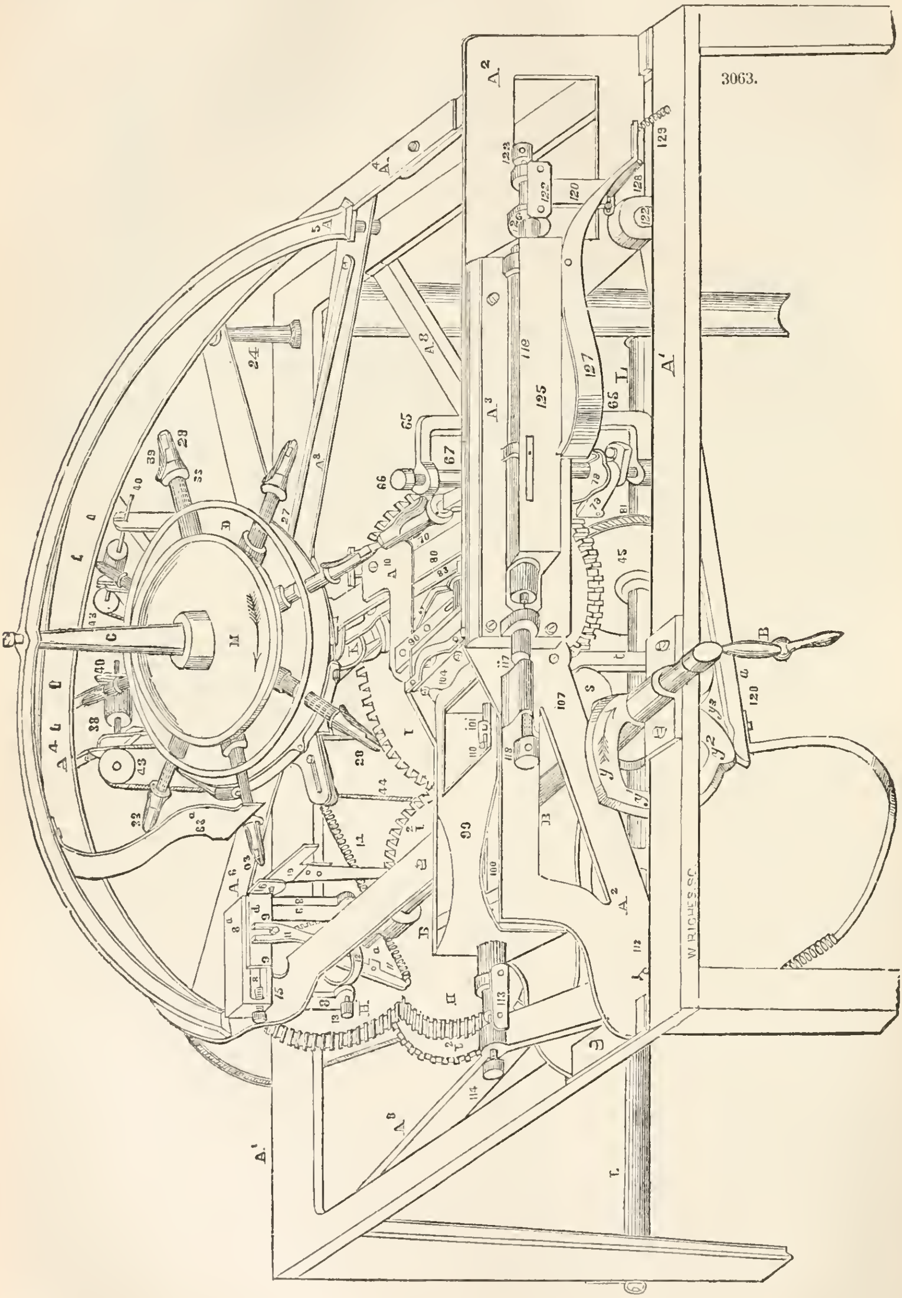
Of the driving-power.—The machine is put in motion through a driving-shaft F, which has its bearings formed in the portion A7 of the fixed frame, shown in Fig. 3064. The shaft F is placed at right angles to the main-shaft B, and both of said shafts are in a horizontal position in the same plane with each other.

On the outer end of the shaft F are fixed a fast pulley 1, a loose pulley 2, a fly-wheel 3, and a pulley 4, for driving the shaft L, which carries the pulleys 45 for driving the pointing mills, and on the inner end of said shaft F is fixed a bevel-pinion G. The aforesaid bevel-pinion G works into the bevel-wheel K, which is fixed on the shaft B, said wheel having four times the number of teeth of the pinion G, so that four revolutions of the driving-shaft F communicate one revolution to the shaft B. The horizontal shaft B is connected with the vertical shaft *e* by bevel and spur geering, so that both the said shafts revolve in the same time in the direction indicated by the arrows on the respective shafts, as is shown in Fig. 3063. The mitre bevel-wheel H1 on the shaft B works into the mitre bevel-wheel H2, which has its axis placed perpendicularly beneath the shaft B. On the axis of the bevel-wheel H2 is fixed a spur-wheel I2, which works into a similar spur-wheel fixed on the vertical shaft *c*.

The pulley 4, Fig. 3067, is connected by a belt to the pulley 5 on the shaft L, for the purpose of communicating an accelerated rotary motion to the shaft L. On the shaft L are the pulleys 45, which are respectively connected by bands 44 with the pulleys 43, Fig. 3063, on the arbors or spindles of the mills or revolving circular files 38, for the purpose of communicating the necessary rapid rotary motion to said mills, by which the points of the pins are ground and sharpened.

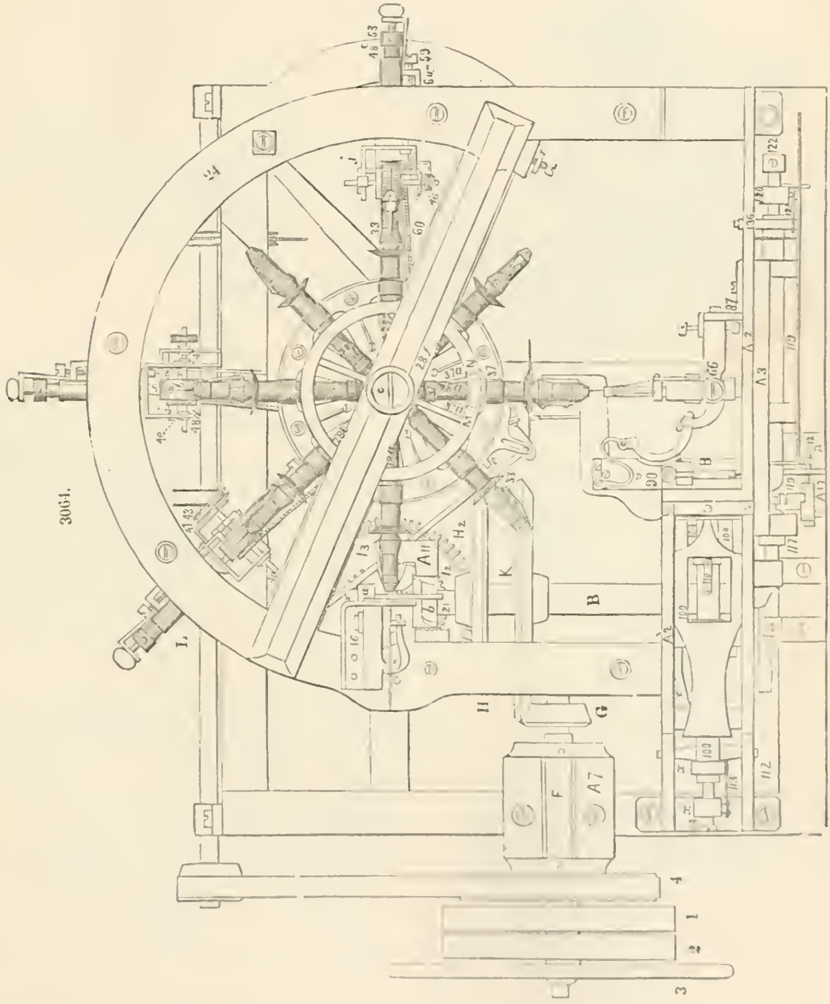
Of the feeding and cutting apparatus—Fig. 3069 is a perspective view of the combined apparatus for feeding in and cutting off the wire, with a portion of the semicircular horizontal part of the frame, to which the principal parts of said apparatus are attached. Other views of said apparatus are represented in Figs. 3063 and 3064. The fixed portion of the feeding apparatus consists of a horizontal part 8*a* and two arms, 8*b* and 8*c*, depending in a perpendicular direction from the under side of said horizontal portion. The horizontal portion 8*a* has an oblong opening through it, extending in a horizontal direction from within towards the shaft *c* outwards. The two vertical surfaces of said portion, 8*a*, are dressed straight and parallel with each other, and the two sides of the aforesaid oblong opening are also dressed straight and parallel with each other. A slide 9*d*, which rests against the front vertical face of the portion 8*a*, is connected through the said opening in 8*a* with a cap, which rests against the back vertical face of the portion 8*a*, and the portion by which the slide 9*a* is connected with the cap 9*b* is so formed and fitted into said opening as to allow said slide to move freely forward and backward, but not to turn or move in any other direction. The slide 9*a* has a stud 9*c* standing out horizontally at right angles to and near the centre of its face. There is a small hole made horizontally through said stud close to the face of the slide, through which, and also through an eye formed for the purpose, near each end of the slide, the wire is introduced in a horizontal direction from right to left. There is a steel cap 10 fitted by a hole in its centre on the stud 9*c*, behind which the wire is introduced as aforesaid, in the manner represented in Fig. 3069. The lever 11 of the feeder has a fork at its upper end to receive the stud 9*c*, and near its lower end it has the stud 11*a* and the plate 11*b* to receive the action of the feeder-cam *a*; the lever 11 is jointed to the extremities of the two arms 8*b* and 8*c* of the feeder-frame 8 *a b c* by the ring 12, and the four centre or pivot screws 13, Fig. 3069, so as to furnish said lever with two horizontal axes intersecting each other at right angles in the manner of a universal joint; by means of which the forked end of said lever is allowed to be alternately pressed against the cap 10 and then removed from it, at the same time that it has a reciprocating motion forward and backward, for the purpose of carrying forward the feeder 9*a* in the act of introducing the wire and then carrying said feeder back, in order to its introducing another portion of wire. The cam *a*, by which the movements and actions of the feeder are produced, is represented in Fig. 3069. Said cam *a* (revolving in the direction indicated by the arrow) acts by the face *a2* on its periphery against the stud 11*a* of the lever 11 to carry forward the feeder 9, and by the face 13, on its periphery, to retain said feeder for a short period in the advanced position to which it had been previously carried; the face *a3* of said cam being concentric with the axis B, on which said cam is fixed; said cam *a* has a rib or raised portion *a4* on its side, by which it acts against the plate 11*b* of the lever 11 to press the forked end of said lever against the cap 10 of the feeder, in order to grasp the wire in the act of feeding it into the machine. A spiral spring 14 is attached to the lower end of the lever 11, below its stud and plate aforesaid, and to some part of the fixed frame, so as to draw obliquely inward that end of said lever and to retract it as soon as the cam *a* recedes after having performed its aforesaid actions respectively on said stud 11*a* and plate 11*b*.

A gage-screw 15 is fitted into the exterior end of the portion 8*a* of the feeder-frame, against the point of which the slide of the feeder stops, when it is carried back in the manner above described by the spring 14. By turning the aforesaid gage-screw 15 out or in, the length of the portion of wire introduced at each operation of the feeder may be graduated according to the proposed length of the pin



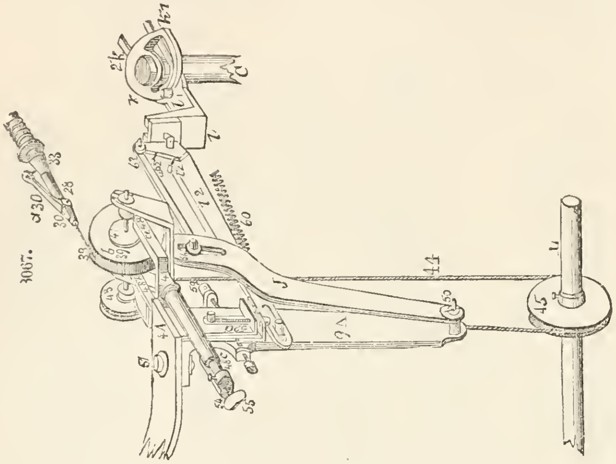
When in the rotation of the cam *a* its rib *a*1 comes against the plate 11*b* of the lever 11, it crowds the lower end of said lever back in the direction of the length of the shaft B, so as to press its upper or forked end against the cap 10, pressing said cap against the wire, so that the wire is embraced and firmly held between said cap 10 and the face of the slide 9, and while the wire continues to be held the rising face on the periphery of the cam *a* comes against the stud 11*d* of the lever 11, crowding the lower end of said lever back in a direction at right angles to the length of the shaft B, and consequently carrying forward the upper or forked end of said lever, which, holding on to the stud 9*e* of the feeder by the fork in its end, carries forward the feeder, holding the wire in the manner above described.

In the regular operation of the machine, where the wire is carried forward by the feeder, the end of the wire enters one of the pointing chucks hereinafter described, which is in readiness to receive it; and in order to insure the entrance thereof a guide is placed near the extremity of said chuck: said guide is in the form of a hollow cone, having its apex directed towards the chuck, and its base towards the feeder. There must be a perforation at the apex of the cone to allow the wire to pass through in a straight line from the feeder to the chuck; and there must also be an opening made in its side to allow the chuck to carry the pin, or wire, out laterally: said guide may be attached to the cutter-stand or any convenient part of the fixed frame.



3064.

Before the concentric face *a*3, before described, of the cam *d*, leaves the stud 11*d*, the rib *d*1 of said cam will leave the plate 11*b*, so as to allow the spring 14 to retract the forked end of the lever 11 from the cap 10; and afterwards said high concentric part of the cam *a* passing away from the stud 11*e*, will leave the feeder free to be carried back by the action of the spring 14, till it is stopped by coming against the gage screw 15. The apparatus for cutting off the wire, and also for holding it after it has been introduced by the feeder, while the feeder is going back and renewing its grasp on the wire, in order to introduce another succeeding portion of wire, is supported by and consists in part of an adjustable frame-piece or stand, which is fastened by a screw on the top of the portion A1 of the fixed frame, close behind the frame 8 of the feeding apparatus, as represented in Fig. 3062. At the interior extremity of the stand 16 it has a portion 16*a* which extends across in front of the interior extremity of the portion 8*d* of the feeder-frame, furnishing in front towards the vertical shaft *c* (or the centre of the revolving table D) a vertical plain surface at right angles to the line in which the wire is fed into the machine. To the aforesaid vertical face of the portion 16*d* of the cutter-stand is fitted a steel plate This plate has a hole through it of a suitable size and in a proper situation to let the wire pass through it in a straight line from the feeder to the pointing chuck, into which chuck the wire enters, previous to a portion of it being cut off to form a pin. A steel cutter 18 is fitted into a groove or socket in the cutter-stock 19, so as to admit of its being adjusted and fixed therein by screws, and to cause the cutting edge of said cutter to lie flat against the plate. The cutter-stock 19 is jointed to the vertical portion 16*d* of the cutter-stand by means of a centre-screw 22, so that 19 forms the short arm of which 19*d* forms the long arm.



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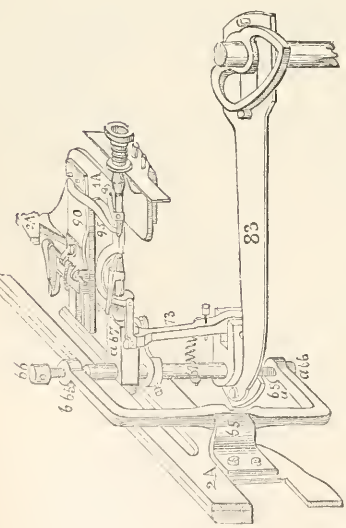
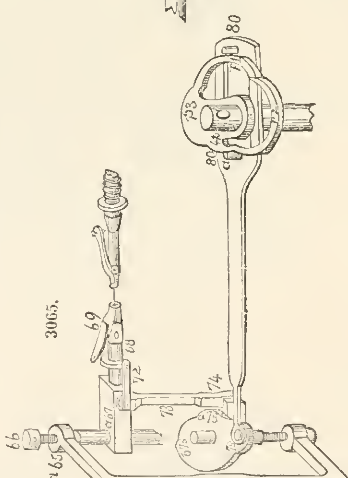


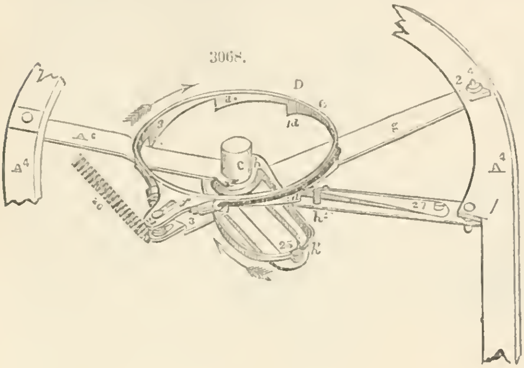
3066.



3065.

A small projection or plate 19*c* extending from the edge of the arm 19*d* of said lever rests upon the periphery of the cutter-cam *b*, and a stud standing out laterally from said arm 19*d* at right angles to the plane of its motion on its centre 22, rests against the side of said cam *b*, on which side the acting parts of said cam are formed. The cam *b* is circular and concentric with the shaft B on which it is fixed, and has its acting parts formed on the side of it next to the aforesaid stud of the lever 19. *b*1 is a recess or low part, which is connected by an inclined portion at one of its extremities to the raised part *b*2, and at its other extremity to the tooth or pivot *b*3; the portion or face *b*2 is a plain surface coinciding with the plane in which the cam *b* revolves; and the tooth *b*3 is a wedge-shaped projection raised upon one extremity of the face *b*2. A spiral spring 235, which connects the extremity of the arm 19*d* with the fixed frame, serves to draw said arm in a direction contrary to that in which it is moved by the action of the cam *b*, and to retract the cutter immediately after its action in cutting off the wire. The cam *b* must be adjusted on the shaft B, in reference to the feeder cam *d*, so that its recess or low part *b*1 will be opposite the stud of the lever 19 during the time in which the said cam *d* is engaged in carrying forwards the feeder to feed in the wire; and while the cam *d* continues to hold the feeder in its advanced position, and before the feeder relaxes its hold upon the wire, in the manner before described, the face *b*2 of the cutter-cam must arrive at the stud of the lever 19, so as to cause the cutter 18 to close upon the wire and hold it without cutting it off; and while the face *b*2 of the cutter-cam is passing the stud, and before the tooth *b*3 reaches said stud, the feeder must relax its grasp on the wire; and then before the feeder begins to advance, and while it remains stationary in its retracted position, the tooth *b*3 of the cutter-cam must pass the stud, by which the cutter 18 will be suddenly further advanced to cut off the wire close to the face of the plate, against which the flat side of the cutter plays, and by the reaction of the spring 235 the stud will be drawn against the

3068.



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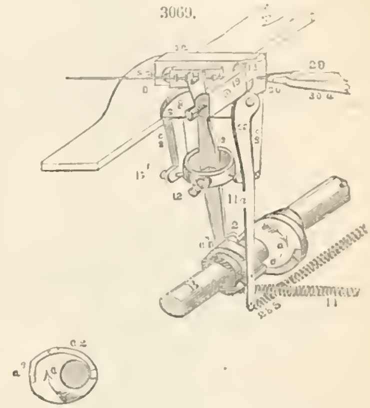
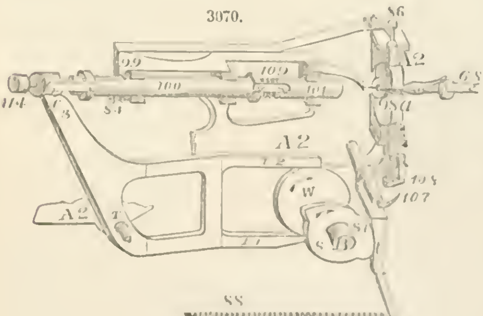


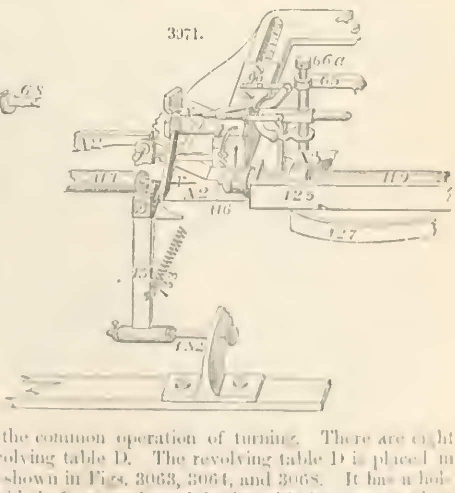
low part *b*1 of the cutter-cam, so as to retract the cutter 18 out of the way, to allow the feeder to introduce another succeeding portion of wire. The length of wire fed in and cut off at each operation of the feeding and cutting apparatus is equal to the length of the pin to be made, and a portion of wire sufficient, by being raised or upset and properly compressed between suitable dies, to form the head of the pin.

Of the pointing-chucks and revolving table, and other parts accessory to their movements.—In the process of sharpening the points of the pins made by the machine herein described, the piece of wire is held and turned round by a chuck formed at the extremity of a revolving axis, in a manner similar to that in which a piece of work is held and turned in the chuck of a turning-lathe; but the end of the wire is reduced to the requisite tapering and pointed form by the grinding action of circular revolving

3070.



3071.



files, and not by the point or edge of a tool, as in the common operation of turning. There are eight such chucks, mounted in suitable bearings on a revolving table D. The revolving table D is placed in a horizontal position on the vertical shaft *c*, as is shown in Figs. 3063, 3064, and 3068. It has a hole in its centre fitted to said shaft, so as to allow said shaft to revolve while the table is at rest, and to allow said table to move round said shaft on its axis or centre of motion, when said table moves round by an intermitting motion. The upper horizontal face of said table furnishes plane surfaces to which are fitted and fastened, by screws, the bearings or boxes of the pointing-chucks 28, and said table has on its back or under side a hub, which rests upon a collar on the shaft *c*, and which is also fitted into a hole in the middle of the girt A6. It has on its under side, near its circumference, a rim extending ver[illegible] tically downwards, which is divided at its lower edge into eight equal divisions or teeth, similar to saw teeth, as is shown in Fig. 3068. In said Fig. 3068 the above-described rim is represented in section with all the other parts of the table removed, in order to show the aforesaid divisions or teeth, which are marked in the figure D 1 to 8.

There is a semicircular groove formed around the circumference of the aforesaid rim, above the bottoms of its teeth, to receive the clip-band *e f*. The clip-band *e f* is formed of a band of round iron or wire of a size to fit the aforesaid groove. The ends of said rod *e* (being straight) are passed through eyes in the yokes *f*, and are secured in that situation by nuts which are screwed on to said ends of the

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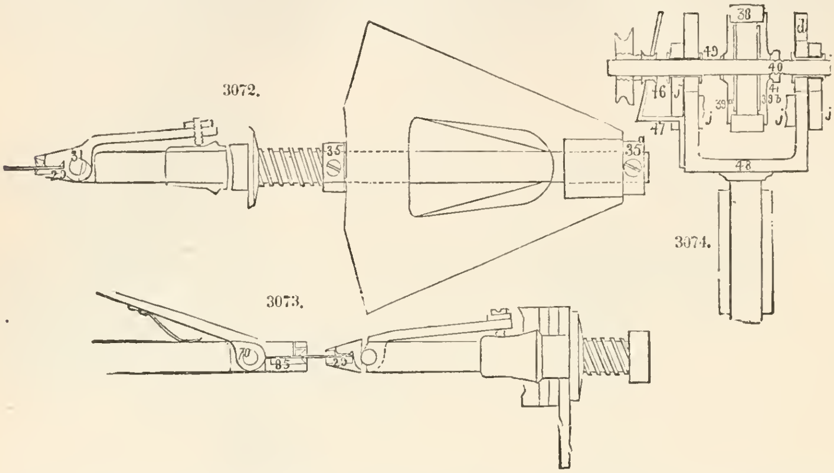

rod *e*. The yoke *f* is placed in a horizontal position, and presents towards the table D a concave side, which is fitted to the groove in the rim of said table. Said yoke *f* has a vertical shot formed through it, the longitudinal centre of which is in continuation of a right line extending horizontally outwards from the centre of the axis *c*. By means of a stud 23 which extends upwards in a perpendicular direction through the aforesaid shot in yoke *f*, from the end of the lever *g* to which said stud is attached, a connection is formed between said yoke *f* and said lever *g*, so that when said lever *g* is moved horizontally

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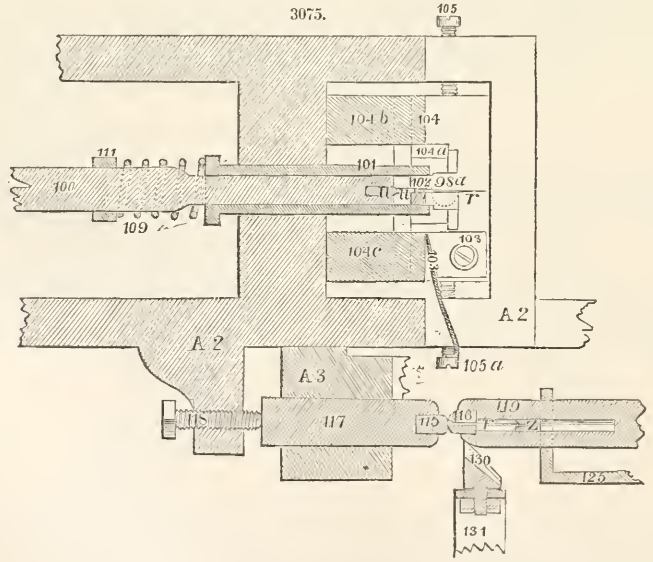

to the right or left hand, it communicates a corresponding movement to said yoke. The lever *g* is connected by a vertical axis 24 to the fixed frame, as is shown also at 24 in Figs. 3063 and 3064; it has a broad part in which is a slot or opening of sufficient dimensions to allow the shaft *c* to pass through it, and to allow said lever to move forwards and backwards to a certain extent around its axis 24. A stud 25 is attached to the broad part of the lever *g*, in a suitable position to receive the action of the cam *h*, which is fixed on the vertical shaft *c*. The cam *h* has two eccentric faces on its periphery, viz., the longer face *h*1 which extends around three-fourths of the circle of the periphery; and the shorter face $h2$ which occupies one-fourth of said circle. A spring 26 connects the end of the lever g with the fixed frame, and draws said lever in such a direction as to incline the stud 25 of said lever inwards towards the vertical axis c.

In the machine herein described the cam h is placed beneath the lever g, and the stud 25 is affixed to the under side of said lever. In Fig. 3068 said cam h is represented above said lever, and the stud 25 affixed to its upper side, in order to show the action of said cam upon said stud.

There is a spring-catch 27 attached to the girt A6, which allows the table D to move round freely in the direction of the arrow, by yielding under the inclined faces of the teeth D of said table; but which prevents or arrests a retrograde movement of said table, by springing up behind the perpendicular faces of said teeth and catching against one of said perpendicular faces if an effort be made to move said table in a retrograde direction. The table moves forwards around the axis c in the direction indicated by the arrow marked on the rim d of said table, as shown in Fig. 3068, one-eighth of a revolution at each revolution of the shaft c. It occupies one-fourth of the time of a revolution of the shaft c in making said movement, and it remains at rest during three-fourths of the time of a revolution of said shaft c. The aforesaid alternate periods of motion and rest of the table D are produced by the above-described combination, which is marked in the figures referred to in the foregoing description with the following letters and figures: C, D, d, (1 to 8,) c, f, 23, g, 24, A1, A4, A6, 27h, (1 to 3,) 25, 26, in the following manner: that is to say, supposing all the parts of the aforesaid combination which are shown in the figures to be in the positions relatively to each other in which they are represented, and that the shaft c and the cam h are in the act of revolving in the direction indicated by the arrows; the face $h1$ of the cam h advancing against the stud 25 of the lever g, will carry back said lever, and with it the clip-band fe; but the table D will be prevented from moving back along with the clip-band ef in consequence of the tooth of said table being arrested by the catch 27; consequently the clip-band will slip round in the groove of said table D, and said table D will remain stationary.

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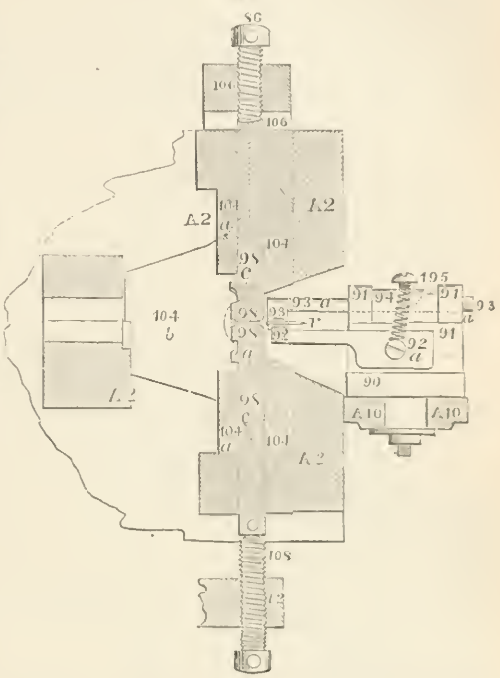
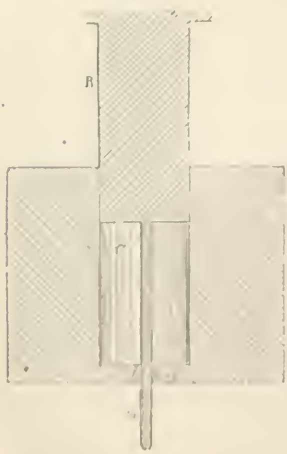


PIPE MACHINE, LEAD. Until 1820 lead pipe was manufactured by casting and drawing something similar to the process of wire-drawing. In 1820, Burr took out a patent in England on the following plan: (in these figures, so much of the machine is represented as is essential

3077



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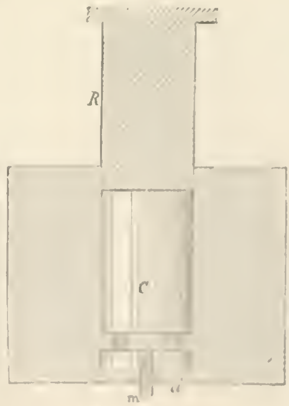

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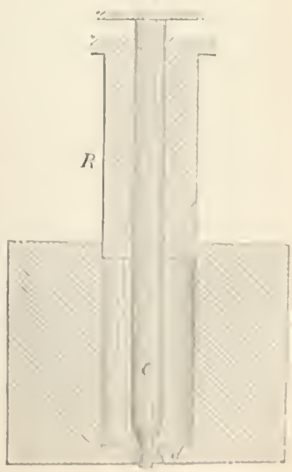
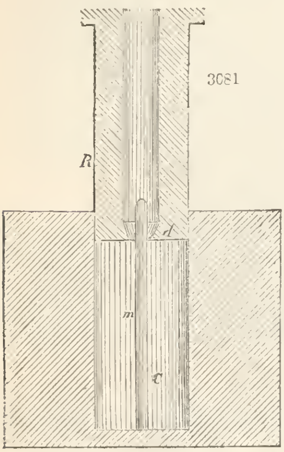


to illustrate the principle of its action, without aiming at accuracy of detail.) A hollow cylinder C, of cast iron (fig. 3077) is furnished with a steel die *d*, of the shape and dimensions of the outside of the proposed pipe. A solid piston or ram R, of cast iron, fits this hollow cylinder as snugly as possible, without friction. To the bottom of this piston is affixed a steel mandril or core *m*, of the length of the cylinder, and of the diameter of the bore of the proposed pipe. When this piston is withdrawn from the cylinder, the point of the mandril is just within the die at the bottom of the cylinder. The cylinder is then filled with melted lead, which is allowed to set. By the action of a hydrostatic press the cylinder is then raised between guides, or the piston lowered (it matters not which), and the solid lead is forced by the action of the piston through the die, and enveloping the mandril runs off the point of the latter as lead pipe. This action continues until the piston has reached the bottom of the cylinder, when the mandril projects nearly its whole length through the bottom of the cylinder.

This was a great improvement on the old method of drawing, but yet accompanied with some objections, one of the most prominent being that, for small pipe, the mandril lacked stiffness to preserve itself from derangement, and the pipe in consequence was irregular in its thickness.

To obviate this, Hanson took out a patent in Aug., 1837, the principle of which was, that the mandril was short, and instead of being fixed to the bottom of the piston or ram, as before, was fixed within the cylinder, and a few inches from the die to a plate or diaphragm, stretched across the cylinder *a* (fig. 3078). The mandril in this case being immovably fixed concentric with the die. To enable the lead to arrive at the die and mandril, this diaphragm or "bridge" was perforated by four large holes, shown in plan fig. 3079, through which the lead in a solid state was forced by the action of the ram, but united again after passing the bridge and before reaching the die and mandril point.



By this means, it is true, the irregularity of the action of the mandril in Burr's plan was avoided, but at a great expense of power, and the pipe made was inferior, the lead not uniting after passing the bridge so perfectly, but that the pipe manufactured by this machine would split at the points corresponding to the divisions of the "bridge."

To overcome this difficulty, as well as that of Burr's, was the object of the patent of Tateham, dated Oct., 1841, in which the piston is truly bored from end to end, and a larger mandril or shaft (fig. 3080) fitted within, nearly of the length of the cylinder, into the bottom of which is fixed the short core or mandril for the bore of the pipe, the mandril remaining as in Hanson's plan, fixed just within the die.

As the hollow piston descends* upon the lead (the mandril shaft rising meanwhile within it), the latter is forced around the shoulder of the mandril, and so through the die into pipe.

At first sight, and in model, this plan would appear to be very effectual, but in practice it is attended with some objections, the principal of which is the difficulty of preserving the smooth, and at the same time tight action of the hollow piston, and the mandril shaft moving within it.

It will be readily foreseen that the great power necessary for the manufacture of pipe, will force the lead between the mandril shaft and the bore of the piston, increasing the friction to a very great extent.

Cornell's improvements consist simply in making the pipe from that part of the lead subjected to the action of the power, and not to move the mass of compressed lead *through* the cylinder to the die. This is effected by making the piston or ram a die holder, and hollow, and affixing the mandril to the bottom of the cylinder, and extending it to the die in the piston bottom (fig. 3081). The effect is evident.

The instant the piston commences its movement, pipe is formed at the die, at one half the expenditure of power necessary when the mass of lead is moved through the cylinder.

PISÉ-WORK. A method of constructing very durable walls of kneaded earth. Any kind of earth that will sustain itself with a small slope, is adapted to the purpose; but that best suited to it is clay, containing small gravel of sufficient consistence to be dug with a spade. It is first well beaten, then screened to separate stones larger than a common hazel nut; after which, it is wetted sufficiently to enable it to retain the form given to it by kneading between the fingers. It is now fit for use, and in applying it to build a wall, a sort of movable box or mould is made for the intended wall, of deal planks put together with their joints ploughed, and tongued, and strengthened with clamps on the outside. These frames rest on cross pieces or putlocks, which pass through the thickness of the wall, and near the ends are mortices, into which are placed upright pieces, secured by wedges at the bottom, and tied with ropes. These uprights are set to the intended thickness of the wall, which is about 20 inches at bottom, and gradually diminishes upwards. The frames are steadied at the top by means of cross sticks or struts, and the ropes are made tight by twisting them with a small piece of wood placed between the folds. The frames being properly fixed, the earth is thrown in, and worked like concrete or mortar; to allow the putlocks to be readily withdrawn, the parts about them must be well wetted. In commencing a wall, the first frame is put at one of the extremities, and the end of the frame closed by planks secured by iron cramps; at the other part, where there is no end, the wall is to be sloped off at an angle of about 60°, for facility in joining on the next piece. In commencing the work, the bottom being well cleaned and sprinkled with water, the laborers bring the masons the prepared earth, and tread it with their feet into a bed 3 or 4 inches thick; they then ram it down with a rammer. In ram-

* For convenience, we assume that the piston descends in all these machines, as it matters but little in elucidating the principle whether the piston descends or the cylinder ascends, but the former method is more easily comprehended.

ming, it is turned round at each stroke, so as to make the work more compact, and unite it with that previously done. By means of the rammer, the first layer is reduced in thickness about one half, and on this compressed bed another layer is spread out, and beaten in the same manner, and so on, until the case is filled. The frame is then taken down, and moved further on, so that the plank entirely covers the inclined part. Lintels are placed over all the apertures, and the finished portions are left for some months to dry. The surface may then be coated with plaster, and the wall is finished.

Cob walls, as they are termed in Devonshire, resemble pisé-work; they are formed of clay, loam, and chopped straw, and are generally 2 feet thick, resting on brick or stone foundations, 3 or 4 feet above the level of the soil; they must be carried up at several times, and not be hurried. After each addition the sides are carefully pared down with an iron cob parer, which resembles a baker's peel. When dry, it is coated with fine stucco or plaster, and if kept dry at its top and foundation, it is very durable.

Walls similar to pisé-work are sometimes made in this country with cement of lime or cement mortar, and small stones or screenings; the interior plastering being laid directly on the walls, the outer being usually left in its rough cast state; the timbers for the floors are inserted as the wall progresses.

PISTOL. See GUN.

PISTON. See PUMP—ENGINE, ETC.

PLANES AND CHISELS.* If we drive an axe, or a thin wedge, into the centre of a block of wood, it will split the same into two parts through the natural line of the fibres, leaving rough uneven surfaces, and the rigidity of the mass will cause the rent to precede the edge of the tool. The same effect will partially occur, when we attempt to remove a stout chip from off the side of a block of wood with the hatchet, adze, paring or drawing knife, the paring chisel, or any similar tool. So long as the chip is too rigid to bend to the edge of the tool, the rent will precede the edge; and with a naked tool, the splitting will only finally cease, when the instrument is so thin and sharp, and it is applied to so small a quantity of the material, that the shaving can bend or ply to the tool, and then only will the work be *cut*, or will exhibit a true copy of the smooth edge of the instrument, in opposition to its being *split* or *rent*, and consequently showing the natural disruption or tearing asunder of the fibres.

The axe or hatchet with two bevils, is intended for hewing and splitting, when applied to *paring* the surface of a block, must be directed at the angle, which would be a much less convenient and less strong position than that of the *side hatchet* with only one chamfer; but for paring either a very large or a nearly horizontal surface, the side hatchet in its turn is greatly inferior to the adze, in which the handle is elevated at some 60 or 70 degrees from the ground, the preference being given to the horizontal position for the surface to be wrought. The instrument is held in both hands, whilst the operator stands upon his work in a stooping position, the handle being from twenty-four to thirty inches long, and the weight of the blade from two to four pounds.

The chisel admits of being very carefully placed, as to position, and when the tool is strong, very flat, and not tilted up, it produces very true surfaces, as seen in the mouths of planes. The chisel when applied with *percussion*, is struck with a wooden mallet, but in many cases it is merely *thrust* forward by its handle. The *paring-knife*, exhibits also a peculiar but most valuable arrangement of the chisel, in which the thrust obtains a great increase of power and control; and in the *drawing-knife*, the narrow transverse blade and its two handles form three sides of a rectangle, so that it is actuated by *traction*, instead of by violent percussion or steady thrust.

The chisel, when inserted in one of the several forms of stocks or guides, becomes the plane, the general objects being to limit the extent to which the blade can penetrate the wood, to provide a definitive guide to its path or direction, and to restrain the splitting in favor of the cutting action. In general, the sole or stock of the plane is in all respects an accurate counterpart of the form it is intended to produce. Although convex surfaces, such as the outside of a hoop, may be wrought by any of the straight planes, applied in the direction of a tangent, it is obvious the concave plane would be more convenient. For the inside of the hoop, the radius of curvature of the plane, must not exceed the radius of the work. For the convenience of applying planes to very small circles, some are made very narrow or short, and with transverse handles, such as the plane for the hand-rails of staircases. The sections of planes are also either straight, concave, convex, or mixed lines, and suited to all kinds of specific mouldings, but we have principally to consider their more common features, namely, the circumstances of their edges and guides; first, of those used for flat surfaces, called by the joiners *bench planes*, secondly, the *grooving* planes; and thirdly, the *moulding* planes. The various surfacing planes are nearly alike, as regards the arrangement of the iron, the principal differences being in their magnitudes. Thus the maximum width is determined by the average strength of the individual, and the difficulty of maintaining with accuracy the rectilinear edge. In the ordinary bench planes the width of the iron ranges from about 2 to 2½ inches.†

The lengths of planes are principally determined by the degree of straightness that is required in the work, and which may be thus explained. The joiner's plane is always either balanced upon *one* point beneath its sole, or it rests upon *two* points at the same time, and acts by cropping off these two points, without descending to the hollow intermediate between them. It is therefore clear, that by supposing the work to be full of small undulations, the spokeshave, which is essentially *a very short plane*, would descend into all the hollows whose lengths were less than that of the plane, and the instrument is therefore commonly used for curved lines. But the greater the length of the plane, the more nearly would its position assimilate to the general line of the work, and it would successively obliterate the minor errors or undulations; and provided the instrument were itself *rectilinear*, it would soon impart that character to the edge or superficies submitted to its action. The following table may be considered to contain the ordinary measures of surfacing planes.

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* Holtzapffel.

† The "iron," is scarcely a proper name for the *plane-iron*, which is a *cutter* or *blade*, composed partly of iron and steel; but no confusion can arise from the indiscriminate use of any of these terms.

Names of Planes.	Lengths in inches.	Widths in inches.	Widths of irons
Modelling Planes, like Smoothing Planes	1 to 5	1/4 to 2	3-16 to 1 1/4
Ordinary Smoothing Planes	6 1/2 to 8	2 5/8 to 3 1/3	1 5/8 to 2 3/8
Rebate Planes	9 1/2	5/8 to 2	5/8 to 2
Jack Planes	12 to 17	2 1/2 to 3	2 to 2 1/4
Panel Planes	14 1/2	3 1/2	2 1/2
Trying Planes	20 to 22	3 1/4 to 3 5/8	2 3/8 to 2 1/2
Long Planes	24 to 26	3 3/4	2 3/4
Jointer Planes	28 to 30	3 3/4	2 3/4
Cooper's Jointer Planes	60 to 72	5 to 5 1/4	3 1/2 to 3 3/4

The succession in which they are generally used, is the jack plane for the coarser work, the trying plane for finer work and trying its accuracy, and the smoothing plane for finishing.

The *mouth* of the plane is in the narrow aperture between the face of the iron, and the *wear*, or face of the mortise; the angle between these should be as small as possible, in order that the wearing away of the sole, or its occasional correction, may cause but little enlargement of the mouth of the plane; at the same time the angle must be sufficient to allow free egress for the shavings, otherwise the plane is said to *choke*. In all the bench planes the iron is somewhat narrower than the stock, and the mouth is a wedge-formed cavity; in some of the narrow planes the cutting edge of the iron extends the full width of the sole, as in the rebate plane.

The amount of force required to work each plane is dependent on the angle and relation of the edge, on the hardness of the material, and on the magnitude of the shaving; but the required force is in addition greatly influenced by the degree in which the shaving is *bent* for its removal in the most perfect manner. The spokeshave cuts perhaps the most easily of all the planes, and it closely assimilates to the penknife; the angle of the blade is about 25 degrees, one of its planes lies almost in contact with the work, the inclination of the shaving is slight, and the mouth is very contracted. The spokeshave works very easily in the direction of the grain, but it is only applicable to small and rounded surfaces, and cannot be extended to suit large flat superficies, as the sole of the plane cannot be cut away for such an iron, and the perfection of the mouth is comparatively soon lost in grinding the blade. Plane irons are usually ground at the angle of 25°, and sharpened on the more refined oilstone at 35°, so as to make a second bevil or slight facet; the irons so ground are placed at the angle of 45°, or that of *common pitch;* it therefore follows, that the ultimate bevil, which should be very narrow, lies at an elevation of 10° from the surface to be planed. In the planes with double irons, the top iron is not intended to cut, but to present a more nearly perpendicular wall for the ascent of the shavings, the top iron more effectually *breaks* the shavings, and is thence sometimes called the *break*-iron. Now therefore, the shaving being very thin, and constrained between two approximate edges, it is as it were bent out of the way to make room for the cutting edge, so that the shaving is removed by absolute *cutting*, and without being in any degree split or rent off.

Some variation is made in the angles at which plane irons are inserted in their stocks. The spokeshave is the lowest of the series, and commences with the small inclination of 25 to 30 degrees; and the general angles, and purposes of ordinary planes are nearly as follows. *Common pitch*, or 45 degrees from the horizontal line, is used for all the bench planes for deal and similar soft woods. *York pitch*, or 50 degrees from the horizontal, for the bench-planes for mahogany, wainscot, and hard or stringy woods. *Middle pitch*, or 55 degrees, for moulding-planes for deal, and smoothing planes for mahogany, and similar woods. *Half pitch*, or 60 degrees, for moulding planes for mahogany, and woods difficult to work, of which bird's-eye maple is considered one of the worst.

Boxwood, and other close hard woods, may be smoothly *scraped*, if not cut, in any direction of the grain, when the angle constituting the pitch entirely disappears; or with a common smoothing-plane, in which the cutter is perpendicular, or even leans slightly forward; this tool is called a *scraping plane*, and is used for scraping the ivory keys of piano-fortes, and works inlaid with ivory, brass, and hard-woods; this is quite analogous to the process of turning the hard woods. The cabinet-maker also employs a scraping-plane, with a perpendicular iron, which is grooved on the face, to present a series of fine teeth instead of a continuous edge; this, which is called a *toothing plane*, is employed for roughing and *scratching* veneers, and the surfaces to which they are to be attached, *to make a tooth* for the better hold of the glue. The smith's-plane for brass, iron, and steel, has likewise a perpendicular cutter, ground to 70 or 80 degrees; it is adjusted by a vertical screw, and the wedge is replaced by an end screw and block.

It is well known that most pieces of wood will plane better from the one end than from the other, and when such pieces are turned over, they must be changed end for end likewise. The plane working *with the grain*, would cut smoothly, as it would rather press down the fibres than otherwise; whereas, *against the grain*, it would meet the fibres cropping out, and be liable to tear them up. The workman will apply the smoothing-plane at various angles across the different parts of such wood according to his judgment; in extreme cases, where the wood is very curly, knotty, and cross-grained, the plane can scarcely be used at all, and such pieces are finished with the steel scraper. This simple tool was originally a piece of broken window-glass, and such it still remains in the hands of some of the gun-stock makers; but as the cabinet-maker requires the rectilinear edge, he employs a thin piece of saw plate. The edge is first sharpened at right angles upon the oilstone, and it is then mostly burnished, either square or at a small angle, so as to throw up a trifling burr, or wire-edge. The scraper is held on the wood at about 60°, and as the minute edge takes a much slighter hold, it may be used where planes cannot be well applied. The scraper does not work so smoothly as a plane in perfect order upon ordinary wood, and as its edge is rougher and less keen, it drags up some of the fibres, and leaves a minute roughness, interspersed with a few longer fibres.

We may plane *across the grain* of hard mahogany and boxwood with comparative facility, as the fibres are packed so closely, like the loose leaves of a book when squeezed in a press, that they may be cut in all directions of the grain with nearly equal facility, both with the flat and moulding planes. But the weaker and more open fibres of deal and other soft woods, cannot withstand a cutting edge applied to them *parallel with themselves*, or laterally, as they are torn up, and leave a rough unfinished surface. The joiner uses therefore, *for deal and soft woods*, a very keen plane of low pitch, and slides it across obliquely, so as to attack the fibre from the one end, and virtually to remove it in the direction of its length; so that the force is divided and applied to each part of the fibre in succession. The moulding planes cannot be thus used, and all mouldings made in deal, and woods of similar open soft grain, are consequently always planed lengthways of the grain, and added as separate pieces. As however many cases occur in carpentry, in which rebates and grooves are required directly across the grain of deal, the obliquity is then given to the *iron*, which is inserted at an angle, as in the skew-rebate and fillister, and the stock of the plane is used in various ways to guide its transit.

Moulding planes.—All the planes hitherto considered, whether used parallel with the surfaces as in straight works, or as tangents to the curves as in curved works, are applied under precisely the same circumstances as regards the angular relation of the mouth, because the edge of the blade is a right line parallel with the sole of the plane; but when the outline of the blade is curved, some new conditions arise which interfere with the perfect action of the instrument. It is now proposed to examine these conditions in respect to the semicircle, from which the generality of mouldings may be considered to be derived.

A small central portion may be considered to be a horizontal line; two other small portions may be considered as parts of vertical dotted lines, and the intermediate parts of the semicircle merge from the horizontal to the vertical line.

The reason why one moulding plane figured to the half-round cannot, under the usual construction, be made to work the vertical parts of the moulding with the same perfection as the horizontal, exists in the fact, that whereas the ordinary plane iron presents an angle of some 45 to 60 degrees to the *sole* of the plane, which part is meant to cut, it presents a right angle to the *side* of the plane, which part is not meant to cut. Thus if the parts of the iron of the square rebate plane, which protrude through the sides of the stock, were sharpened ever so keenly, they would only *scrape* and not *cut*, just the same as the scraping plane with a perpendicular iron. When, however, the rebate plane is meant to *cut at the side*, it is called the *side-rebate plane*, and its construction is then just reversed, that is, the iron is inserted perpendicularly to the sole of the plane, but at an horizontal angle, or *obliquely to the side of the plane*, so that the cut is now only on the one side of the plane, and which side virtually becomes the sole. A second plane sloped the opposite way, is required for the opposite side, or the planes are made in pairs, and are used for the sides of grooves, and places inaccessible to the ordinary rebate plane. The square rebate plane, if applied all around the semicircle, would be everywhere effective so long as its shaft stood as a radius to the curve, as then the angle of the iron would be in the right direction in each of its temporary situations. But in this mode a plane to be effective throughout, demands either numerous positions of the plane, or an iron of such a kind as to combine these several positions. Theoretically speaking therefore, the face of the cutter suitable to working the entire semicircle or bead, would become a cone, or like a tube of steel bored with a hole of the same diameter as the bead, turned at one end externally like a cone, and split in two parts.

As all the imperfections in the actions of moulding-planes occur at the vertical parts, there is a general attempt to avoid these difficulties by keeping the mouldings flat, or nearly without vertical lines. For example, concave and convex planes, called *hollows and rounds*, include generally the fifth or sixth, sometimes about the third of the circle; and it is principally in the part between the third and the semicircle that the dragging is found to exist; and therefore, when a large part of the circle is wanted, the plane is applied at two or more positions in succession. In a similar manner large complex mouldings often require to be worked from two or more positions with different planes, even when none of their parts are undercut, but in which latter case this is of course indispensable. And in nearly all mouldings the plane is not placed perpendicularly to the moulding, but at an angle so as to remove all the nearly vertical parts, as far towards the horizontal position as circumstances will admit.

Planing Machines for Wood.—In using hand-tools, the instrument rests immediately upon the face of the work under formation; and in repeating any one result, the same careful attention is again required in every successive piece. But in the machines acting by cutting, the accuracy is ensured far more readily, by running either the work or the tool, upon a straight slide, an axis, or other guide, the perfection of which has been carefully adjusted in the first formation of the machine; and the slide or movement copies upon the work, its own relative degree of perfection. The economy of these applications is therefore generally very great, and they are frequently most interesting, on account of the curious transitions to be observed from the hand processes to the machines, in some cases with but little, in others with considerable change in the general mode of procedure.

The first planing machine for wood is supposed to have been that invented by General Bentham, who took out a patent for it in 1791; it was based on the action of the ordinary plane, the movements of which it closely followed. This contrivance reduced the amount of skill required in the workman, but not that of the labor; it appears to have been but little used. The board to be planed was sometimes laid on a bench, at other times fixed by long cheeks having teeth, which penetrated its edges; the iron of the plane extended the full width of the board, and the stock of the plane had slips to rest on the bench and check the cutting action, when the board was reduced to the intended thickness.

For feather-edged boards, the two slips were of unequal thickness; for those intended to be taper in their length, the guide rails had a corresponding obliquity, and were fixed to the bench. The plane was moved to and fro by a crank, it was held down to its work by weights, and the plane was lifted up in the back stroke to remove the friction against the cutter.

The *scale-board plane*, abbreviated into *scabbard plane*, for cutting off the wide chips used for making hat and bonnet boxes, is in like manner, a plane exceeding the width of the board; it is loaded with weights, and dragged along by a rope and windlass, the projection of the iron determines the thickness of each shaving or scale-board. This construction is also reversed, by employing a fixed iron, drawing the wood over it, and letting the scale-board descend through an aperture in the bench; each of these modes is distinctly based on the common plane.

The late Mr. Joseph Bramah took out a patent in 1802 for a planing machine for wood; one of which may be seen in the Gun Carriage Department, Woolwich Arsenal. The timber is passed under a large horizontal wheel, driven by the steam engine at about ninety revolutions per minute; the face of the wheel is armed with a series of twenty-eight gouges, placed horizontally and in succession around it; the first gouge is a little more distant from the centre, and a little more elevated than the next, and so on. The finishing tools are two double irons, just like those of the joiner, but without the advantage of the mouth.

In France, planing machines for wood were patented as early as 1817–18 by M. Roquin, and M. Manneville in 1835. The first was intended for planing, grooving, and tonguing, and moulding for the purpose of ornamant. The Board was placed on a platform or caariage, adjustable by screws to suit different thicknesses, to which the boards or planks are desire to be reduced. The planes were "cylindrical rotating planes." In Manneville's, feed rollers were introduced, and the tonguing and grooving was performed by circular saws.

In this country the most successful machine for planing wood, is the invention of Mr. Woodworth, patented in 1828, and reissued in 1845; it consisted of a rotary cylinder on which were fastened the blades or cutters, placed above or laterally to a carriage on which was placed the board to be planed, which was moved forward by rack and pinion. The cylinder revolved opposed to the movement of the board, and rollers were introduced bearing upon the upper surface, so as to prevent the board being drawn up to the cutter. The following is the claim of the reissue patent:

"What is claimed therein as the invention of Wm. Woodworth, deceased, is the employment of rotary planes substantially such as herein described, in combination with rollers, or any analogous device to prevent the boards from being drawn up by the planes, when cutting upwards; or from the reduced or planed to the unplaned surface as described."

And afterwards,

"The effect of the pressure rollers in these operations, being such as to keep the boards, etc., steady, and prevent the cutters from drawing the boards towards the centre of the cutter wheels, whilst it is moved through by machinery. In the planing operation the tendency of the plane is, to lift the boards directly up against the rollers; but in the tonguing and grooving the tendency is to overcome the friction occasioned by the pressure of the rollers."

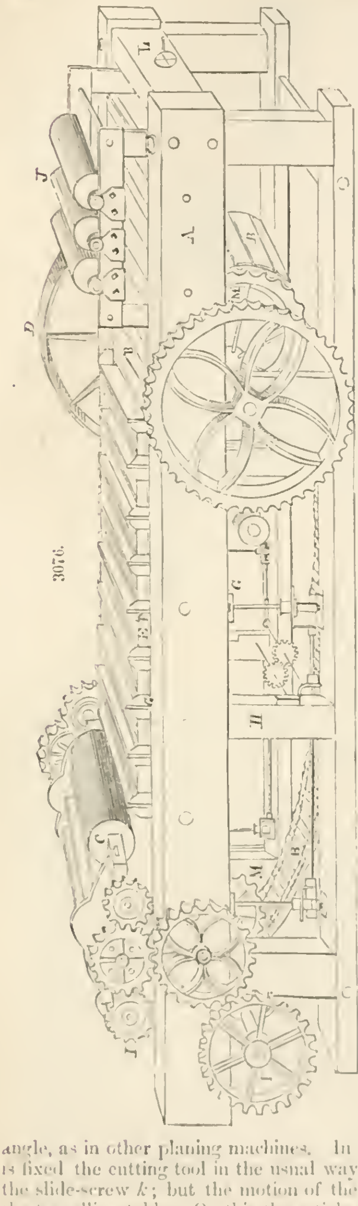
Woodworth also united the tonguing and grooving machine to the planer, by which both operations were performed at one and the same time.

Woodworth's planer has been a fruitful source of litigation. The only novelty seems to have been in the pressure rollers to keep down the board, and the union of the tonguing and grooving with the planing.

Previous to the machine of Woodworth, Hill's machine was constructed, consisting of a rotary cutter similar to Woodworth's, but placed beneath the bench; the board was pressed down on the bench by means of rollers; in this machine boards were planed but not reduced to an uniform thickness. To obviate this, an improvement was made on this machine in 1850 by N. G. Norcross. He has made the cutting cylinder movable, vertically, which it was not before, and has connected it with his rest, that is with the pressure roller, so that when the latter is forced upwards by the increased thickness of the board, it draws the cutter upwards with it, which thereby is made to cut just as much more from the under side of the board, as the roller is pressed up by the increased thickness. By this concontrivance the edge of the cutter is kept in a fixed relation to the rest, or in other words, the pressure roller, the space between them being always the same, whereas in Hill's, and also in Woodworth's the edge of a knife had a fixed rotation to the bed, and not to the pressure roller. To obviate the use of the rotary cutter and continuous feed, which by many were supposed to be inventions of Woodworth and covered by his patent, many machines with stationary cutters or planes were made, beneath which the board to be planed was forced, one of which is here introduced; but the rotary cutter is by far the simplest and most economical in regard to power. The Woodworth planer still continues to be the one in common and general use for the planing of boards or thin plank, but for the planing of timber, the Daniells' planer is generally preferred. This machine consists essentially of two arms revolving parallel with the face of the timber to be planed, near the extremities of which are inserted two narrow planes or gouges, the timber lies upon a carriage, and the feed is effected by a rack and pinion. Upon the shaft to which the arms are attached, is a long drum or pulley, to which motion is given by means of a narrow belt; the shaft can be raised or depressed, even whilst the machine is in operation, by which means a thinner or thicker chip or shaving may be taken off, or successive shavings may reduce the timber to the thickness required. A machine somewhat similar to this, is sometimes used for the planing of iron, but it does not leave a finished surface.

Tonguing and grooving is usually performed by revolving cutters; the cutter irons being generally of the hook form or duck bill. The same form of cutter is used in setting mouldings; they are roughed by cutters and then forced through stationary irons with cutting edges, corresponding in form to the moulding required. Wave mouldings, such as are used in cars and on furniture, are finished on a machine somewhat similar to the iron planer, the wave motion being given by a pattern on the carriage, which in its passage vibrates an arm connected with the tool.

Planing Machine, Wood. J. P. Woodbury's patent. A Fig. 3076 is the frame that contains the machinery. B is the travelling platform, which is formed of lags, and linked together similar to some of the well-known horse powers, the upper part of which runs on ways or rollers, which sustain it perfectly level. C is the rollers over the platform, which serve to aid the lower platform to carry the board under the stationary cutters. D is the pulley where the power is to be applied to drive the board through the machine. It operates and turns the chain-wheels and shafts M, thereby moving the platform, and making an endless feeding power. E is the stocks or cast-iron beds to which the cutters are attached. Said cutters are similar to those of a common plane, and are firmly screwed to the beds which extend across the machine, and attached at each end to the cast iron frame G, where they are each adjusted and held by set-screws. F is the yielding-bar mouth-piece, which also extends across the machine, and is held down by springs under the same. This bar is as near the cutting edge as possible, and it serves to hold the grain of the wood together just at the cutting edge, which wholly prevents splitting or tearing the wood. It adapts itself to the inequalities of the board or plank without clogging, and thereby produces a perfect surface. G is the frame that holds the cutters, stocks, and mouth-pieces in their proper places, and is to be raised or lowered to suit the different thicknesses of material. H is the crank with the geering attached to raise and lower the frame G, which holds the cutters. I is the geer-wheels, that connect the feeding rollers C to the endless travelling platform B. J is a series of rollers, which hold the board over the cutters, to plane the under side of the board, if required. L is a wheel attached to a screw to move a horizontal slide on which rests the frame that holds the rollers J, and to which is attached four wedges. The wheel and screw L move the horizontal slide, thereby raising and lowering the rollers to admit of different thicknesses of material. M is the chain-wheels on which the endless platform revolves. The board is entered between the platform B and the rollers C, and carried through under the stationary cutters E, which plane and reduce the board to a uniform thickness. It then moves forward between the rollers J and under the cutters K, which plane the under side, if required.



3076.

The above described machine produces a most excellent surface, and does the work with great rapidity.

The patent includes planing, tonguing, and grooving machinery.

Machines for Planing Iron.

Planing Machine, Hand. The following figures represent three views of the machine: Fig. 3077 is a front elevation, Fig. 3078 is a side elevation, and Fig. 3079 a plan. The same parts are denoted by the same letters in all the figures.

A A the supporting legs of the machine, on which rests B B the bed frame. To this is bolted the upright frame for carrying the slides.

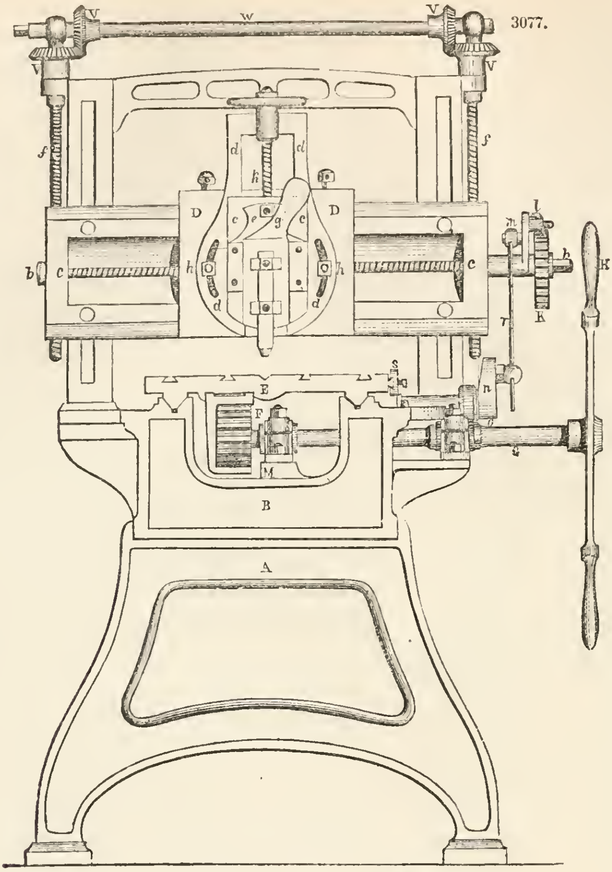
C, the vertical slide. On this are cast projecting pieces *a*, through which the carrying screws *f f* pass. By these screws the slide is raised and depressed at pleasure by the geering at their upper extremities.

D, the horizontal slide, which is carried across the slide C by a screw *b b*, which has its bearings in the slide *c c*, which has between it and D a slide-carrier *d d*, admitting of a small amount of circular motion on the stud-bolts *h h*. These pass through circular slots in the plate, and are provided with pinching-nuts to retain the slide in the position desired. By this provision the slide may be set at any required angle, as in other planing machines. In front of the cutter slide is placed the tool box *e* and *g*, to which is fixed the cutting tool in the usual way. This slide is moved by the hand wheel on the upper end of the slide-screw *k*; but the motion of the cross-slide D is obtained by a self-acting apparatus from E E, the travelling table. On this the article to be planed is fixed by bolts, sliding in dovetailed grooves in the usual way.

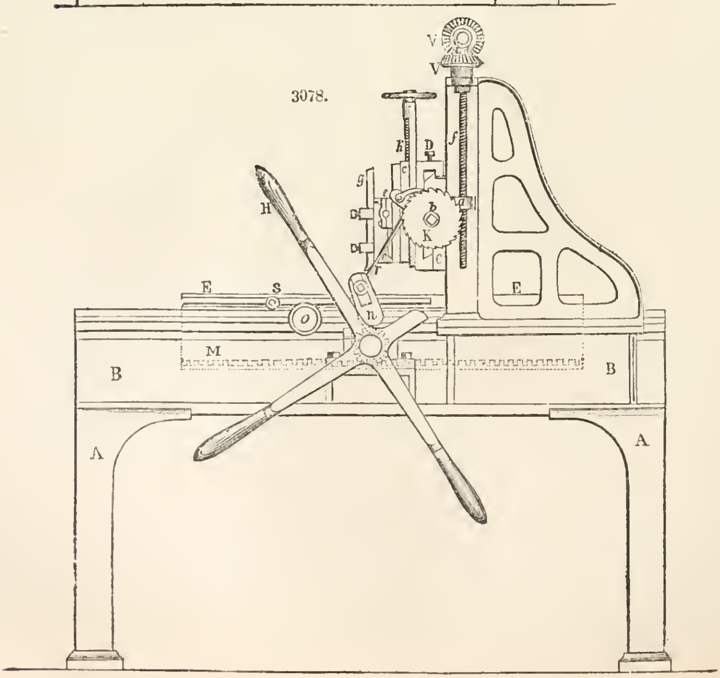
F, the driving pinion which geers into the rack M on the under side of the travelling table E. The pinion is keyed on the end of G the driving shaft, on one end of which is the driving pinion F, and on the other H a hand cross, keyed on the end of the shaft G for working the pinion F, which travels the work table E by means of the rack M attached to its under side.

K, a ratchet-wheel fast on one end of the slide screw *b b*.

L, a click working in the ratchet-wheel K. This click is guided in the length of its travel at each stroke by the position of the sliding studs in the pieces *m* and *n*, which are connected by the rod *r*. The studs slide in grooves in the pieces *m* and *n*, and can therefore be set at any required distances from the centres of motion; and accordingly, the number of teeth over which the click is carried depending upon the positions of the studs, the amount of feed motion of the screw *b b* can be regulated at pleasure.



3077.



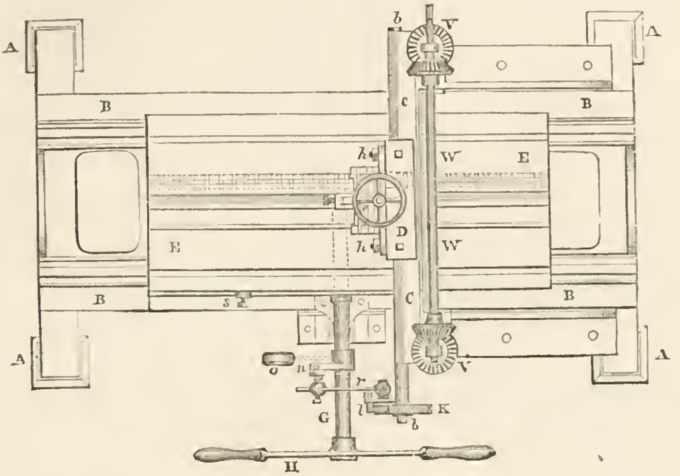
3078.

M, the travelling rack, made fast to the table and worked by the pinion F. The form of the rack is shown in transverse section in Fig. 3077, and an elevation and plan are shown in Figs. 3078 and 3079.

o, a balance-weight on the end of a lever projecting from the same small shaft on which the crank-lever is fixed. On the opposite end of this small shaft is fixed another lever, placed so that it is depressed by the tapet S, when the travelling table is moved towards the back of the machine; by this the crank-lever *n* is depressed and the weight *o* raised at the same instant.

S is a tapet on the travelling table, and which may be shifted to any required position and fixed there by a pinching-screw with which it is provided. The position of this tapet is regulated according to the length of the travel of the table at the time.

3079.



V V V V, four bevel-wheels, geered pair and pair, for turning the screws *f f* to raise or lower the vertical slide C C, to suit the work upon the table. Two of the wheels are fast upon the upper ends of the screws, and two are in like manner made fast on W a cross-shaft, on which are two of the bevel-wheels V V for working the elevating screws *f f*. This shaft has a square at one end to receive the eye of a crank-handle or hand-wheel. It has its bearings in two bored pieces which rest on the upper ends of the screws, and against the eyes of the wheels keyed on them, and are retained in their places by check-pins in the usual way.

PLANING MACHINE, by Archibald Mylne, Glasgow. This machine has some peculiarities which render it worthy of a place among the higher order of tools of the same kind.

Fig. 3080 is a side elevation, and Fig. 3080[2] a front elevation of the entire machine, with the same references.

k is the bed-frame of the machine, carried on legs or supports *i*. The bed-frame is formed of one casting, with two projecting edges of a Λ shape, which are planed true, and fitted to corresponding V-shaped grooves in the under side of the travelling table *m*, contrary to the usual arrangement in planing machines.

F is the upright frame for carrying the slides; and *m* the sliding table for carrying the work to be planed. The work is fixed to the table by bolts with dovetail heads, which slide in grooves of corresponding form, running the length of the table. The upright frame F is formed of two side brackets bolted down to strong flanges cast on the bed frame *k*, and joined together at top by a cross-piece, which gives to the frame the necessary rigidity and strength. The faces of these cheeks and cross-piece are planed true and polished. This is requisite in respect of the vertical faces, as upon these the vertical slide *a a* moves when it is elevated and depressed by its screws *u u*; and the cross piece is polished to avoid unseemly contrast of appearance.

A is the driving-belt for the forward motion of the table, passing round a large pulley, as shown in Fig. 3080.

B, a cross-belt driving a smaller pulley for the return motion of the table, which is thus made quicker than the forward motion. These belts can be shifted from fast to loose pulleys, as may be observed by Fig. 3080, in which they are shown upon their loose pulleys.

D, a pinion fast on the pulley-shaft.

E, a wheel driven by the pinion D, and keyed fast on a shaft which passes through the bed frame of the machine, and carries the two fast pinions which give motion to the sliding-table by geering into racks on the under side of it, shown in the end elevation. These two racks (or double rack) have the teeth of the one opposite the space of the other, so as to render the motion smooth and uniform.

n n', Fig. 3079, are tapets to reverse the motion of the table.

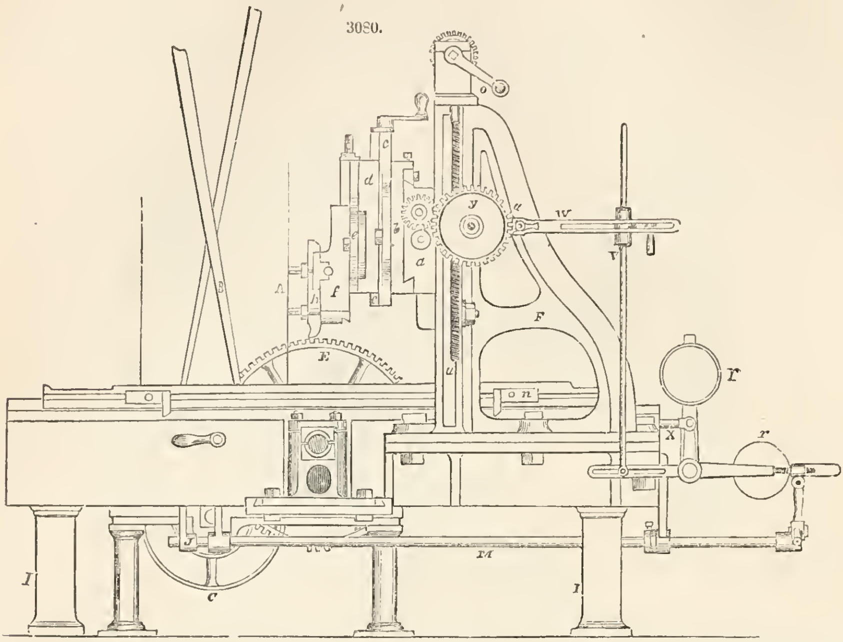
g, a double lever keyed on a hollow shaft which works freely on the driving-shaft.

x, Fig. 3079, a rod having one end attached to a lever, fast on the same shaft with the lever *t*, which carries the weights *r r'*, and has its other end attached to a lever keyed on the same hollow shaft with double lever *g*.

M, a traverse-shaft connected by a lever with the shaft to which the lever *t* is attached.

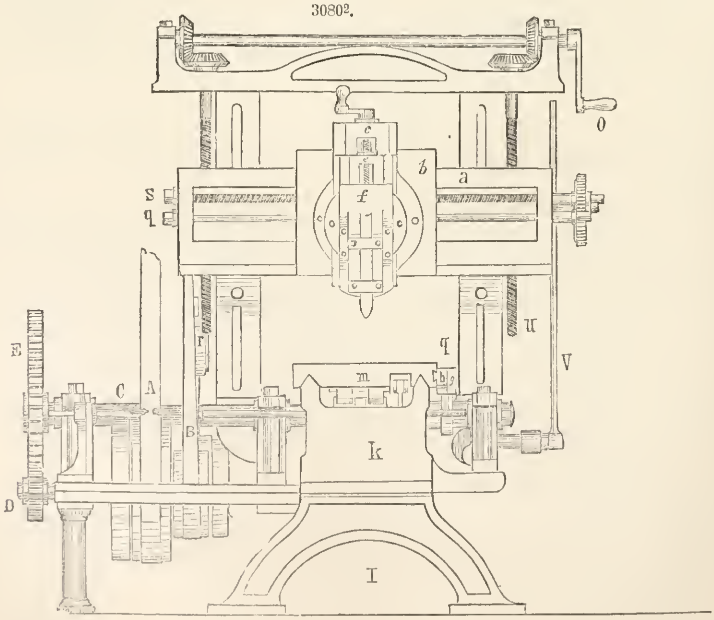
J, a lever fast on the shaft M; and C, Fig. 3080^2, a guide for the belts connected with the lever J which has one of its ends flat to prevent it from turning round, and at the same time to allow it to slip lengthwise and shift the belts from the fast to the loose pulleys.

3080.



The machine is set in motion by moving the belt-guide towards the off-side of the machine, by which the belt is shifted on the narrow pulley, which is the driver. The sliding table is thus put in motion and moves towards the back part of the machine, until the tapet *n*, catching one of the legs of the

3080^2.



lever *g*, turns it over, throwing outward the weight *r*, by the connecting-rod *x*, which is worked by a lever fast on the hollow shaft with *g*.

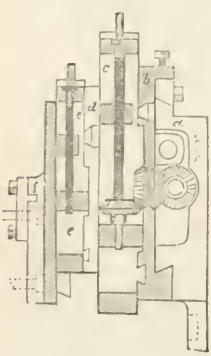
The weights *r r'*. and lever *t*, being fast on the same shaft and connected by a link with M, the whole s simultaneously put in motion, and the upper weight *r* being thrown off the balance, the belt-guide is pulled by the lever J until the belt A is shifted to the loose pulley, and the cross-belt B to the fast pulley, to produce the return motion. On the return of the table the tapet *n'* turns over the lever *g* in the opposite direction, and the reversing motion is produced in the same manner. The tapet *n'* stands further out than *n*, so that each of them can only touch one leg of the lever *g*. They are also made to slide in dovetail grooves, and have pinching screws to fix them, to suit the length of work and its position on the table.

The lever *t*, which moves with the weights *r r'*, communicates motion to the slides on the frame F A section of these slides is shown at Fig. 3081, and detached parts in Figs. 3082 to 3086, the same letters being used to denote the same parts on all the figures.

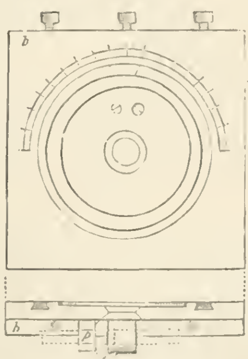
a, the vertical slide attached to the upright frame of the machine by four screwed pins, which pass, pair and pair, through long grooves in the cheeks of the frame F, and the slide being set at the requisite height by the screws *u u*, it can then be tightened by jam-nuts on the ends of the pins against the faces of the frame, and retained in the required position.

b, the cross-slide which moves across the breadth of the machine, upon the face of the vertical slide *a*. Motion is communicated to it by a screw which has its bearings *s s* in the ends of the vertical slide, and which passes through a nut attached to the back of the slide *b*, as shown in Fig. 3081. The slide is guided, and also securely retained, on the slide *a* by dovetail faces formed on the back, and which correspond to dovetails formed on *a*. The upper dovetail is made adjustable, Fig. 3081, to allow for any wear of the surfaces which may take place. On the face of the slide is a graduated arc to regulate the setting of the slide-carriage *c*, which is attached to it by fixing screws and nuts, Fig. 3080. The screws have dovetail heads, which slide in an annular groove, Fig. 3082, and pass through two holes in the circular pieces cast on the edges of the carriage *c*. The bolts are put in from the back of the slide *b* through a recess cast in it for that purpose. The carriage thus admits of being placed and set at any required angle with the slide *b*, as shown by Fig. 3087, and the details of the mode in which this is effected is explained by Figs. 3082 and 3083, and partially by Figs. 3081 and 3080.

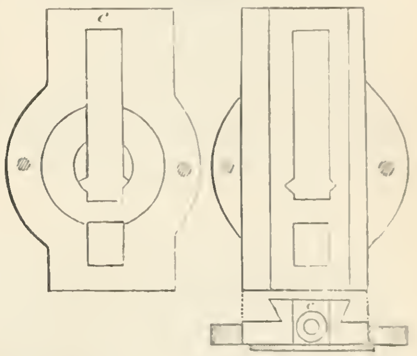
3081.



3082.



3083



In the carriage, *c* is a screw with bearings at its two extremities, in the metal of the carriage. It is kept from moving endways by a ruff on its upper end, over which passes a ring of malleable iron, fixed to the carriage by screwed pins tapped into the metal. On the lower end of this screw is fixed a small bevel-wheel, which geers with one of a pair checked and bolted together, so that motion cannot be communicated to the one without the other being moved simultaneously in the same direction. The second of the wheels geers with a similar wheel upon the rod *q q*, Fig. 3080², and their common bearing consists of the V shaped groove formed by the backs of the wheels being placed against each other. This groove is truly turned to fit the corresponding V shaped edge of an annular recess cut in the centre of the cross-slide *b*, (see sections, Figs. 3081 and 3082) The purpose of this arrangement of wheels will be explained presently.

On the face of the carriage *c* a projecting piece is cast, which is planed with dovetail edges, Fig. 3083, to receive corresponding dovetails of the slide *d*, Fig. 3081. On the back of this slide is also fixed a nut through which the screw in the carriage *c* passes, for the purpose of raising and depressing the slide, especially when set obliquely, according to the circumstances of the work under operation.

e is a second slide carriage in all respects similar to the carriage *c*, except that it is smaller. It is attached to the slide *d* also by bolts with dovetail heads, which work in an annular groove in the face of the slide *d*, and the ends of the bolts, which are screwed to receive the fixing nuts, pass through holes in the projecting lugs cast on the edges of the carriage, which can thus be set at any required angle on the face of the slide *d*.

The slide *f* is similar to that marked *d*, and is attached to the face of the carriage *e* in exactly the same manner; and is, moreover, moved by the screw of its carriage, with which it is connected by a nut, Figs. 3081 and 3086, to any position required within the range of its travel. The tool-box is attached to this slide by a flexible joint, which is easily understood from Figs. 3081 and 3083. The use of the joint is to prevent the tool *h* from cutting during the returning of the work table, which in this arrangement of slides would be apt to injure the more delicate parts of the machine, and possibly the work under operation, particularly as the return motion of the table is much too quick for cutting. Very little motion of the joint is required to allow the tool to clear the work

The mode of fixing the tool is by T-headed bolts and glands, as shown in Figs. 3080 and 3086. In this last the tool and glands are removed, but the fixing bolts are dotted in their positions.

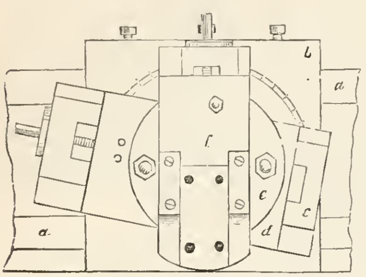
u u, screws revolving in the projecting ends of the top rail, and working into nuts on the back of the slide *a*.

o, handle to turn the screws by means of a system of bevel-wheels, in order to raise or depress the slide *a* to suit the work to be planed, the slide *a* having fixing bolts to secure it to the planed faces of the frame at the required height.

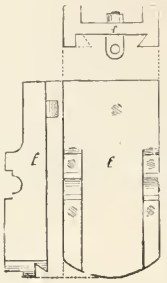
w, a lever with a spring-catch which may be geered into the wheel *y*.

v, a rod connecting the lever *t* with the lever *w*. The spring-catch being in geer, the wheel *y* receives motion from the lever *t*, and being geered with a pinion on the end of the cross slide-screw, which revolves in bearings *s s*, it communicates its motion to the screw and cross-slide *b*. The amount of feed is adjusted by shifting the studs in the slots of the levers *t* and *w*; and the direction in which the slide is wanted to be moved is regulated according as the spring-catch is geered above or below the axis of the lever *w*.

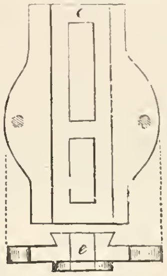
3087.



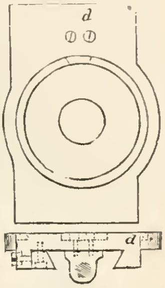
3086.



3085.



3084.



This self-acting feeding motion is also communicated to the down-cutting slide *d* by shifting the pinion from the end of the screw to the end of the small shaft which works in the bearings *q q*, Fig. 3080 On this shaft is a small bevel-wheel shown at Figs. 3081 and 3082, which is carried round by having a key projecting into a groove continued the whole length of the shaft. This wheel is carried along the shaft by a projecting piece on the slide *b*, Fig. 3082, and its motion is communicated to that on the end of the slide-screw in *c*, Fig. 3081, by means of two similar intermediate wheels placed in slide *b*, as above described.

The front slide *f* is not commonly attached to planing machines; but it is valuable where work is to be done which requires two or three different angled surfaces to be planed, and which can be done with this machine by arranging the slides before starting, no shift being afterwards required.

Fig. 3087 shows the slides set at different angles.

PLANING MACHINE, SELF-ACTING COMPOUND, by Nasmyth, Gaskell & Co. The machine represented in Figs. 3088, 3089, 3090, and 3091 is remarkable for compactness and elegance of arrangement, and for the accuracy and dispatch with which a description of work that, previously to the introduction of such machines, could only be intrusted to the most expert and skilful mechanic, but which can, by its means, be executed by workmen of the most ordinary capacity. It is especially applicable to the finishing of the numerous small levers used in locomotive engine and tool-making, and is admirably adapted, not only to the planing of the sides and edges of such levers, but also to the finishing of their rounded ends, which otherwise could only be accomplished by the rude and tedious process of chipping and filing.

Fig. 3088 is a side elevation of the machine.

Fig. 3089 is a view of the front end or face.

Fig. 3090, a general plan; and

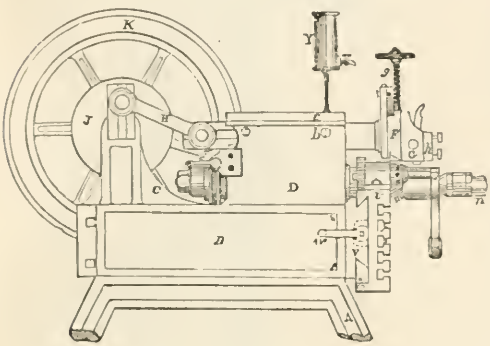
Fig. 3091, a transverse section through the principal working parts.

General description.—The frame upon which the machine rests, and which is used for the purpose of raising it to a convenient height, is composed of two cast-iron cheeks A A, strengthened by flanges, and held together at the lower end by two stay-rods *a a*. These frames are disposed at an angle to each other, in order to give greater stability to the structure. The main body of the machine consists of a cast-iron table or box B bolted to the frames by internal flanges, as shown in the section, Fig. 3091, and on the upper side of this table are cast the bracket C, carrying the driving-spindle, and the rectangular chamber D, furnished with bearings for the other working parts of the machine. The square cast-iron sliding-bar E, which carries the tool-holder, is accurately planed, and fitted into a recess in the upper portion of the piece D. It is of essential importance that the slide E should move accurately and without play in a rectilinear and horizontal direction, and for this purpose it is secured laterally by the adjusting screws *b b*, and vertically by the wrought-iron plate or cover *c*, fixed to the frame by the six countersink screws *d d d*.

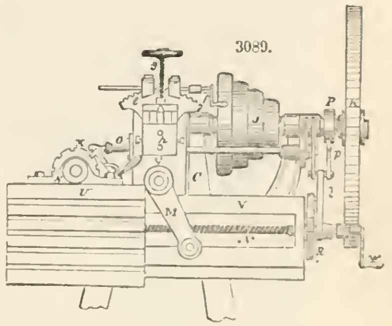
On the front end of the square slide E is cast a flat rectangular plate, which serves as the fixed point of resistance to the various motions of which the tool-box is susceptible. The first of these is a rotary motion, which is impressed upon it by a toothed quadrant plate *e*, worked by an endless screw on the axis *f*. This arrangement enables the workman to set the tool at any required angle to the work. On the upper edge of that part of the tool-box marked F, is fixed a nut, through which works a screw *g*, surmounted by a handle or small hand-wheel This screw is used for raising or depressing the tool, and thereby adapting it to the diameter or height of the work to be executed, as well as for regulating the depth of cut. The part G, which is thus acted upon by the screw *g*, is furnished with two parallel cheeks accurately dressed on their internal surfaces, and fitted to receive the tool-holder *h*. The tool itself is inserted into a square hole passing through the piece *h*, and fixed firmly to it by two pinching-screws. The tool-holder *h* is so formed as to admit of a small amount of rotary motion round two centre screws passing through the cheeks of the piece G, and by this means accidents arising from the friction of the tool against the work in the return stroke are prevented.

The mode in which motion is communicated to the tool-box is as follows: The extremity of the square slide E opposite to that on which the tool-box is fixed, is traversed by a longitudinal slot or groove *i*, adapted for the reception of a bolt-head, as shown in the transverse section, Fig. 3094. The projecting part of the bolt passes through a hole in the end of the connecting-rod H, the opposite end of which is attached by another bolt to a rectangular cast-iron piece I, fixed to the end of the driving-spindle, and acting as a crank for converting the rotary into a rectilinear motion. The crank I is traversed throughout its whole length by a slot *i*, the form of which, as well as of that in the slide E, is shown in the section, Fig. 3094. By means of these slots the length of the stroke and the position of the tool may be easily and accurately adjusted to suit the work, as will be sufficiently obvious by inspection of Fig. 3088. The driving-spindle works in two bearings, one of which, as before mentioned, is cast on the bed of the machine B, and the other is formed in the extremity of a bracket bolted to the side of it. The velocity of the driving-spindle is varied and regulated by means of the cone-pulley J and fly-wheel K.

3088.



3089.

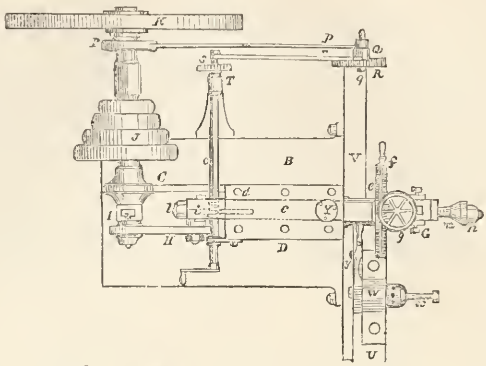


The planing of circular surfaces is effected, in this machine, by means of a hollow cylindrical cast-iron mandrel L, Figs. 3091 and 3092, accurately turned and fitted into the body of the machine, the centre being exactly under that of the square slide E. This mandrel is provided with a conical bearing on the front end, and is traversed by a malleable iron bolt *l*, secured to its opposite extremity by a nut. The head of the bolt *l* is formed into a cylindrical socket, into which, by means of a cotter, is fixed another bolt, having two conical pieces *m m*, one of which is immovable, and forms part of the bolt, while the other slides upon it, and is adjusted by means of the nut *n*. These pieces are used for the purpose of fixing the work M, upon which the machine is to operate; and from their conical form, adapt themselves to any required diameter, so as to insure, without any trouble in setting, the concentricity of the outer surface with the eye.

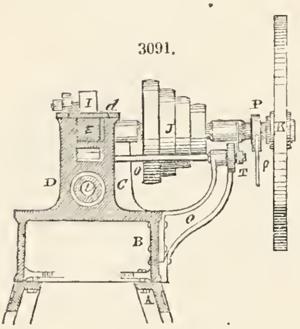
The motion of the mandrel L, with its appendages, is effected by means of the worm-wheel N, which is fixed to its inner end by a large circular nut screwed to the cast-iron mandrel itself, independently of the bolt *l*, which passes through it. The worm wheel N geers with an endless screw on the horizontal axis *o*, working in two bearings, one of which is formed by a small malleable iron piece bolted to the body of the machine D, and the other extends considerably beyond the table, and is supported by the bracket O bolted to it, as shown in the section, Fig. 3091. The axis *o*, besides the self-acting mechanism which we are about to describe, is provided with a handle, by which it can at pleasure be moved by the attendant workman. The self-acting geer, which, in Fig. 3093, is shown detached from the machine, consists of an eccentric P, fixed upon the driving-spindle, and by means of the rod *p p*, communicating a reciprocating motion to the slotted lever Q, which motion is again conveyed by the rod *r r* to the smaller slotted lever S. The centres of motion of these levers are respectively on the extremities of the traverse screw *v*, which is used only in flat planing, and on that of the axis *o*, of the endless screw, and on these centres they are fitted to move loosely without turning them. The slots which traverse the levers are for the purpose of altering the feed to any required amount. The motion of the levers is communicated to their axes by the double pawls *q* and *s*, which work respectively into the wheels R and T, fixed upon their centres *v* and *o*. These wheels act in this case as ratchet wheels, and from the peculiar form given to the pawls, they may be made to move either backwards or forwards by simply reversing the direction of the pawls.

For the purpose of planing flat surfaces with this machine, it is provided with a cast iron face plate U U, which is traversed by several slots, cast on its exterior surface, and adapted to receive the bolts by which the work is to be fixed to it. The back of the face plate is planed and fitted to move transversely along the slide V, by means of adjustable dovetail pieces, in the manner we have already so frequently had occasion to describe. This motion is effected by means of the screw *v*, which is worked by the mechanism above described, and which, having a bearing at each end of the slide V, passes along a recess cast in its surface, and works into a brass nut fixed on the back of the face-plate U. The traverse screw *v* is provided with a handle *w*, for the purpose of setting the work into its proper position under the tool, before bringing the self-acting mechanism into geer.

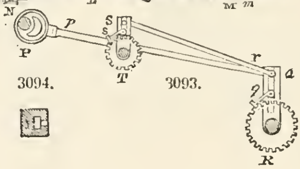
3090.



3091.



3092.



3094. 3093.

PLATE-BENDING MACHINE, by Robert Napier, Glasgow. This species of machine, originally confined to the tinsmith's shop, has recently—enlarged in its dimensions and rendered more complete in its mechanism—become indispensable in the operations of boiler-making and iron-ship building, in which plates are required to be bent to various degrees of curvature. The example given is the design of Mr. Elder, the manager of Mr. Napier's works, and is one of the largest yet made, being intended principally for use in the building yard, where plates of greater thickness come under operation than those required in boiler-making.

Fig. 3098 is a side elevation of the machine, and Fig. 3099 an end view towards the driving-geer.

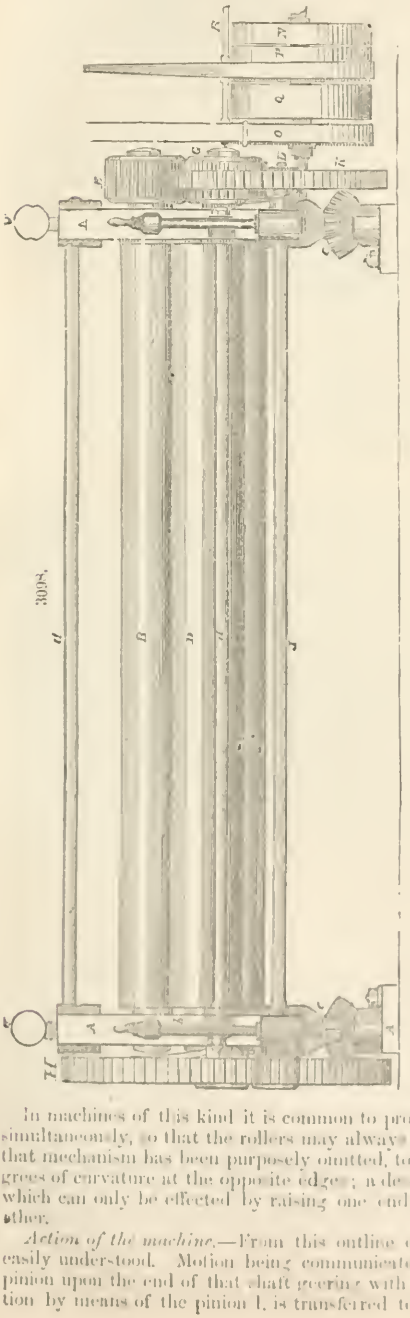
Fig. 3100 is a plan corresponding to Fig. 3098.

General description.—The frame of the machine consists of two very strong end standards A A, cast with soles to admit of their being bolted down to a solid stone foundation. They are braced together by four strong rods of malleable-iron *a a a*, the screwed ends of which pass through projections on the standards, of such thickness that the nuts by which they are secured are nearly flush with the outside of the frames, thus obviating the necessity for having the geering far overhung.

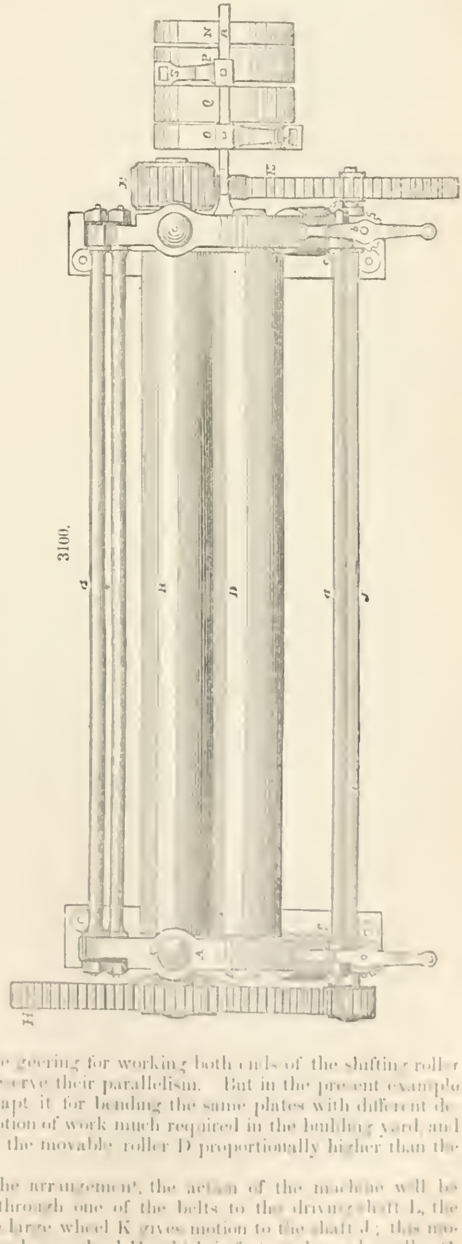
The three rollers B C D are solid; the dimensions of each being 12 inches diameter, and 10 feet long within their bearings. The two rollers B and C are placed in the same vertical plane; but the third roller D moves in a plane inclined at an angle of thirty degrees to the vertical plane. On one end of the roller B is keyed a strong pinion E, which geers with another pinion of the same size marked G on the end of the lower roller C. On the opposite end of this last is fixed a large spur-wheel H into which works a pinion I on the shaft J, which has a bearing in each of the two standards, and carries on its other end a large spur-wheel K, commanded by a pinion upon the driving-shaft L. One end of this shaft is carried in a bearing in the adjacent standard of the machine, and the other in an independent standard M bolted to the foundation. It carries four pulleys, two of which, N O, are fast upon the shaft, and the other two, P Q, of double the breadth of the former, are loose. On these are two belts, the one cross and the other open, so that the rollers may be driven in either direction according as the motion is communicated by the open or the cross belt. The belts are shifted on their pulleys by means of the hand-bar R, on which are the guide-arms S T, so placed that in reversing the motion of the machine, the belt thrown out of action shall have passed entirely from its fast pulley before the other shall have passed from its loose pulley to the fast one. This arrangement obviates the injurious effect so common in machines furnished with this species of driving-geer, of the one belt acting against the other during a part of the time of shifting, thereby occasioning much unnecessary tear and wear of the belts.

The upper roller B is adjusted to the thickness of the plate to be bent by two strong set-screws U U, which work in hexagonal brass nuts inserted into recesses in the standards. These screws bear against a steel plate resting upon the brass block in which the roller revolves, and which is of course placed over the journal, the pressure being upwards; and thus the roller is kept pressed down upon the plate, as it passes through the machine in the operation of bending.

The roller D is adjusted to the required position by the double hand-crank on the upper end of the vertical spindle *b b*, which communicates by means of a pair of small bevel-wheels *c c* with the screws *d d*, working into long brass nuts *e e* inserted in recesses of the frame. The upper ends of these nuts support the bearings of the roller, which may consequently be raised and lowered at pleasure, according as the spindle is turned in one direction or the other. The nuts *e e* are prevented from turning round with the screws by feathers upon the back of the brasses fitting into grooves on the ends of the nuts.



3098.



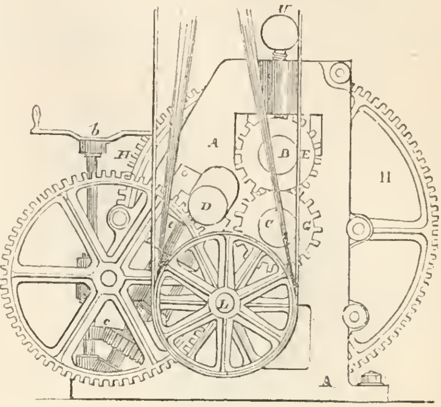
3100.

In machines of this kind it is common to provide gearing for working both ends of the shifting roller simultaneously, so that the rollers may always preserve their parallelism. But in the present example that mechanism has been purposely omitted, to adapt it for bending the same plates with different degrees of curvature at the opposite edges; a description of work much required in the building yard, and which can only be effected by raising one end of the movable roller D proportionally higher than the other.

Action of the machine.—From this outline of the arrangement, the action of the machine will be easily understood. Motion being communicated through one of the belts to the driving-shaft L, the pinion upon the end of that shaft gearing with the large wheel K gives motion to the shaft J; this motion by means of the pinion I, is transferred to the large wheel H, which is fast on the under roller C

This roller being put in motion, communicates an equal velocity to the upper roller B by means of the pinions E and G which geer together. The roller D, the position of which determines the degree of curvature of the plate under operation, is only driven by the friction of the plate against it as it passes between the two other rollers.

3099.



Literal references.

A A, the end standards of the machine.
a a a, stay-rods, 2 inches diameter, for connecting the two standards.
B, the upper roller, 12 inches in diameter, and 10 feet long between its bearings, which are $5\frac{1}{2}$ inches in diameter.
C, the lower roller, of the same dimensions.
D, the shifting-roller, of the same dimensions.
b, the upright spindle for setting the roller D.
c, small bevel pair worked by the spindle *b*.
d, a screw, $2\frac{5}{8}$ inches diameter, and $\frac{5}{8}$ inch pitch.
e, brass nut into which the screw *d* works.
E, a pinion on the end of the top roller B; pitch $2\frac{1}{2}$ inches, number of teeth 16.
G, a similar pinion on the lower roller C.
H, a large spur-wheel on the opposite end of the roller C; pitch $1\frac{3}{4}$ inch, number of teeth 100.
I, a pinion of 13 teeth, working into the spur-wheel H.
J, a wrought-iron shaft conveying motion to the pinion I from
K, a spur-wheel at the opposite end of the machine; pitch $1\frac{1}{2}$ inch, number of teeth 75.
L, the driving-shaft of the machine.
M, a standard for supporting the exterior end of the driving-shaft.
N O P Q, fast and loose pulleys for setting in motion, stopping, and reversing the machine.
R, the hand-bar for shifting the belts.
S T, guide-arms fixed on the hand-bar R.
U U, screws for adjusting the top roller.

PLATINUM. (So called from the Spanish word plata, *silver*, on account of its color.) A metal of a white color, exceedingly ductile, malleable, and difficult of fusion. It is the heaviest substance known, its specific gravity being 21·5. It undergoes no change from air or moisture, and is not attacked by any of the pure acids; it is dissolved by chlorine and nitromuriatic acid, and is oxidized at high temperatures by pure potossa and lithia. It is only found in South America and in the Uralian Mountains: it is usually in small grains of a metallic lustre, associated or combined with palladium, rhodium, iridium, and osmium; and with copper, iron, lead, titanium, chromium, gold, and silver; it is also usually mixed with alluvial sand. The particles are seldom so large as a small pea, but sometimes lumps have been found of the size of a hazel-nut to that of a pigeon's egg. In 1826 it was first discovered in a *vein* associated with gold, by Boussingault, in the province of Antioquia, in South America. When a perfectly clean surface of platinum is presented to a mixture of hydrogen and oxygen gas, it has the extraordinary property of causing them to combine so as to form water, and often with such rapidity as to render the metal red-hot: *spongy platinum*, as it is usually called, obtained by heating the ammonio-muriate of platinum, is most effective in producing this extraordinary result; and a jet of hydrogen directed upon it may be inflamed by the metal thus ignited, a property which has been applied to the construction of convenient instruments for procuring a light. The equivalent of platinum is about 98. It is precipitated from its nitromuriatic solution by sal ammoniac, which throws it down in the form of a yellow powder, composed of bichloride of platinum and sal ammoniac.

PNEUMATICS. The science which treats of the mechanical properties of elastic fluids, and particularly of atmospheric air.

Elastic fluids are divided into two classes—permanent gases and vapors. The gases cannot be converted into the liquid state by any known process of art; whereas the vapors are readily reduced to the liquid form by pressure, or diminution of temperature. In respect of their mechanical properties there is, however, no essential difference between the two classes.

Elastic fluids, in a state of equilibrium, are subject to the action of two forces; namely, gravity, and a molecular force acting from particle to particle. Gravity acts on the gases in the same manner as on all other material substances; but the action of the molecular forces is altogether different from that which takes place among the elementary particles of solids and liquids; for, in the case of solid bodies, the molecules strongly attract each other, (whence results their cohesion,) and, in the case of liquids, exert a feeble or evanescent attraction, so as to be indifferent to internal motion; but, in the case of the gases, the molecular forces are repulsive, and the molecules, yielding to the action of these forces, tend incessantly to recede from each other, and, in fact, do recede, until their further separation is prevented by an exterior obstacle. Thus, air confined within a close vessel exerts a constant pressure against the interior surface, which is not sensible, only because it is balanced by the equal pressure of the atmosphere on the exterior surface. This pressure exerted by the air against the sides of a vessel within which it is confined is called its *elasticity*, or *elastic force*, or *tension*.

Conditions of equilibrium.—In order that all the parts of an elastic fluid may be in equilibrium, one condition only is necessary; namely, that the elastic force be the same at every point situated in the same horizontal plane. This condition is likewise necessary to the equilibrium of liquids, and the same circumstances give rise to it in both cases; namely, the mobility of the particles, and the action of gravity upon them. Conceive a close vessel to be filled with air, or a gas; and let a and b be two molecules situated in the same horizontal plane. It is evident that if the two molecules are in a state of equilibrium, the force with which a repels b must be exactly counteracted by that with which b repels a, for otherwise motion would take place. The same thing takes place in respect of every horizontal section of the gas; but the pressure on each section varies with its altitude. Suppose c and d to be two molecules situated in a horizontal section, *lower* than that in which are a and b. It is evident that the molecules c and d sustain a greater pressure than a and b; for, in the first place, the whole of the pressure on a and b is transmitted to them by the principle of the equality of pressure in all directions; and, in the second place, they sustain a new pressure, arising from the weight or gravity of all the molecules situated between the two horizontal planes $a\,b$ and $c\,d$.

The principle which has just been explained is proved experimentally by the diminution of the pressure of the atmosphere at greater altitudes. A column of air reaching from the ground to the top of the atmosphere exerts a pressure equal to the weight of a column of mercury of the same diameter, and whose height is equal to that in the barometric tube. Now, on carrying the barometer to the top of a mountain, for example, the mercurial column is observed gradually to become shorter as we ascend; and the diminution of the column, and consequently of atmospheric pressure, is connected with the increase of altitude by a certain constant law, which enables us to deduce the one from the other, and to apply the barometer to the very important purpose of determining the relative altitudes of places on the surface of the earth.

The volumes of gases are inversely as the pressures which they support.—This fundamental property of elastic fluids is called the *Law of Mariotte*, from its having been discovered by that philosopher in France. It has been verified in several ways, on all the known gases; and, in the case of dry air, its verification has been pushed, by MM. Dulong and Arago, to pressures equivalent to twenty-seven atmospheres. (Lamé *Cours de Physique.*) It also holds true in respect of vapors or steam, subjected to a smaller degree of pressure than that which is necessary to reduce them to the liquid state; and even for mixtures of different gases. It is important, however, to observe, that it is supposed no variation of temperature has taken place during the experiment.

The density of bodies being inversely as their volumes, the law of Mariotte may be otherwise expressed, by saying, *the density of an elastic fluid is directly proportional to the pressure it sustains.* Under the pressure of a single atmosphere, the density of air is about the 770th part of that of water; whence it follows that, under the pressure of 770 atmospheres, air is as dense as water. Thus, the average atmospheric pressure being equal to that of a column of water of about 32 feet in altitude, at the bottom of the sea, at a depth of 24640 ($= 770 \times 32$) feet, or $4\frac{2}{3}$ miles, air would be heavier than water; and though it should still remain in a gaseous state, it would be incapable of rising to the surface.

Effects of heat on the elasticity of the gases.—The repulsive energy of the molecules of the elastic fluids is greatly augmented by an increase of temperature; and it is of the utmost importance in many physical inquiries to ascertain the relation between the temperature and the elastic force. If the air and several other gases, sustaining the same constant pressure, are exposed to an increase of temperature which affects all of them equally, it is proved, by observation, that they all undergo an equal expansion; that is to say, the increase of volume of all the gases is the same for equal augmentations of temperature, and proportional to these augmentations. Experience also shows that, within a considerable range of temperature, the indications of the air thermometer differ very little from those of the mercurial thermometer; so that, within this range, the expansion of any gas whatever is proportional to the increase of temperature indicated by the degrees of the ordinary thermometer. From the temperature of melting ice to that of boiling water, or from zero to 100° of the centigrade thermometer, Gay-Lussac found the expansion of air subjected to a constant pressure, to be in the ratio of unity to 1·375; which gives an expansion of 0·00375 for each centigrade degree. This being assumed, let V be the volume of any gas at the zero temperature, P its elastic force, or the pressure it sustains, and D its density. Let $a = \cdot 00375$, and suppose the values of V and D to become V′ and D′ when the temperature is increased t degrees; then the pressure P being supposed constant, we have evidently

$$V' = V\,(1 + a\,t);$$

and the density being inversely as the volume, we have, also,

$$D' = \frac{D}{1 + a\,t}.$$

Now, suppose the pressure to be varied without any change of the temperature, and let p denote the new pressure, and d the corresponding density; the law of Mariotte gives

$$P : D' :: p : d, \text{ whence } p = \frac{P\,d}{D'};$$

and, on substituting for D′ its value given by the preceding formula, and making $\frac{P}{D} = k$, we obtain

$$p = k\,d\,(1 + a\,t)$$

for the expression of the elastic force of any gas in a function of its density and temperature.

The coefficient k is constant for the same gas, but has a different value for different gases, depending on their densities or specific gravities. With respect to atmospheric air, its value may be found thus: The density of air, compared with water, is 0·0013, and that of mercury 13·59; therefore, supposing the height of the barometer to be 30 inches, the value of k, or the height of a column of air of uniform density, exerting on its base a pressure equal to that of the atmosphere, is 30 in. $\times \frac{13 \cdot 59}{\cdot 0013} =$ 313860 inches, or 26155 feet, (about five miles,) the temperature being that of freezing water

Of the motion of the gases.—Elastic fluids, in escaping from a vessel by a small orifice or tube, into a vacuum, observe, like liquids, a law first discovered by Torricelli; namely, that the velocity of the mole cules, when they escape from the orifice, is equal to that which they would have acquired by falling through a height equal to the height of a vertical column of uniform density, producing the same pressure as is exerted by the gas at the level of the orifice. Thus, it has just been shown that the pressure of the atmosphere, when the barometer stands at 30 inches, and the temperature is that of freezing, is equal to that which would be produced by a column of air of uniform density extending to an altitude of 26155 feet. Now, putting $g =$ the accelerating force of gravity $= 32$ feet per second, the velocity which a heavy body would acquire by falling in a vacuum from a height of 26155 feet, is $\sqrt{(2\,g \times 26155)} = 8\sqrt{26155} = 1294$ feet in a second; which, therefore, is the velocity with which air rushes into a vacuum. If the temperature varies, the velocity will vary also, and will become $1294\sqrt{(1 + a\,t)}$. For example, if the temperature were 16° centigrade, (about 61° of Fahrenheit,) the velocity would be 1332 feet per second.

Since the densities of the gases are proportional to the pressures they support, air will always rush into a vacuum with the same velocity, whatever its density may be in the vessel from which it escapes; for the homogeneous column of the same density, and exercising the same pressure as the air in the vessel, must, in all cases, have the same altitude.

The velocities with which the different gases enter a vacuum are inversely as the square roots of their densities; for they are proportional to the square roots of the altitudes from which the molecules are supposed to fall, and these altitudes are inversely as the densities. Thus, hydrogen gas, the lightest of all the gases, and whose density is only 0·0688 of that of air, would enter a vacuum with a velocity of 4933 (= 1294 divided by the square root of 0·0688) feet in a second. It is to be remarked, however, that all those laws relative to the flow of gases, are rather inferences from theory than truths demonstrated by direct experiment.

In the case of air or any gas flowing into a space containing a gas of an inferior density, the velocity will be the same as that of an incompressible liquid of similar density with the effluent gas, and capable of exercising a pressure equal to the difference between the pressures of the two gases. Taking, for example, the case of a gas flowing from a gasometer into the atmosphere: let h denote the height of the barometer, and $h + \mathrm{H}$ that of the column of mercury exercising a pressure equal to the elasticity of the effluent gas, so that H is the difference of the two pressures. Also, let Δ denote the density of mercury, d that of the gas in the gasometer corresponding to the pressure $h + \mathrm{H}$, and v the velocity per second; then

$$v = \sqrt{\left(2\,g\,\mathrm{H}\frac{\Delta}{d}\right)} = 8\sqrt{\left(\mathrm{H}\frac{\Delta}{d}\right)}.$$

Now if, in the formula $p = k\,d(1 + a\,t)$, we substitute the pressure in the gasometer $(h + \mathrm{H})\,\Delta$ for p, and also for k its value as above determined in feet, this expression will become,

$$v = 1294\sqrt{\left\{\frac{\mathrm{H}}{h + \mathrm{H}}(1 + a\,t)\right\}},$$

where v is expressed in feet. If, therefore, A denote the area of the orifice in feet, the volume or number of cubic feet discharged in a second will be v A. It is to be observed, that the volume thus determined is the volume of a gas of the same density as in the gasometer; if it were required to find the number of cubic feet, at a different density, corresponding to the pressure of a mercurial column whose height $= h'$, it would be necessary to multiply the above expression by the ratio $(h + \mathrm{H}) \div h'$.

From the experiments of D'Aubuisson, it has been ascertained that air, in passing through an orifice pierced in a thin plate, forms a *vena contracta*, whose area, as in the case of a liquid, is 0·65 of the area of the orifice. The application of cylindric adjutages increases the quantity issuing through the orifice to 0·93, and a conical tube to 0·95. The length of the adjutage may be 20 or 30 times the diameter of the orifice before the discharge begins to be diminished by friction. If, therefore, we suppose the gas to flow through a cylindric tube, and assume the multiplier 0·93; and also express the area of the orifice in terms of the diameter of the tube, which we shall suppose $= m$ feet; then, observing that $4\,\mathrm{A} = 3{\cdot}14159 m^2$, the formula for the number of cubic feet discharged in a second, the density being measured by $h + \mathrm{H}$, will become

$$945\,m^2\sqrt{\left\{\frac{\mathrm{H}}{h + \mathrm{H}}(1 + a\,t)\right\}}.$$

POLARIZATION OF LIGHT. Light which has undergone certain reflections or refractions, or been subjected to the action of material bodies in any one of a great number of ways, acquires a certain modification, in consequence of which it no longer presents the same phenomena of reflection and transmission as light which has not been subjected to such action. This modification is termed the *polarization of light;* its rays being supposed, according to particular theoretical views, to have acquired *poles* (like the magnet) or sides with opposite properties.

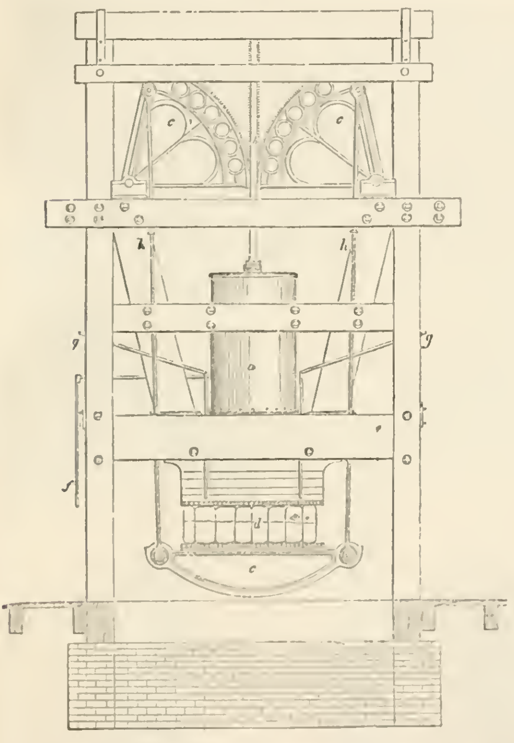
The polarization of light may be effected in various ways, but chiefly in the following: 1. By reflection at a proper angle from the surfaces of transparent media, as glass, water, &c. 2. By transmission through crystals possessing the property of double refraction. 3. By transmission through a sufficient number of transparent uncrystallized plates placed at proper angles. 4. By transmission through a number of other bodies imperfectly crystallized, as agate, mother of pearl, &c. The saccharometer lately invented is based upon this property of light.

POTASSIUM. This extraordinary metal was discovered by Davy, in the year 1807, and was one of the first fruits of his researches into the chemical powers of electricity. Its properties are so remarkable, that it was for a time doubted whether it could with propriety be placed among the metals; but the progress of discovery has removed all difficulty upon that point, by making us acquainted with other metallic substances, the properties of which are, as it were, intermediate between those of potassium on the one hand, and the common metals on the other. One of the striking peculiarities of potassium is mechanical rather than chemical, namely, its low specific gravity, it being the lightest known solid; another is its intense affinity for oxygen, and its consequent energetic action when placed upon water, where it immediately takes fire. The specific gravity of potassium is ·865 at the temperature of 60°; it is solid at the ordinary temperature of the atmosphere; at 80° it becomes soft, and at 150° is perfectly liquid; at 32° it is brittle, and has a crystalline texture. In color and lustre it resembles mercury. Its attraction for oxygen is such that it immediately loses its brilliancy on exposure to air, and becomes converted into potassa.

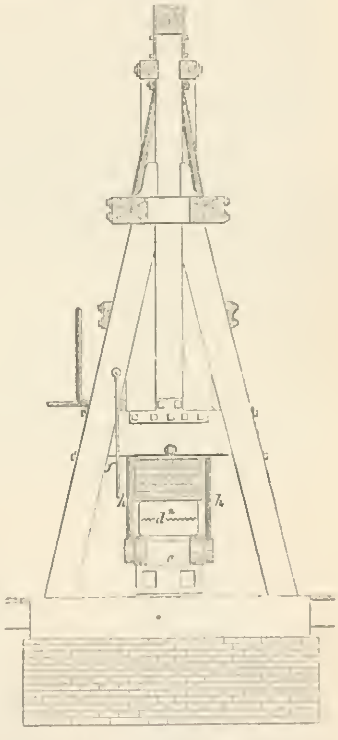
PRESS. Under the head of hydrostatic press will be found a full description of Bramah's most useful invention, and this is in general use for the baling of goods for shipment, for the pressing of paper among printers and lithographers, for the corrugation of iron and metals. It was used by Stephenson for raising the tubes of the Conway and Menai Bridges, and by Brunel for the launching of the Leviathan. It is the most compact of all machines for the transfer and multiplication of power, but is slow in its operation, as usually the speed when driven by power is the same with and without the maximum load.

To obviate this difficulty, a steam press has been invented by Philos B. Tyler, called the PROGRESSIVE LEVER STEAM, 16th January, 1845, which is extensively used in the baling of cotton.

3099.



3100.



Looking to the fact that at the commencement of the operation the resistance is very small, scarcely perceptible, and gradually increases as the density of the cotton increases under the action of the press. Mr. Tyler conceived the happy thought of interposing between the piston rod of the engine and the follower of the press, what are known in mechanics as progressive levers; that is, levers so arranged that at the commencement of the operation, when the resistance presented by the cotton is at its minimum, the arms in connection with the follower shall be at their greatest length, and those in connection with the piston at their shortest, and, as the resistance increases, that these relations of the arms of the levers shall be changed gradually and in proportion to the increasing resistance of the cotton, until at the end of the operation—when the cotton presents its maximum resistance—the arms of the levers in connection with the piston shall be at their greatest length, and those in connection with the follower at their shortest.

By this combination, mechanically true and admirably adapted to the purpose, Mr. Tyler was enabled to produce a steam press which will compress a bale of cotton within the smallest practicable compass with a steam-cylinder and piston of very small capacity, and economize to the utmost the consumption of steam; for at no time from the commencement to the end of the operation, is there any more steam applied and consumed than what is necessary to meet and overcome the resistance presented by the cotton and the necessary friction of the mechanism.

There are various modes of applying the principle of this invention, for there are various modifications of the progressive lever, all of which may be employed to form the connection between the piston and the follower of the press, on the principle invented by Mr. Tyler; but the arrangement selected and adopted by him is represented in the accompanying engravings, in which Fig. 3099 is a front, and Fig. 3040 a side elevation.

In this arrangement the bed *a* is inverted and attached to the under side of a beam *b* of the frame, to the upper side of which beam is secured the cylinder *c*, of the steam-engine, to avoid undue strain on the frame; for in this way the beam is simply exposed to a crushing force.

Within the cylinder there is a piston of the usual construction, the rod *d* of which is provided on opposite sides with cogs *c c*, to form two racks which engage the cogs of two sector-racks *f f*, that turn on fulcrum-pins *g g*. As the fulcrum-pins of these two sectors have to bear the brunt of the power applied, the boxes in which they turn are secured at the angles formed by a cross-beam *h*, and the sides *i i* of the frame, and from the under side of this cross-beam, there are two diagonal braces which extend down to, and rest on the beam *b*, each side of the steam-cylinder.

The sectors are connected with the follower R of the press by means of four connecting-rods *l l l l*, two on each side.

The steam-cylinder is provided with the requisite steam and discharge pipes and valves, by means of which the attendant admits steam from a boiler to the under side of the piston, and, at the end of the operation, permits it to escape.

From the foregoing it will be seen that when steam is admitted the piston is forced up, which causes the two sectors to vibrate, and by reason of their connections to draw up the follower, forcibly compressing the cotton between its upper surface and the under surface of the bed until the cotton is compressed into a bale *m*, of the required density, which is then tied up in the usual way.

It will be observed that the line of action of the piston-rod on the two sectors is always at the same distance from their fulcra, so that these two will be constant levers during the entire operation, but the connecting-rods attached to the follower being jointed to the sectors, as these vibrate upwards, the lines of the rods gradually approach the fulcra; hence the leverage of these connections gradually decreases during the operation; and from this it follows that the leverage power with which the piston acts on the follower, gradually increases in the ratio of the increasing resistance of the cotton.

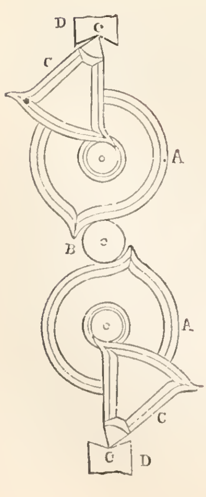
This is a good form of press, both from the soundness of the principle on which it rests, and the simplicity of the mechanical arrangement employed to carry out that principle. In practice it is found to economize fuel and labor, and is so easily managed by ordinary hands that it will supersede many other presses for this purpose.

A press similar in principle to this, but worked by hand instead of power, is used in many of the smaller cotton factories for the baleing of goods.

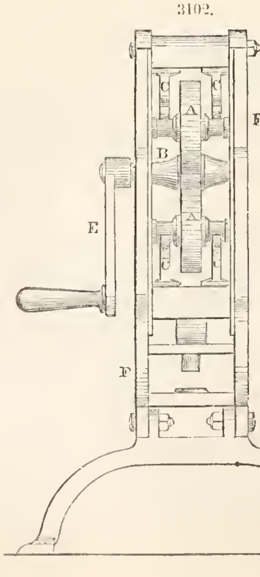
PRESS. Dick's *Anti-Friction Cam.* For punching and shearing iron and metals, a new principle of press has been introduced by Mr. Dick of Meadville, Pennsylvania, called the anti-friction cam: the machines are extensively made at Holyoke, Massachusetts. The principle of their construction will be readily understood from the following cuts and description:

Fig. 3102 represents the elevation, Fig. 3103 a section, and Fig. 3104 the combination of cams on a larger scale of one form of these presses intended for a punch. A A are two eccentric wheels; B is a roller between; *c c* are two pairs of sectors, constituting the bearings of the axes of the eccentric

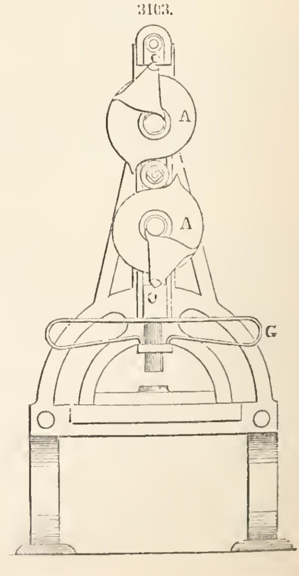
3101.



3102.



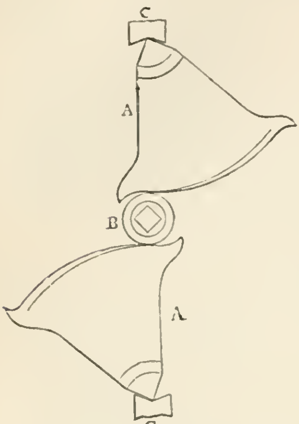
3103.



wheels; D D are sections of the follower and bearing of the sectors. The axes of the sectors are angular or edge shaped.

The centre roller B is made to revolve by means of the winch or lever E, which carries by its tractive qualities the two eccentric wheels A A, the axes of which having their bearing on the face of the sectors,

3104.



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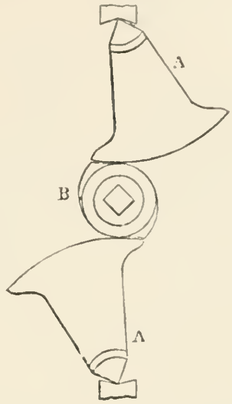
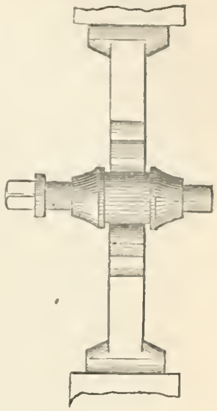


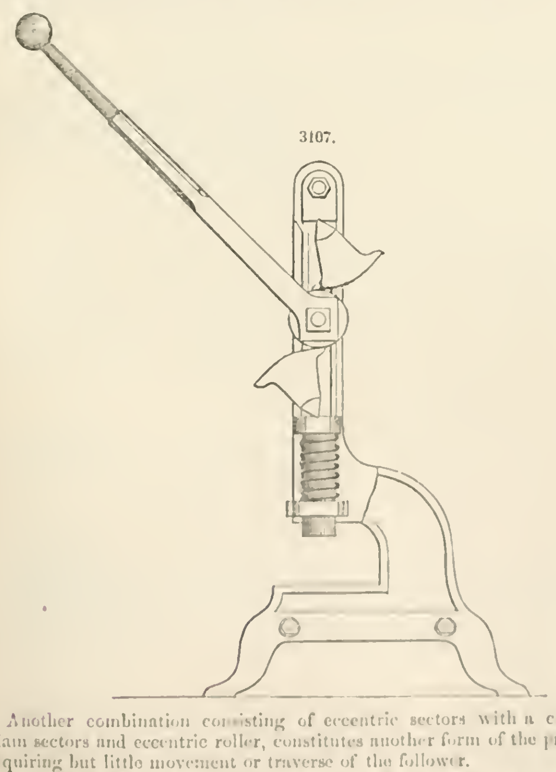
3106.



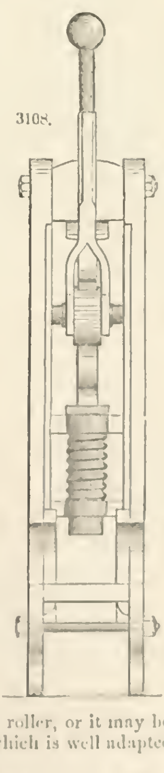
are transferred the length of their faces right and left; and as the sectors are edge shaped at their centre of motion *o o*, they necessarily revolve free from the impediment of rubbing surfaces, and consequently without friction.

When the eccentric wheels have made their revolution, the follower will have moved the sum of two eccentrics. When the press is constructed so that the follower moves down, a spring G may be used to return the moving parts to their places when the press is relaxed.

3107.



3108.



Another combination consisting of eccentric sectors with a centre roller, or it may be made with plain sectors and eccentric roller, constitutes another form of the press which is well adapted to purposes requiring but little movement or traverse of the follower.

A A, Fig. 3104, are two eccentric sectors; B is a centre roller; C C are sections of the follower and bearing. Fig. 3106 is an edge view of the same, showing the longitudinal extension of the edges corstituting the axes of the sectors. Fig. 3107 is a view of the same as it is set in the frame, with one side of the frame removed. Fig. 3108 is an edge view of the same with frame and lever all complete.

For further illustration of mechanical devices which may be ranked among presses, see EMBOSSING MACHINE, PUNCHING AND SHEARING MACHINE, PRINTING PRESS, ETC., ETC.

PRINTING MACHINE, S. W. Francis' Patent. The principal feature of this invention consists in arranging a row of hammers in a circle, so that, when put in motion, they will all strike the same place, which is the centre of the said circle. The paper is not touched by the operator till the page is finished, being worked by means of a spring and catch, so connected with the keys, that it moves the paper the distance of one letter whenever a key is struck. On the face of each hammer a letter is cut in relief, in such a position, that its impression on the paper is parallel with those of the others. When within four letters of the end of the line, a little bell rings, giving notice to the operator that the word, if of more than one syllable, must be divided by a hyphen. At the end of each line, the "car," which carries the paper, is drawn back, and the paper is moved the distance of two lines, in a direction perpendicular to the printed line, by means of a catch hereinafter described. The keys are connected with actions somewhat similar to those used in pianos, by means of wires and bell-cranks, which actuate the hammers. There is also an arrangement for rendering the simultaneous *action* of two or more hammers impossible. It is obvious that by causing two or more hammers to strike against each other, serious injury would be caused—rendering machines, where key-boards are used, practically useless.

Fig. 3109 represents a top or plan view of the machine (in part); fig. 3110 a detailed section of an action and hammer, and fig. 3111 an open and front view of the stop-bolts beneath the keys, for the purpose of preventing the downward motion of more than one at the same time.

(Fig. 3109). *B* is one of the sides, which together with the cross-bars *F* and *C*, fig. 3110, forms part of the frame to which all parts of the mechanism are secured. Fig. 3110. The keys *K L*, *K' L*, are disposed in a longitudinal series under the cross-bar *C*. They all carry a counter weight *M*, which brings them by gravity to rest against the board *A*. Their downward motion is checked by a cross-bar into which the screw *R* enters—two pins act as guides for each key. Under and between the keys, (fig. 3111,) a row of vertical stop-bolts *P Q*, *P' Q'*, *P'' Q''*, are pivoted by screws *R*, *R'*, *R''*, and are in contact with each other; the tops are bevelled on both sides, and are lodged in corresponding recesses of and between the keys. The recesses are made twice as large as the tops of the stop-bolts *P Q*, *P' Q'*, which enter them. By this arrangement it is impossible to bring down more than one key at the same time; for supposing a key *K'*, depressed, the stop-bolt *P Q*, placed on the left side of the key, with all the other stop-bolts on the same slide is pushed simultaneously in the same direction. The same effect is produced on the right side beginning with stop-bolt *P' Q'*, and so on. If, however, it is attempted to bring down two keys at once, all the stop-bolts between them, being equally pressed to the left and right, will keep their places directly under the spaces between the keys, whereby the two keys which are acted upon, are prevented from coming more than $\frac{1}{16}$ of an inch.

(Fig. 3109.) The keys are connected with the "actions" by means of wires *V*, *V'*, *V''*, *S*, *S'*, *S''*, and bell cranks *T*, *T'*, *T''*. These actions and the hammers are attached to a circular frame *Y*, (in fig. 3110,) which is fastened to central opening of the board *A*, (fig. 3110). Each action is composed of a rocker *p* movable on a fulcrum, of a pawl *p*, having its fulcrum attached to the upper end of the hammer at *Z*. When a key *K*, is depressed, that part of it to which the wire *S* is attached at *o''*, pulls upon the rocker *p'*, moving the pawl *p*, and thereby causing the hammer *V* to strike the stud *Pl*.

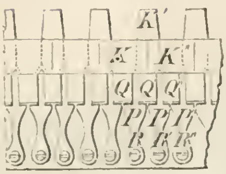
(Fig. 3109). An arm *k* projects, from which hangs a stud, fig. 3110, against the end of which all the hammers are made to strike. This arm moves on a cam, and is turned up on either side, while the paper is put in the car *g' d' e'*, which moves on rails *c*, *b'*.

The inking is effected by a silk band *p*, which is carried on four pulleys similar to *l*, secured on two sliding brackets similar to *z v*. The brackets may be elevated when the band is inked—it retaining ink for four days. The paper is carried upon a "car," sliding between two rails *c b'*; this car consists of a quadrangular frame *d' e' f' g'*, supporting two rollers *h' i'*, and the heavy flat bar *J'*, to which the latter is united by means of levers *p' q'*, *n' n'*, and rod *m'*, in such a manner, that when J' is raised from the frame, along a circle the centre of which is at *n'*, the roller *i'* is equally raised by moving round the axis *p' q'*. The paper to be printed is first placed upon the roller *h'*, the roller *i'* is then brought down upon it, and the weight of the bar *J'* causes the rollers to hold together.

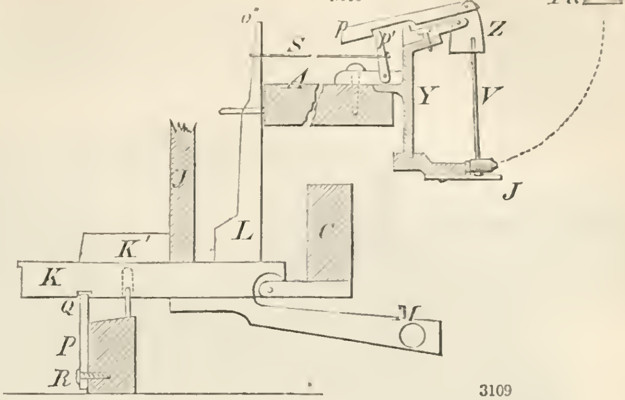
The car is propelled by a spring power, which consists of a spiral spring pulling the car by means of string *s'* passing over pulleys in a direction contrary to the lines to be printed. To the opposite end of the car is attached a cord *a'*, which, passing over a pulley, winds around a barrel *b''*; the latter is firmly mounted upon a round disc *c''*, which is furnished with a row of pins near the periphery thereof. *d'* is a catch; on the under side it has a notch, through which the pins may pass in one direction only; this is effected by means of a spring which causes the opening by the pressure of the pins against it, thus establishing a bar against the passage of the said pins; hence, against the revolution of the disc in that direction. The catch is connected by a proper system of leverage with the frame *g'' h''* and the side of the caseing. The frame bears against a stud by means of a spring, but when acted upon by either of the levers *L*, (fig. 3110,) it will also actuate the catch by withdrawing the spring from the said pressure of the pins. The spring thus relaxed allows the passage of one pin, but backs against the next following one. These are the means employed to feed the "car," and consequently the paper, the distance of one single letter, until the whole line is completed.

The knob *q''*, is then pulled so as to bring the stud *Pl.*, (fig. 3110,) to bear against the first letter of the next following line. The moving of the paper in a direction perpendicular to the lines is effected by means of a spider-wheel *v''*, made fast to the shaft end of the roller *i'*, and by means of a lever *S''*, and spring *u*. When the car is pulled to the right, one of the spokes of the spider-wheel *v''* is pressed against the inclined side of the lever *S''*, and is turned the distance of two lines; but when the car goes back, the spring *u* plays and the position of the spider-wheel *v''* remains unchanged. The pulley similar to *l* is

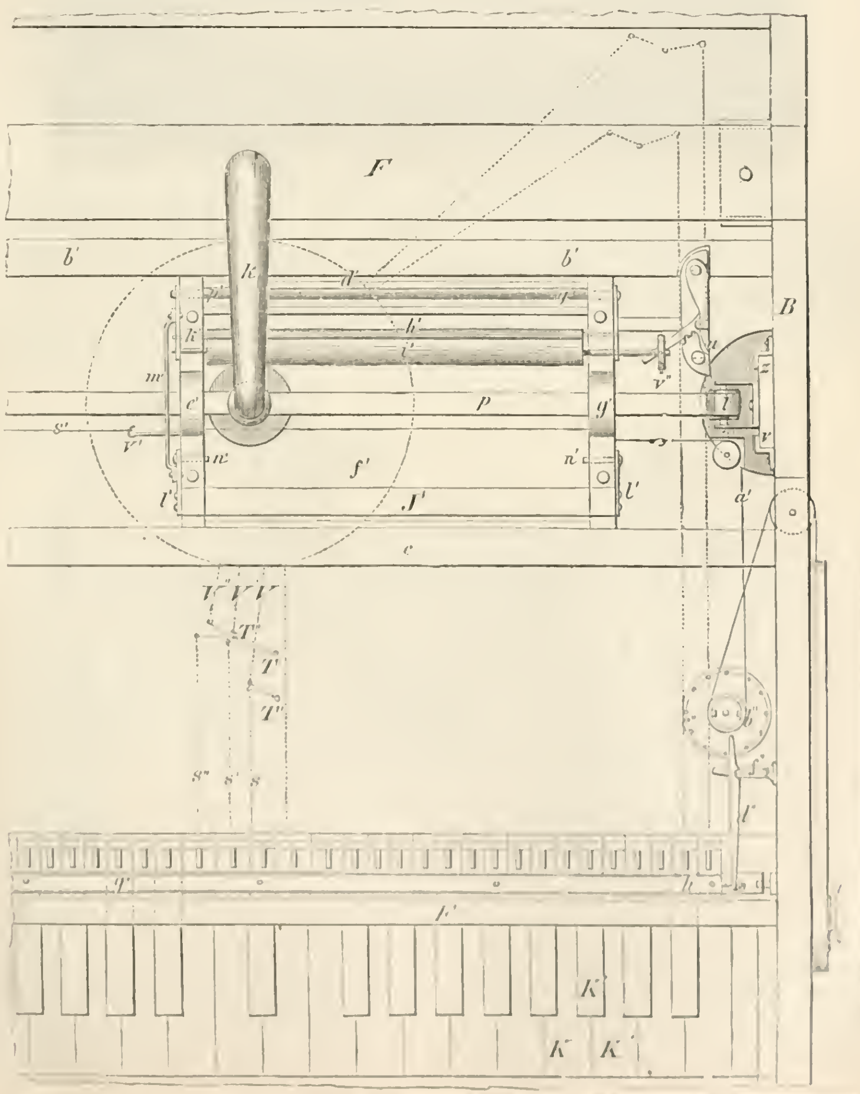
3111



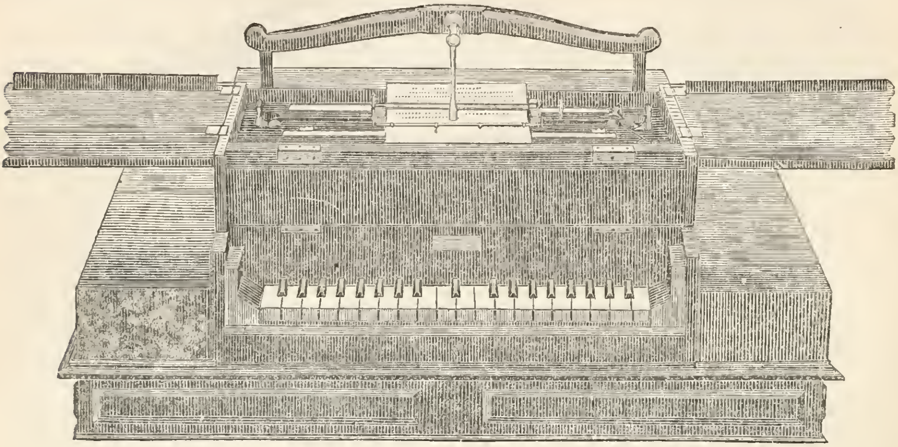
3110



3109

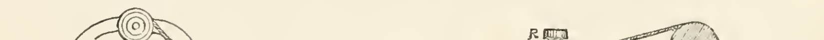


free on the shaft of the band pulley, and carries a ratchet so arranged in relation to a ratchet wheel upon the shaft, that when the car is moved to the right the pulley turns freely, and when the car moves to the left, the pulley carries the other pulley with it; the band is thus caused to follow the movements of the car, and every letter strikes it in a different place. The band is placed between two pieces of paper, a thick one below and a thin one above; by this means two copies are printed at the same time and with equal facility.



The above description with the cuts, explains fully the construction of a machine necessarily somewhat complicated, but not necessarily liable to derangement by use. On examining the above cut or perspective view of the complete machine, it will be seen to resemble a piano in its general form and arrangements, in its finger-board, and in the position of the manuscript or rather proof. The keys respond as easily to the touch, and the letters appear on the paper in front of the operator. The average size of this portable machine is two feet square, not much larger than a writing desk.

PRINTING-PRESS, LITHOGRAPHIC. Fig. 3109 is a front elevation of a lithographic printing press, by William Smart, of London. The principle of it consists in the whole of the press-work, with the ex-

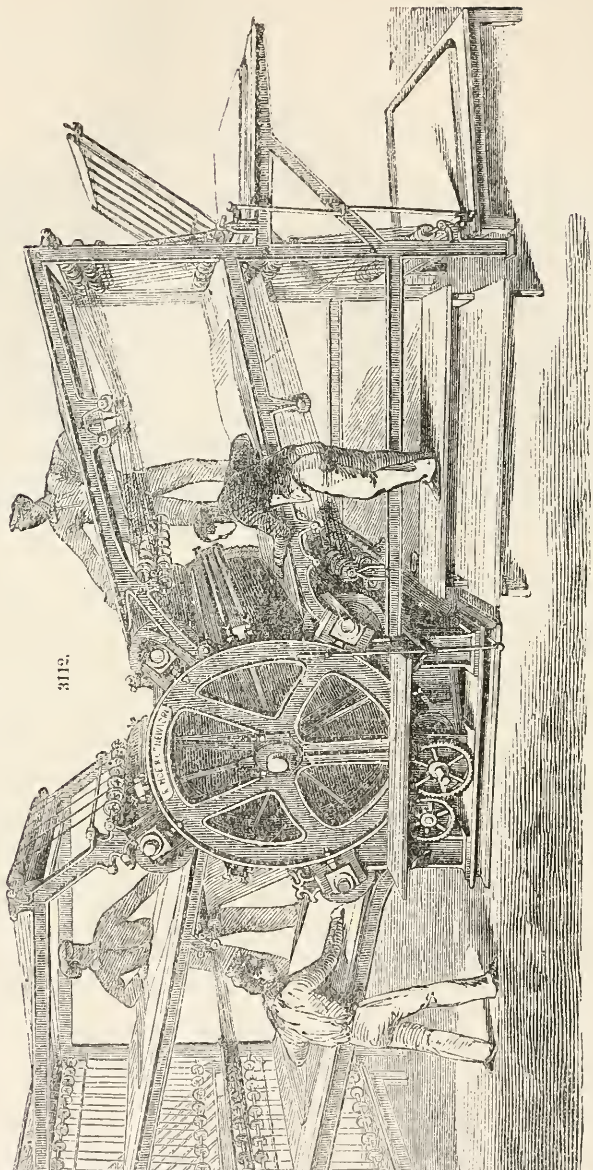


ception of the operation of laying on and taking off the paper, being performed by a series of movements resulting from the first motion given to the machine, and not requiring the aid of hand labor to perform the work as heretofore. A portion of the standard frame is removed at one end. A A are the standard and body frames of the machine. B E is the driving-shaft and pinion, receiving motion from steam or any motive agent, and communicating the same to the wheel C, which takes into and geers with D, thereby giving motion to the wheel G, which drives the pinion F. Keyed on the main shaft with the pinion F is a large toothed wheel H, moving loosely on its centre or shaft, the periphery of which is perforated with the stud holes at the side, of sufficient size to enable the studs, when brought in contact with them, to enter into and take hold of the wheel H; for this purpose a ring or disk of metal keyed to the main shaft with the projecting studs is employed, so that by any lateral action, caused by a shifting clutch-box on the main shaft, the wheel H may be coupled with the fixed disk by the studs entering into and uniting the two together, and revolve with the main shaft; mounted, also, upon this shaft, there is a concentric double-action motion rack I, in which a pinion takes into, first on the outside thereof, thereby causing the toothed wheel H to be thrown in play during the printing process in one direction; and secondly, on the inside, by passing through an opening in the periphery of the rack, and reversing the wheel. J is a horizontal rack, moving longitudinally in the direction of a machine, in a suitable iron bed, in geer with the large toothed wheel H. K is a wooden bed or sleeper fixed to the traversing-frame, on which a rectangular slab of slate is fitted to receive the stone L at the top. M are surplus head standards carrying the wetting and inking apparatus; this part of the improvement consists in giving motion by means of the endless strap from the driving rigger on the main shaft to the doctor ink-roller, which revolves at right angles with the supply and distributing rollers situated underneath, in the manner represented by the figures 1, 2, 3, 4, 5, 6, 7, 8, 9; for example, by the revolutions of the rollers 2 3 moving on the face of the doctor they receive ink therefrom and convey it, through the intervention of other rollers, to the stone, thereby completing the process of inking in the manner described. N is the water-trough and sponge-box. It consists of a vessel of water having a series of tubes passing through the bottom of the box with their upper ends above the surface of the water, whilst their lower ends communicate with the sponge. A warp of cotton is placed in the upper ends of the tubes, and allowed to descend into the trough below the water, which causes, by capillary attraction, the water contained in the trough to pass down the tubes in connection with the sponge, and supply it with water without overcharging it. This box is brought down on the surface of the stone when passing under for the purpose of wetting, and remains until the subsequent process of inking is performed, when, upon the stone returning to the centre of the machine from which it started, to receive the paper, the action of a cam, so operating upon a vertical rod in connection with it, causes the box to be raised and the stone to pass out in readiness for the next operation. O is a small framing mounted on the body standards A, for carrying the scraper and tympan-roller P. Q is the scraper, fixed to a strong cross-head, which is regulated to any height by the screw R in the centre. S is the tympan-cloth, which is fixed at one end to a bar T; the other end is coiled round a roller P, on the shaft of which a pulley-wheel is fixed, having a cord or rope bearing on it in such a manner that by the effect of this rope passing over another pulley, suspended at a distance apart, as shown, it shall cause, by the action of a weight at one end, the tympan cloth to be kept stretched, so that when the traversing-frame, with the stone, is passing under the scraper, it may catch hold of the bar T, and by the onward motion of the traversing-frame unwind the tympan-cloth and lay it over the stone until it shall have passed under the scraper and completed the printing operation. When, by the pressure being withdrawn from underneath the stone, the weight suspended from the end of the cord in connection with the pulley P is then the medium through which the bed and stone is driven back into the centre of the machine ready for the next operation, by reason of the weight acting in such a manner that when the tympan-cloth has been unwound and placed on the surface of the stone, the mode of again winding it up is only effected by the proximity of the bar T to the roller P producing the diminution in the space from the contraction of the tympan-cloth. To apply the power to the scraper and the traversing-frame, a pressure roller is employed, actuated by a cam producing pressure at given times, such as when the stone is passing under the scraper; but as soon as it has performed such operation the pressure will be withdrawn, and the means employed to assist its return rendered free to act. There is an arrangement consisting of a long bar or bearer U, with a counterbalance weight affixed; this bar passes along the sides of the frame-work, and touches the boss of the cam-wheel V, to which is attached a concentric arm revolving with it; the movement produced by such means on the long lever is for throwing a stop behind the traversing-frame and checking its further progress when not required, at the same time giving to it an elasticity by the application of a spiral spring, so as to prevent concussion. On the means employed for throwing the driving-wheel H in and out of geer, depends the proper working of the machine. The means of employing studs, as described, consist in fixing two peripheries together by pressing the projecting pins on one periphery into the opposite holes in the other; for this object a side lever with a forked end is placed in connection with the clutch-box on the main shaft, which it shifts laterally within the limits of its fulcrum by the rotation of a cam placed on the sides of the toothed wheel V; this lever, so acted upon by the cam, requires a corresponding pressure to keep it up to its work. To do this, the weight is applied and attached to it by a cord passing over the wheel Y and attached to the lever, so that when the cam moves the end of the lever outwards the weight X will be raised, but when it falls it will tend to move inward and throw out of geer the coupling disk aforesaid. When motion is given to the driving-shaft B by E, and communicated through the train of toothed geering wheels to the main shaft F, such motion, in consideration of the parts arranged for such purposes, is caused to move the traversing-frame by reason of the teeth of the wheel H taking into the teeth of the horizontal rack, and propelling it in either direction by the reversing rack. The rollers may be made of india rubber and kept cool in a trough of cold water.

PRINTING-PRESS. We cannot do better under this head than to exhibit the various presses manufactured for this purpose, by R. Hoe & Co., of New York.

Type-revolving, fast printing machine.—Fig. 5112. A horizontal cylinder of about four and a half feet in diameter is mounted on a shaft, with appropriate bearings; about one fourth of the circumference of the cylinder constitutes the bed of the press—the periphery of which portion is adapted to receive the form of types—the remainder is used as a cylindrical distributing table. The diameter of the cylinder is less than that of the form of types, in order that the distributing portion of it may pass the impression cylinders without touching. The ink is contained in a fountain placed beneath the large cylinder, from

3112.

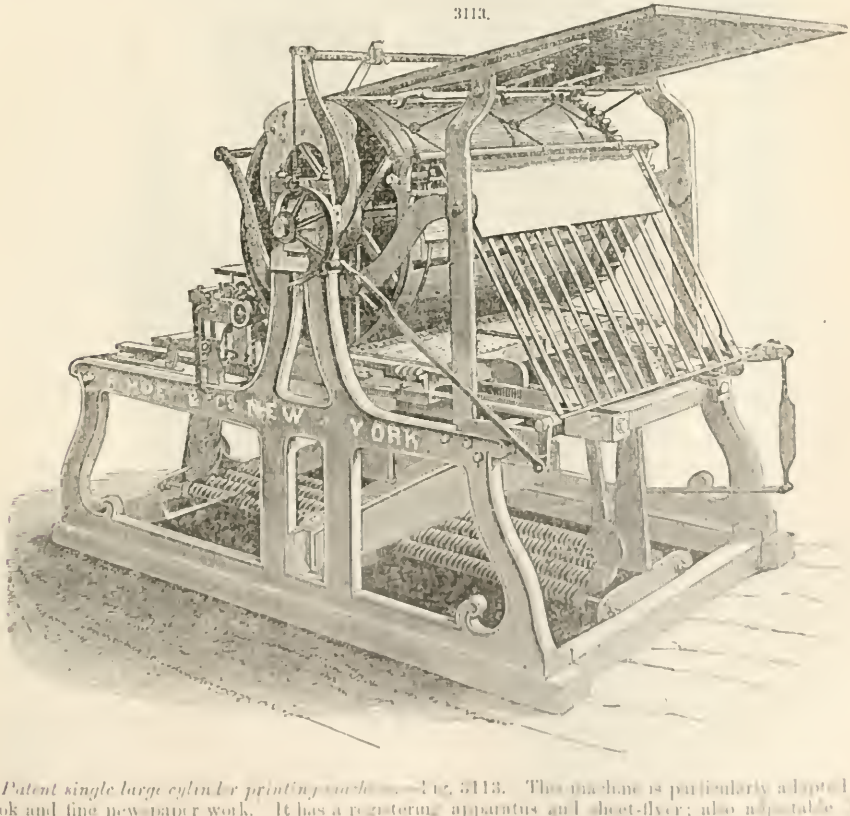


which it is taken by a ducter roller and transferred, by a vibrating distributing roller, to the cylindrical distributing table; the fountain-roller receives a slow and continuous rotary motion, to carry up the ink from the fountain.

The large cylinder being put in motion, the form of types thereon is, in succession, carried to four or more corresponding horizontal impression cylinders, arranged at proper distances around it, to give the impression to four or more sheets, introduced one by each impression cylinder. The fly and feed boards of two of the impression cylinders are similar to those on the well-known double-cylinder press; on the other two, the sheet is fed in below and thrown out above. The sheets are taken directly from the feed-board by iron fingers attached to each impression cylinder. Between each two of the impression cylinders there are two inking-rollers, which vibrate on the distributing surface while taking a supply of ink, and at the proper time are caused to rise, by a cam, so as to pass over the form, when they again fall to the distributing surface. Each page is locked up upon a detached segment of the large cylinder, called by the compositors a "turtle," and this constitutes the bed and chase. The column-rules run parallel with the shafts of the cylinder, and are consequently straight; while the head, advertising, and dash rules are in the form of segments of a circle. A cross-section of the column-rules would present the form of a wedge, with the small end pointing to the centre of the cylinder, so as to bind the types near the top; for the types being parallel, instead of radiating from the centre, it is obvious that if the column-rules were also parallel, they must stand apart at the top, no matter how tight they were pressed together at the base; but with these wedge-shaped column-rules, which are held down to the bed or turtle by tongues, projecting at intervals along their length, and sliding in rebated grooves cut crosswise in the face of the bed, the space in the grooves, between the column-rules, being filled with sliding blocks of metal, accurately fitted, the outer surface level with the surface of the bed, the ends next the column-rules being cut away underneath to receive a projection on the sides of the tongues, and screws at the end and side of each page to lock them together, the types are as secure on this cylinder as they can be on the old flat bed.

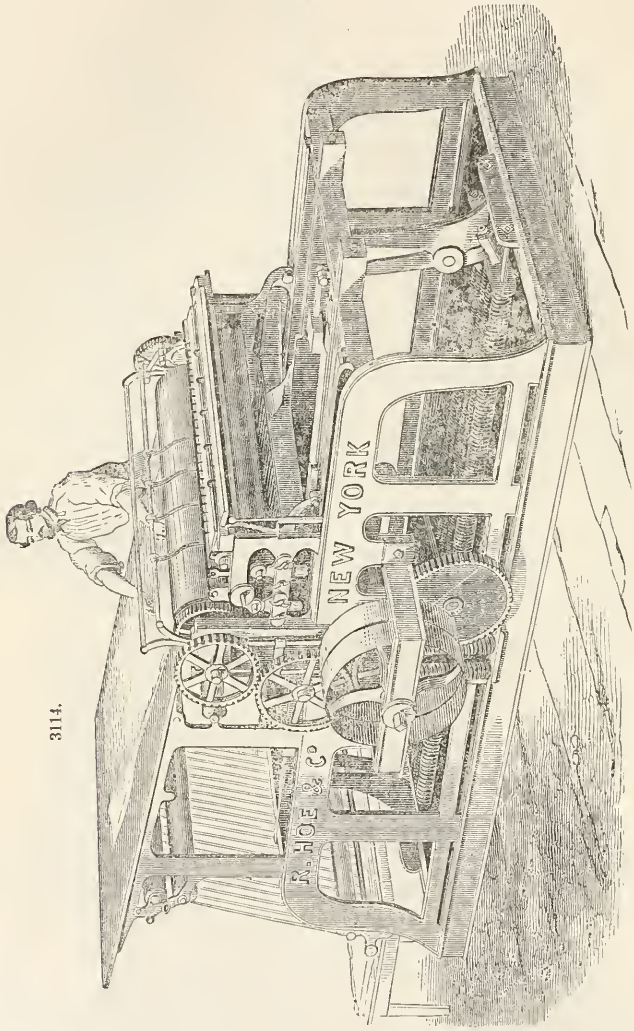
Fig. 3112 represents a press with four impression cylinders, capable of printing 10,000 impressions per hour. Four persons are required to feed in the sheets, which are thrown out and laid in heaps by self-acting flyers, as in the ordinary cylinder presses. A press with eight impression cylinders will print 16,000 or more impressions per hour.

3113.



Patent single large cylinder printing-machine.—Fig. 3113. This machine is particularly adapted to book and fine newspaper work. It has a registering apparatus and sheet-flyer; also adjustable iron bearers, so that stereotype may be worked with the same facility and beauty as type forms. One boy is required to lay on the sheets, and the press may be driven by man or steam power. With the same attendance, it will print, say from 1,000 to 2,000 impressions in an hour, according to the size of the press and the quality of the work desired.

Single small-cylinder printing-machine.—Fig. 3114. In this press the form of types is placed upon a flat bed, and the impression taken upon the paper by means of a cylinder, while the form is passing under it. The small size of the cylinder allows the machine to be constructed in a very compact manner, so as to shorten the distance which the bed travels, thereby considerably increasing the number of impressions in a given time, beyond the single large-cylinder press.



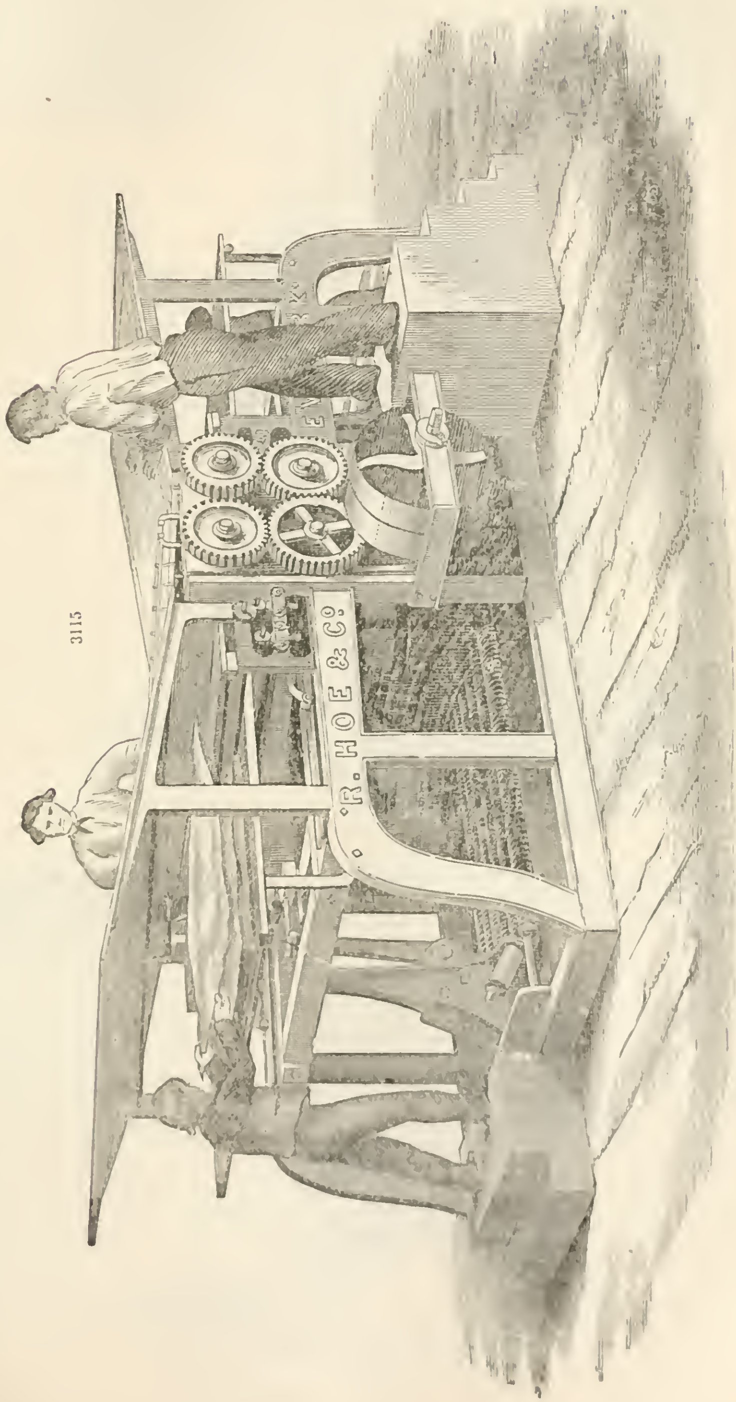
3114.

This machine is of convenient height for use. One person only is required to feed down the paper whose position is but a step from the floor. It will give from 2,000 to 3,000 impressions per hour, with perfect safety to the machinery. The printed sheets are thrown out by a fly-frame in a uniform pile. Register sufficiently accurate for newspaper and job work is obtained by the patent feed-guides, which are attached to each press. When required, a registering or pointing apparatus is furnished, and the press may then be used advantageously for book-work.

The press is made in the same manner as the double-cylinder press described above, with buffers similarly arranged to prevent noise.

Double-cylinder printing-machine.—Fig. 3115. In its arrangement this press is similar to the single small-cylinder machine; except that it has two impression cylinders each alternately giving an impression from the same form. The sheets are supplied by two attendants, and, if required to print short editions of various sizes, it will be necessary to have a boy at each end of the press to receive the printed sheets; but where large editions or forms of uniform size are worked, not requiring frequent changes of the tape-wheels, the self sheet-flying apparatus is very efficient and economical, placing the printed sheets in heaps with precision, and dispensing entirely with the two boys otherwise required for that purpose.

The large amount of printing ordinarily done on these presses, and the consequent speed required, have rendered necessary greatly increased strength and weight of material in all the parts, together with

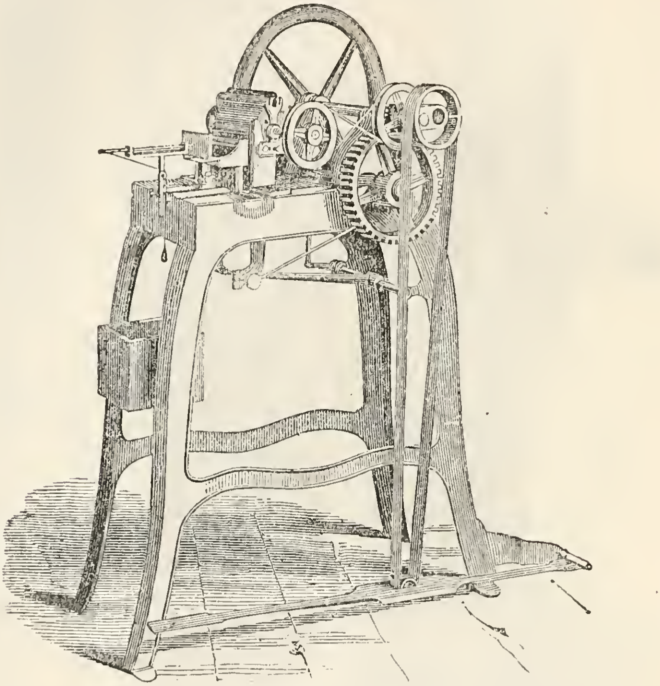


3115

simplicity in the mechanical arrangements, and the utmost perfection of workmanship. The noise and annoyance occasioned by the concussion of the bed against the springs, which are placed at each end of the machine to overcome the momentum of the bed, has been removed by means of adjustable india-rubber buffers placed at the points of contact, which in no way interfere with the lively and certain action of the spiral springs.

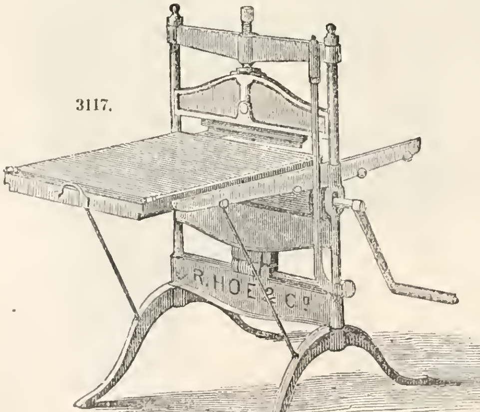
Patent machine card-press.—Fig. 3116. For printing cards and small circulars, this machine is not surpassed. It is worked by either a crank or treadle, and will print from 1,000 to 1,500 cards per hour and may be used also for printing note-paper and small circulars. Its feeding apparatus for cards is self-acting. Size of chase inside 6¼ by 5 inches.

3116.



Improved lithographic-press.—Fig. 3117. This is believed to be the best press in use for lithographic printing. The side-rods and top beam are made of wrought-iron; the bed and stone are raised to the scraper by a lever and steel cam, working on a steel friction-roller; the impression is regulated by a

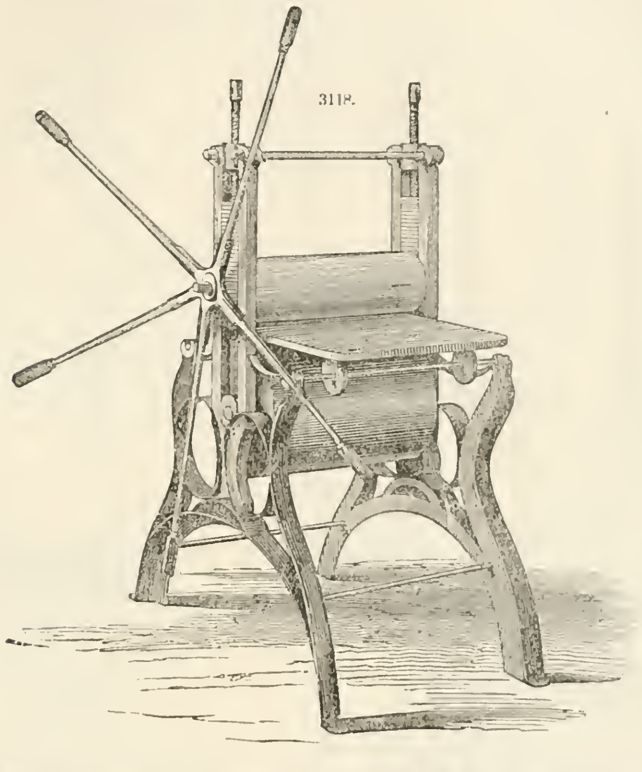
3117.



single screw through the top beam; the scraper is hung on a pivot, that it may accommodate itself to inequalities in the surface of the stone; the bed is made of the toughest ash plated with iron, with iron runners, which run on friction-rollers; the tympan-frame is wrought-iron, with screws and nuts for stretching the tympan. The larger sizes are geered, so as to enable the printer to take an impression from the largest stone with ease.

Copperplate-press.—3118. The side-frames, cylinders, and bed are made of cast-iron; the cylinders are turned and the bed planed perfectly true. The shafts through the cylinders, the braces, arms, and screws, are of wrought-iron, the bearings of composition.

3118.



PROJECTION. Projections are of various kinds, according to the situations in which the eye is supposed to be placed in respect of the body and the plane on which it is to be projected; but there are three which, by reason of the frequency of their use, are particularly deserving of attention, namely the *orthographic*, the *stereographic*, and the *central* or *gnomonic*.

1. *Orthographic projection.*—In this projection the eye is supposed to be at an infinite distance, and the *plane of projection*, i. e., the plane on which the representation is made, perpendicular to the direction of the rays of light, which are all parallel to each other. The laws of this projection are easily deduced. 1. Any point in space is projected by drawing a straight line from it perpendicular to the plane of projection. 2. A straight line perpendicular to the plane of projection is projected into a point. A straight line parallel to the plane of projection is projected into an equal straight line; and a straight line inclined to the plane of projection, is projected into a straight line which is shorter than the first in the proportion of the cosine of the angle of inclination to radius. 3. A plane surface perpendicular to the plane of projection is projected into a straight line. 4. A circle parallel to the plane of projection is projected into an equal circle; but a circle oblique to the plane of projection is projected into an ellipse, of which the greater axis is equal to the diameter of the circle, and the lesser axis is equal to that diameter multiplied by the cosine of the obliquity.

The orthographic projection has a multitude of applications. The plans and sections by which artificers execute their different constructions are orthographic projections of the things to be constructed; and a solid body may be represented in all its dimensions by orthographic projections on two planes at right angles to each other.

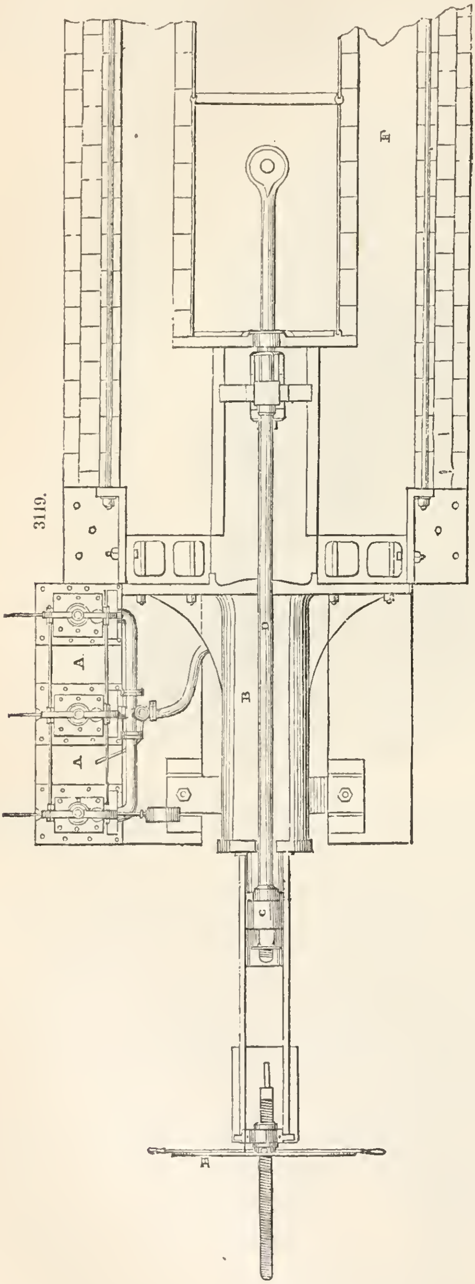
2. *Stereographic projection of the sphere.*—In this projection the eye is supposed to be situated at the surface of the sphere, and the plane of projection is that of the great circle, which is everywhere 90° from the position of the eye.

Two of the principal properties of this projection are the following: 1. The projection of any circle on the sphere which does not pass through the eye is a circle; and circles whose planes pass through the eye are projected into straight lines. 2. The angle made on the surface of the sphere by two circles which cut each other, and the angle made by their projections, is equal.

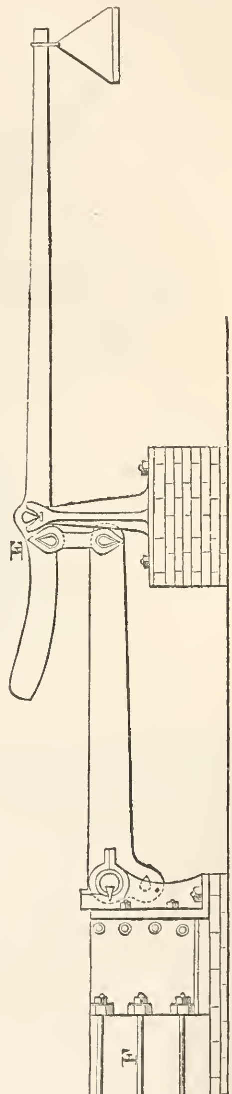
3. *Gnomonic or central projection.*—In this projection the eye is situated at the centre of the sphere and the plane of projection is a plane which touches the sphere at any point assumed at pleasure. The

point of contact is called the *principal point;* and the projections of all other points on the sphere are at the extremities of the tangents of the arcs intercepted between them and the principal point. As the tangents increase very rapidly when the arcs exceed 45°, and at 90° become infinite, the central projection cannot be adopted for a whole hemisphere.

3119.



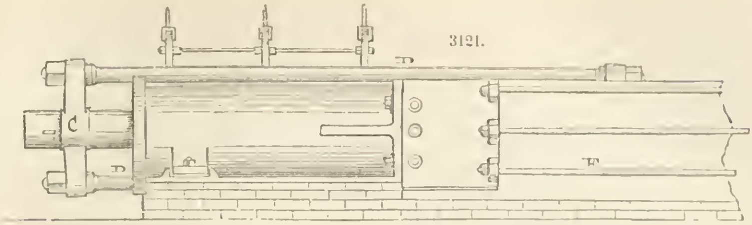
3120.



PROVING MACHINE, HYDROSTATIC, *for proving chain-cables.* Figs. 3119, 3120, 3121 and 3122 represent a machine designed and constructed by Wm. M. Ellis, engineer, United States Navy Yard, Washington.

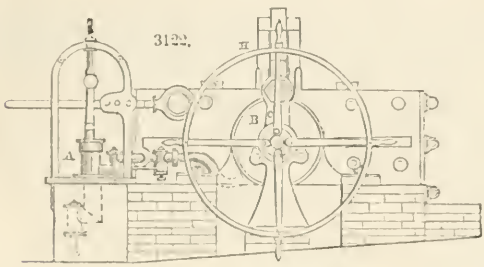
A A, plan, Fig. 3119, water cistern, with three force-pumps

3121.

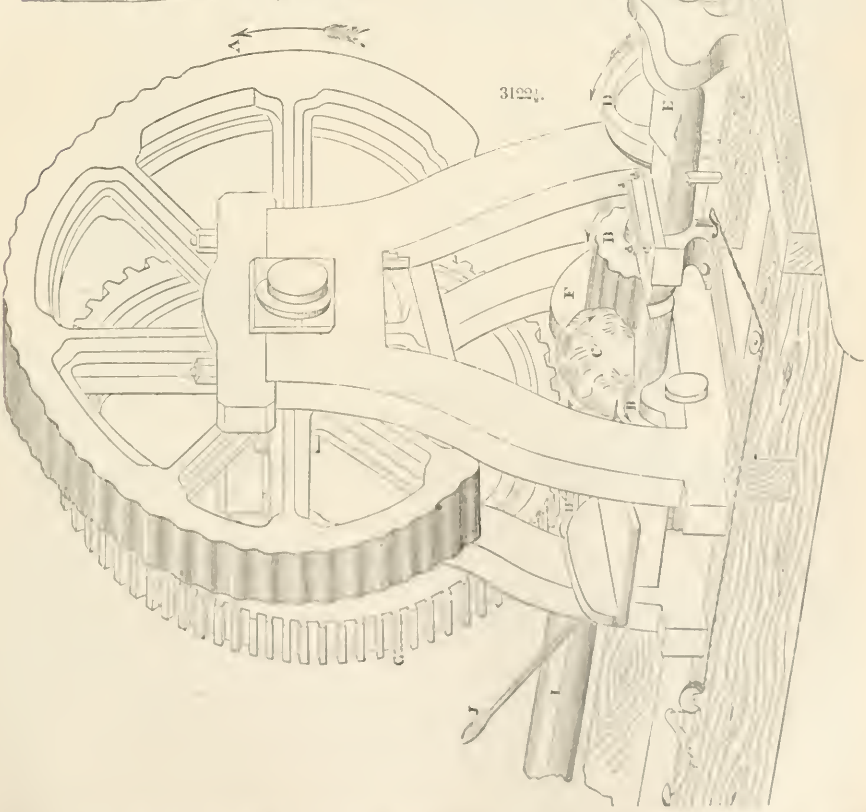


B, hydrostatic cylinder. C C, wrought-iron cross-heads. D D, wrought-iron bars, connecting cross-heads C C. F, granite sills.
H, screw-wheel, for forcing back the ram.
E, Fig. 3120, compound levers, for ascertaining the strain: proportion, 1 to 200. Fig. 3122, section.

3122.



3122½.



PUDDLER'S BALLS, MACHINE FOR COMPRESSING, by J. F. Winslow, Troy, N. Y. In Fig. 3122½, A is the rotating cam-formed compressor. B B, two cylindrical bed rollers. C, puddler ball of iron, resting upon and between the two bed rollers in position for being compressed by the rotating cam A. D, helical shaped cam, keyed on to the neck of one of the bed rollers B and revolves with it, and which forces outward the ram or hammer E, which, when released from the cam, a powerful helical spring which is inserted into a cavity in the outer end of the ram throws forward against the loop of iron and upsets it—the opposite end of the loop, or ball, or bloom being supported against the heavy flanch F, which is cast upon one of the bed-rollers, and serves as an anvil against which to upset or hammer the blooms. G, spur-wheel on the end of the shaft that supports the cam A. H, spur-pinion on the driving-shaft I. This pinion works into two others of corresponding size, one on the end of each bed roller. This driving-pinion H being interposed between the two on the bed-rollers and the spur-wheel G, gives the peripheries of all the rollers and the cam a direction the reverse of the periphery of the ball C, and all being in motion no waste or abrasion of the hot iron can ensue, as the ball must necessarily revolve upon its axis and be retained in proper place between the rollers and compressers I, shipping-bar. J, shaft communicating with the driving power.

Advantages.—1. Great expedition in shingling puddlers' iron, one of these machines being sufficient to do the work for 25 puddling furnaces. 2. The almost entire saving of shinglers' wages. 3. No waste of iron—turning out the blooms while very hot, enabling the roller to reduce them to very smooth and sound bars. 4. Scarcely no expense for repairs. 5. A very small amount of power required to operate it. 6. The ends of the blooms being thoroughly upset.

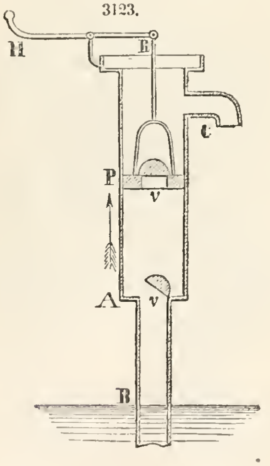
PULLEY. See Mechanical Powers.

PUMPS.—*The common pump.* Fig. 3123 represents a section of the common suction pump. A C is a cylinder or barrel, in which a piston P is moved up and down by means of a piston-rod R, attached to the extremity of the lever, R H, of the first kind. In the piston is a valve *v* lifting *upwards;* and at the bottom of the barrel is another valve V, also lifting *upwards.* A B is a pipe, passing from the bottom of the barrel into the well from which the water is to be raised.

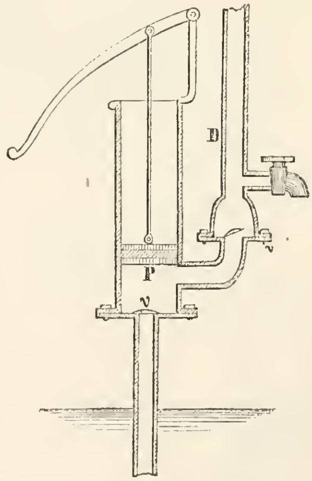
In the downward stroke of the piston, it plunges amongst the water in the barrel of the pump; the valve V closes, and the valve *v* opens, and allows the water to pass to the upper side of the piston. In an upward stroke the valve *v* closes, and the valve V opens, and, by the pressure of the atmosphere, the water follows the piston in its ascent, whereas the water above the piston is pushed before it, and thus the fluid is discharged in a stream at the mouth C of the pump; and so on to any number of strokes.

If a perfect vacuum were formed by the piston as it ascends, the water would be raised, on an average, to the height of 34 feet above the level of the water in the well, which is the height of a column of water calculated to balance the average pressure of the atmosphere.

3123.



3124.



The common forcing pump.—This pump, Fig. 3124, raises water from the well into the barrel on the principle of the suction pump just described, Fig. 3123, and then the pressure of the piston on the water elevates it to any height that may be required.

Here P is a solid piston working up and down in a barrel; V a valve, lifting upwards, placed at the top of the pipe descending into the well; *v* a valve, also lifting upwards, placed in a pipe D, which conveys the water to the cistern.

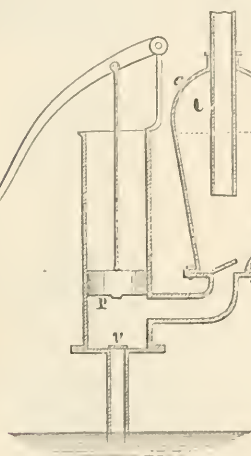
In a descending stroke of the piston, the valve V closes and the valve *v* opens, and the water, being pressed before the piston, is forced up the pipe D to the higher level required; on the contrary, in an ascending stroke, the valve *v* closes by the pressure of the external air and the water in the pipe D; the valve V opens, and the water rises into the barrel of the pump by the pressure of the atmosphere on the water in the well; and so on to any number of strokes.

The forcing pump with an air-chamber.—This engine, Fig. 3125, merely differs from the preceding one by having an air-chamber *c c v* connected with the vertical pipe D. This air-chamber is a closed vessel, having the pipe D descending into it, and a valve *v* opening and closing its communication with the barrel of the pump. When the piston P descends, the water is forced through the valve *v* into the air-chamber, so that as soon as the water rises above the lower orifice of the pipe D, the air in the upper part of the chamber is contracted or compressed; and this compression of the air causes it to exert a continuous pressure upon the surface of the water in the chamber, which forces the fluid up the pipe D, and thus a constant discharge into the cistern is sustained. In the common forcing pump the water is only discharged at each downward stroke of the piston, whereas, in the present case, the pressure of the air in the chamber sustains the discharge through the vertical pipe D during the intervals taken up by the upward strokes of the piston.

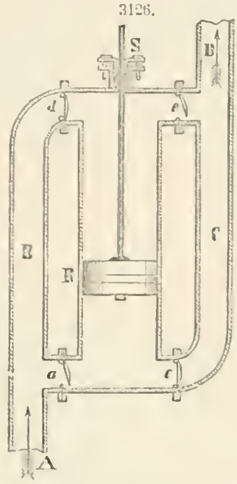
The great defect of this engine is as follows:—after the pump has been some time in action the air in the chamber becomes absorbed by the water passing through it, so that at length it is found that nearly all the air at first in the chamber has passed away with the water discharged by the pump.

Double-acting pump.—This pump, Fig. 3126, is designed to remedy the defect of the preceding one. It is simply a double-acting forcing pump. P is a solid piston which moves up and down in a cylinder; the rod of this piston passes through a stuffing-box at S for the purpose of keeping the cylinder air-tight. On the opposite sides of the cylinder are two pipes A B and C D; where A B descends into the well, and C D conveys the water to the reservoir. There are four valves *a b c e* opening and closing, as the case may be, the communication of these pipes with the cylinder. These valves all lift in the same direction, that is, to the right. Suppose the cylinder and pipes filled with water, then in an upward stroke of the piston, the valves *a* and *c* are opened, and *e* and *b* are closed; the water is forced by the piston through the valve *e* and then up the vertical pipe C D; at the same time the water, by the atmospheric pressure, rises up the pipe A, and opening the valve *a* follows the piston in its ascent: on the contrary, when the piston descends, the valves *a* and *e* are closed, and *c* and *b* are opened; the water is then forced through the valve *c*, up the vertical pipe C D, and the water from the well enters the cylinder through the valve *b*, and follows the piston in its descent; and so on to any number of strokes.

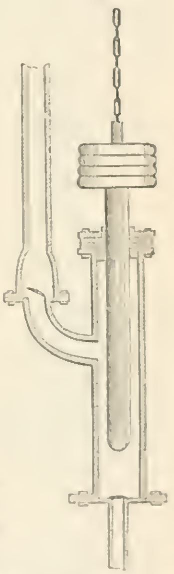
3125.



3126.



3127.



Another variation of the forcing pump, called a plunger-pump, Fig. 3127, consists in making the piston of the same length as the cylinder but rather less in diameter, so that it may be moved freely in the former without touching the sides. These pistons are made wholly of metal, and turned smooth and cylindrical, so as to work through a stuffing-box or cupped leathers. The quantity of water raised at each stroke has therefore no reference to the capacity of the cylinder, however large that part of one of these pumps may be, for the liquid displaced by the piston can only be equal to that part of the latter that enters the cylinder. It is immaterial at what part of the cylinder the forcing or ascending pipe is attached, whether at the bottom, near the top, or at any intermediate place. Small pumps of this kind are now commonly employed to feed steam boilers and for other purposes, and are worked by levers like the ordinary lifting and forcing pumps, the pistons being preserved in a perpendicular position by slings.

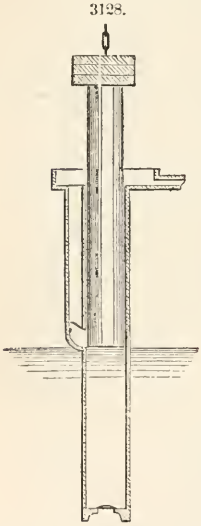
This is one of the most valuable modifications of the forcing pump. The friction of the piston is not only greatly reduced, but the boring of the cylinder is dispensed with; an operation of considerable expense and difficulty, particularly so, before efficient apparatus for that purpose was devised. Another advantage is the facility of tightening the packing without taking out the piston or even stopping the pump.

There is another species of plunger-pumps, Fig. 3128, in which the stuffing box is dispensed with, and consequently the piston works without friction. A square wooden tube, or a common pump log of sufficient length, and with a valve at its lower end, is fixed in the well as shown in Fig. 3128. The depth of the water must be equal to the distance from its surface to the place of delivery; and a discharging pipe having a valve opening upwards is united to the pump tree at the surface of the water in the well. The piston (a solid piece of wood) is suspended by a chain from a working beam, and loaded sufficiently with weights to make it sink. As the liquid enters the pump through the lower valve, and stands at the same level within as without, whenever the piston descends, it necessarily displaces the water, which has no other passage to escape but through the discharging pipe, in consequence of the lower valve closing. And when the piston is again raised as in the figure, a fresh portion of water enters the pump and is driven up in like manner.

Fig. 3129 is a pump to raise water without any friction of solids; making use of quicksilver instead of leather to keep the air or water from slipping by the sides of the pistons. One form of it is represented by the figure. A is the suction-pipe, the lower end of which is inserted in the water to be raised. Its upper end terminates in the chamber C, and is covered by a valve. The forcing-pipe B, with a valve at its lower end, is also connected to the chamber. Between these valves a pipe, open at both ends, is inserted and bent down, as in the figure. The straight part attached to it is the working cylinder of the pump, and should be made of iron. Another iron pipe, a little larger in the bore than the last, and of the same length, is made to slide easily over it. This pipe is closed at the bottom and suspended by chains or cords, by which it is moved up and down. Suppose this pipe in the position represented, and filled with mercury—if it were then lowered, the air in the cylinder and between the valves would become rarified, and the atmosphere pressing on the surface of the water in which the end of A is placed, would force the liquid up A till the density of the contained air was the same as before; then by raising the pipe containing the mercury, the air, unable to escape through the lower valve, would be forced through the upper one; and by repeating the operation, water would at last rise and be expelled in the same way, *provided* the elevation to which it is to be raised does not exceed thirteen times the depth of the mercurial column around the cylinder; the specific gravity of quicksilver being so many times greater than that of water. When the depth of the former is 30 inches, the latter may be raised as many feet in the suction-pipe and forced up an equal distance through the forcing one, making together an elevation of sixty feet; but if water be required higher, the depth of the mercurial column in the movable pipe must be proportionably increased. To make a small quantity of mercury answer the purpose, a solid piece of wood or iron that is a little less than the cylinder is secured to the bottom of the movable vessel as shown in the centre: this answers the same object as an equal bulk of mercury.

These pumps have their disadvantages: they are expensive; and however well made, the quantity of quicksilver required is considerable—the agitation consequent on the necessary movement soon converts it into an oxide and renders it useless. Great care is also required in working these machines: if the movements are not slow and regular, the mercury is very apt to be thrown out; to prevent which the upper end of the vessel containing it is dished or enlarged. For the reasons above stated, they have never been extensively employed in the arts.

3128.



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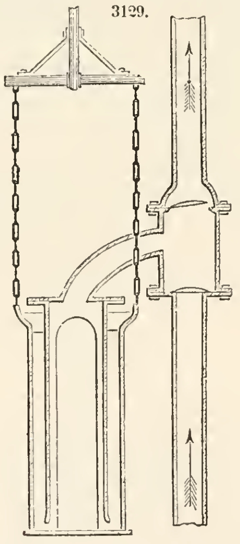

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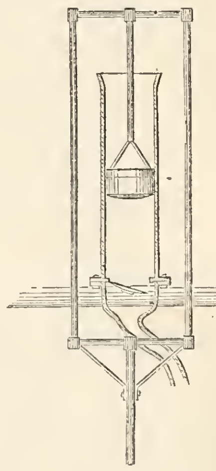


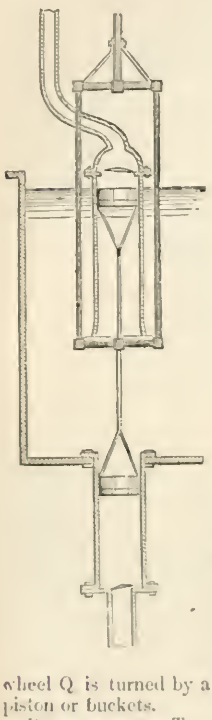
If a common atmospheric pump be inverted, as shown in Figs. 3130 and 3131, its cylinder immersed in water, and the valves of the upper and lower boxes reversed, it becomes a forcing, or, as it is sometimes named, a *lifting* pump; because the contents of the cylinder are lifted up when the piston is raised, instead of being driven out from below by its descent. In a lifting pump the liquid is expelled from the top of the cylinder—in a forcing one from the bottom: it is the water above the piston that is raised by the former; and that which enters below it, by the latter. The piston-rod in the figure is attached to an iron frame that is suspended to the end of a beam or lever. The valve on the top of the piston, like that at the end of the cylinder, opens upwards. When the piston descends (which it does by its own weight and that of the frame) its valve opens and the water enters the upper part of the cylinder, then as soon as it begins to rise its valve closes, and the liquid above it is forced up the ascending pipe. Upon the return of the piston the upper valve is shut by the weight of the column above it, the cylinder is again charged, and its contents forced up by a repetition of the movements. Machines of this description are of old date. They were formerly employed in raising water from mines.

Lifting pump.—The modern form of this pump is represented in Fig. 3132. The working cylinder being generally metal, and having a strong flanch at each end: the upper one is covered by a plate with a stuffing-box in the centre through which the polished piston-rod moves; and the under one by another to which the suction-pipe is attached, and whose orifice is covered by a valve.

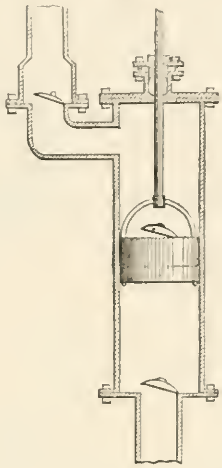
The fire-engine.—This engine, Fig. 3133, is simply a combination of two forcing pumps, having a common air-chamber H, and the same suction-pipe F descending to the water intended to supply the engine. The beam A B, turning on its centre of motion K, works the two pistons C and D; so that while the one is descending the other is ascending, thereby keeping up a continuous flow of water into the air-chamber H. A flexible tube E, of leather, called *a hose*, is attached to the discharge-pipe, to enable the engine-man to direct the stream of water upon any particular spot. The degree of compression attained by the air in the chamber regulates the velocity with which the water is projected from the nozzle L of the hose.

If, for example, the air be compressed to one half its original bulk, then it will act upon the surface of the water in the chamber with a pressure equivalent to that of the atmosphere, and the water would be raised in the pipe E to the height of about 34 feet, or it would be projected from the nozzle L with a velocity equal to that which a body would acquire in falling freely, by the force of gravity, from this height.

3131.



3132.



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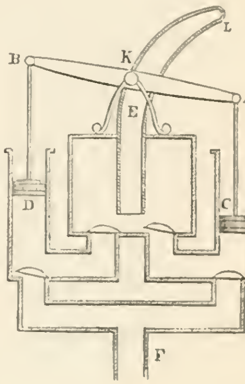
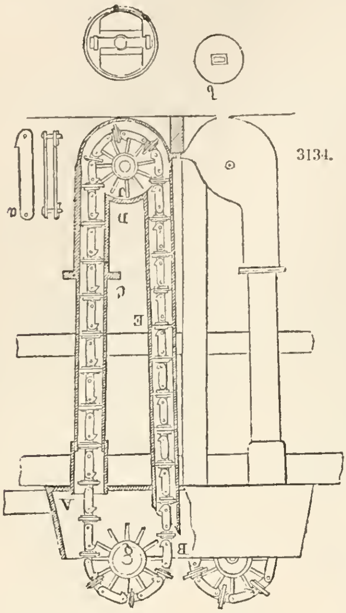


The chain pump.—This engine, Fig. 3134, consists of a continuous chain A B C, to which are attached a series of pistons or buckets for raising the water. This chain passes downwards through the wooden tube E, and returns upwards through C, extending over two *sprocket* wheels Q and J. The arms or teeth of the upper wheel Q, acting upon the notches or teeth cut upon the links of the chain, put the chain of pistons or buckets in motion. The lower portion C D of the ascending tube is lined with a brass barrel, in which the pistons or buckets are fitted; so that whilst they are ascending through this barrel, the water is lifted and discharged at the top A of the tube. The wheel Q is turned by a winch. *a* shows the shape of the links forming the chain, *b* the section of the piston or buckets.

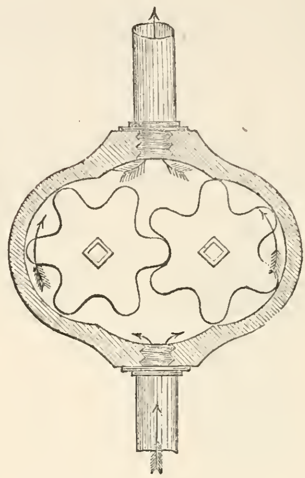
Rotary pumps.—Two cog-wheels, the teeth of which are fitted to work accurately into each other, are inclosed in an elliptical case. The sides of these wheels turn close to those of the case, so that water cannot enter between them. The axle of one of the wheels is continued through one side of the case, (which is removed in the figure to show the interior,) and the opening made tight by a stuffing-box or collar of leather. A crank is applied to the end to turn it, and as one wheel revolves, it necessarily turns the other; the direction of their motions being indicated by the arrows. The water that enters the lower part of the case is swept up the ends by each cog in rotation, and as it cannot return between the wheels in consequence of the cogs being there always in contact, it must necessarily rise in the ascending or forcing pipe. The machine is, therefore, both a sucking and forcing one. Of rotary pumps this is not only one of the oldest, but one of the best. Fire-engines made on the same plan were patented about twenty five years ago in England, and more recently pumps of the same kind in this country.

Rotary pumps may be divided into classes according to the forms of and methods of working the pistons, or those parts that act as such; and according to the various modes by which the *butment* is obtained. It is this last that receives the force of the water when impelled forwards by the piston it also prevents the liquid from being swept by the latter entirely round the cylinder or exterior case and compels it to enter the discharging pipe. In these particulars consist all the essential differences in rotary pumps. In some the butments are movable pieces that are made to draw back to allow the piston to pass, when they are again protruded till its return; in others they are fixed, and the pistons themselves give way. It is the same with the latter; they are sometimes permanently connected to the axles by which they are turned, and sometimes they are loose and drawn into recesses till the butments pass by. In another class the pistons are rectangular, or other shaped pieces that turn on centres, something like the vanes of a horizontal wind mill, sweeping the water with their broad faces round the cylindrical case, till they approach that part which constitutes the butment, when they move edgeways and pass through a narrow space which they entirely fill, and thereby prevent any water passing with them. In other pumps the butment is obtained by the contact of the peripheries of two wheels or cylinders, that roll on or rub against each other. Fig. 3135 is of this kind: while the teeth in contact with the ends of the case act as pistons in driving the water before them, the others are fitted to work so closely on each other as to prevent its return. Fig. 3136 exhibits another modification of the same principle.



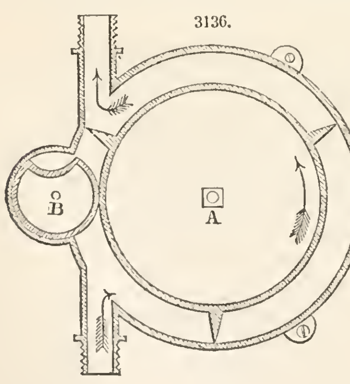
3134.

3135.

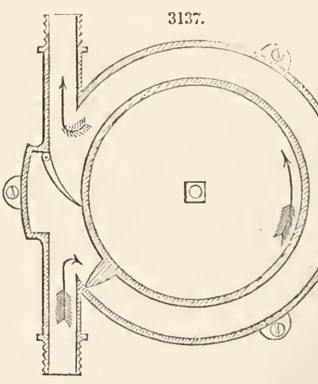


Eve's patent rotary steam-engine and pump.—Within a cylindrical case a solid or hollow drum A, Fig. 3136, is made to revolve, the sides of which are fitted to move close to those of the case. Three projecting pieces or pistons, of the same width as the drum, are secured to or cast on its periphery: they are at equal distances from each other, and their extremities sweep close round the inner edge of the case, as shown in the figure. The periphery of the drum revolves in contact with that of a smaller cylinder B, from which a portion is cut off to form a groove or recess sufficiently deep to receive within it each piston as it moves past. The diameter of the small cylinder is just one-third that of the drum. The axles of both are continued through one or both sides of the case, and the openings made tight with stuffing-boxes. On one end of each axle is fixed a toothed wheel of the same diameter as its respective cylinder; and these are so geered into one another, that when the crank attached

3136.



3137.



to the drum-axle is turned (in the direction of the arrow) the groove in the small cylinder receives successively each piston; thus affording room for its passage, and at the same time by the contact of the edge of the piston with its curved part, preventing water from passing. As the machine is worked, the water that enters the lower part of the pump through the suction-pipe, is forced round and compelled to rise in the discharging one, as indicated by the arrows. Other pumps of the same class have such a portion of the small cylinder cut off, that the concave surface of the remainder forms a continuation of the case in front of the recess while the pistons are passing; and then by a similar movement as that used in the figure described, the convex part is brought in contact with the periphery of the drum till the piston's return.

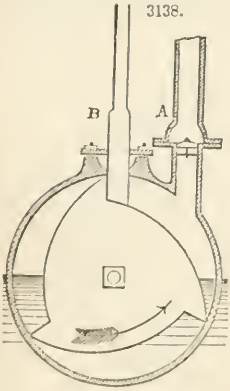
All rotary pumps are both sucking and forcing machines, and are generally furnished with valves in both pipes, as in the ordinary forcing pumps. The butments are always placed between the apertures of the sucking and forcing pipes.

There is another class of pumps that bears some relationship to the preceding; one of these is shown in Fig. 3137. The butment consists of a curved flap that turns on a hinge; it is so arranged as to be received into a recess formed on the rim or periphery of the case, and into which it is forced by the piston. The concave side of the flap is of the same curve as the rim of the case, and when pushed back forms a part of it. Its width is, of course, equal to that of the drum, against the rim of which its lower edge is pressed; this is effected in some pumps by springs, in others by cams, cog-wheels, &c., fixed on the axles, as in the last one. The force by which the flap is urged against the drum must exceed the pressure of the liquid column in the discharging pipe. The semicircular pieces on the outer edge of the case represent ears for securing the pump to planks or frames, &c., when in use. The arrows in the figures show the direction in which the piston and water is moved.

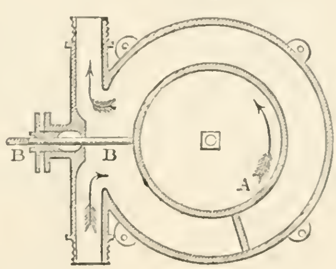
Nearly a hundred years before the date of Watt's patent, *Amontons* communicated to the French Academy a description of a rotary pump substantially the same as represented in Fig. 3137. It is figured and described in the first volume of *Machines Approuv.*, p. 103: the body of the pump or case is a short cylinder, but the piston is elliptical, its transverse diameter being equal to that of the cylinder, hence it performed the part of two pistons. There are also two flaps on opposite sides of the cylinder.

In other pumps the flaps, instead of acting as butments, are made to perform the part of pistons; this is done by hinging them on the rim of the drum, of which, when closed, they also form a part: they are closed by passing under a permanent projecting piece or butment that extends from the case to the drum.

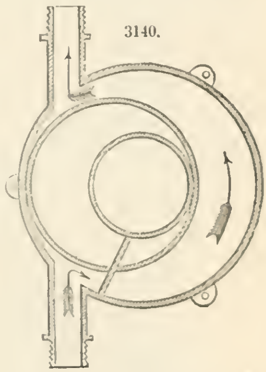
3138.



3139.



3140.



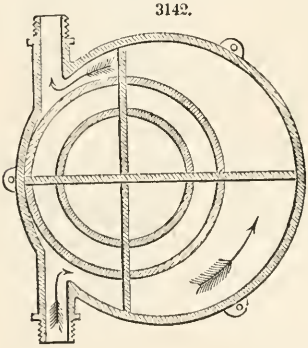
In Fig. 3138 the butment is movable. A solid wheel, formed into three spiral wings that act as pistons, is turned round within a cylindrical case. The butment B is a piece of metal whose width is equal to the thickness of the wings, or the interior breadth of the cylinder; it is made to slide through a stuffing box on the top of the case, and by its *weight* to descend and rest upon the wings. Its upper part terminates in a rod, which, passing between two rollers, preserves it in a perpendicular position. As the wheel is turned, the point of each wing (like the cogs of the wheel in Fig. 3135) pushes before it the water that enters the lower part of the cylinder, and drives it through the valve into the ascending pipe A; at the same time the butment is gradually raised by the curved surface of the wing, and as soon as the end of the latter passes under it, the load on the rod causes it instantly to descend upon the next one, which in its turn produces the same effect. This pump is as old as the 16th century, and probably was known much earlier. Besides the defects common to most of its species, it has one peculiar to itself: as the butment must be loaded with weights sufficient to overcome the pressure of the liquid column over the valve, (otherwise it would itself be raised and the water would escape beneath it;) the power to work this pump is therefore more than double the amount which the water forced up requires. The instrument is interesting, however, as affording an illustration of the early use of the sliding-valve and stuffing box; and as containing some of the elements of recent rotary pumps and steam-engines.

The pump represented by Fig. 3139 consists also of an exterior case or short cylinder within which a small and solid one A is made to revolve. To the last an arm or piston is attached or cast in one piece with it, the sides and ends of which are fitted to bear slightly against the sides and rim in the case. A butment B B slides backwards and forwards through a stuffing box, and is so arranged (by means of a cam or other contrivance connected to the axle of the small cylinder on the outside of the case) that it can be pushed into the interior as in the figure, and at the proper time be drawn back to afford a passage for the piston. Two openings near each other are made through the case on opposite sides of B B, and to these the suction and forcing pipes are united. Thus when the piston is moved in the direction of the arrow on the small cylinder, it pushes the water before it, and the vacuity formed behind is instantly filled with fresh portions driven up the suction-pipe by the atmosphere; and when the piston in its course descends past B B it sweeps this water up the same way.

Fig. 3140 represents another rotary engine. This is also a reinvention. Like many others, it consists of two concentric cylinders or drums, the annular space between them forming the pump-chamber but the inner one, instead of revolving as in the preceding figures, is immovable, being fixed to the sides of the outer one or case. The piston is a rectangular and loose piece of brass or other metal accurately fitted to occupy and move in the space between the two cylinders. To drive the piston, and at the same time to form a butment between the orifices of the induction and eduction pipes, a third cylinder is employed, to which a revolving motion is imparted by a crank and axle in the usual way. This cylinder is eccentric to the others, and is of such a diameter and thickness that its interior and exterior surfaces touch the inner and outer cylinders, as represented in the cut, the places of contact preventing water from passing: a slit or groove equal in width to the thickness of the piston is made through its periphery, into which slit the piston is placed. When turned in the direction of the large arrow, the water in the lower part of the pump is swept round and forced up the rising pipe, and the void behind the piston is again filled by water from the reservoir into which the lower pipe is inserted. This machine was originally designed, like most rotary pumps, for a steam-engine.

In others the pistons slide within a revolving cylinder or drum that is concentric with the exterior one. Fig. 3141 is a specimen of a French pump of this kind. The butment in the form of a segment is secured to the inner circumference of the case, and the drum turns against it at the centre of the chord line; on both sides of the place of contact it is curved to the extremities of the arc, and the sucking and forcing pipes communicate with the pump through it, as represented in the figure. To the centre of one or both ends of the case is screwed fast a thick piece of brass whose outline resembles that of the letter D; the flattened side is placed towards the butment, and is so formed that the same distance is preserved between it and the opposite parts of the butment, as between its convex surface and the rim of the case. The pistons, as in the last figure, are rectangular pieces of stout metal, and are dropped into slits made through the rim of the drum, their length being equal to that of the case, and their width to the distance between its rim and the D piece. They are moved by a crank attached to the drum-axle. To lessen the friction and compensate for the wear of the butment, that part of the latter against which the drum turns is sometimes made hollow; a piece of brass is let into it and pressed against the periphery of the drum by a spring.

3142.



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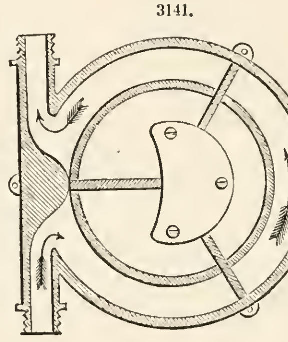


In Fig. 3142 the axis of the drum or smaller cylinder is so placed as to cause its periphery to rub against the inner circumference of the case. Two rectangular pistons, whose lengths are equal to the internal diameter of the case, cross each other at right angles, being notched so as to allow them to slide backwards and forwards to an extent equal to the widest space between the two cylinders. The case of this pump is not perfectly cylindrical, but of such a form that the four ends of the pistons are always in contact with it. An axle on the drum is moved by a crank. Fire-engines have been made on the same principle.

Rotary pumps are as yet too complex and too easily deranged to be adapted for common use. To make them efficient, their working parts require to be adjusted to each other with unusual accuracy and care: their efficiency is, by the unavoidable wear of those parts, speedily diminished or destroyed. The expense of keeping them in order exceeds that of others; and they cannot be repaired by ordinary workmen, since peculiar tools are required for the purpose.

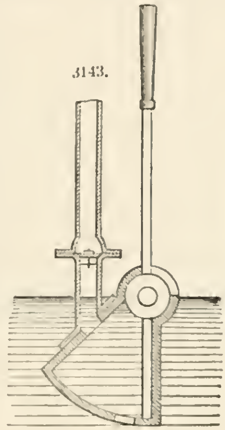
This remark holds true of all the rotary pumps we have seen, including Gwynne's, which is nothing more than Dimpfel's fan, Fig. 1612, applied to raising water; it is without the merit of novelty in principle, and in practice will be found worthless for the reasons above given.

Reciprocating rotary pumps.—One of the obstacles to be overcome in making a rotary pump, is the passage of the piston over the butment, or over the space it occupies. The apparatus for moving the butment as the piston approaches to or recedes from it, adds to the complexity of the machine; nor is this avoided when that part is fixed, for an equivalent movement is then required to be given to the piston itself in addition to its ordinary one. In reciprocating rotary pumps these difficulties are avoided by stopping the piston when it arrives at one side of the butment, and then reversing its motion towards the other; hence these are less complex than the former. They are, however, liable to some of the same objections, being more expensive than common pumps, more difficult to repair, and upon the whole less durable.

Fig. 3143 consists of a close case of the form of a sector of a circle, having an opening at the bottom for the admission of water, and another to which a forcing-pipe with its valve is attached. A movable radius or piston is turned on a centre by a lever as represented; thus, when the latter is pulled down towards the left, the former drives the contents of the case through the valve in the ascending pipe.

Fig. 3144 consists of a short horizontal cylinder; a portion of the lower part is separated from the rest by a plate where the suction-pipe terminates in two openings that are covered by clacks *c c*. The partition A extends through the entire length of the cylinder, and is made air and water tight to both ends, and also to the plate upon which its lower edge rests. The upper edge extends to the under side of the axle to which the piston B is united. One end of the axle is passed through the cylinder, and the opening made tight by a stuffing-box; it is moved by a crank or lever. Near the clacks *c c* two other openings are made through the plate, to which the forcing-pipes are secured. These tubes are bent round the outside of the cylinder and meet in the chamber C, where their orifices are covered by clacks. Thus when the piston is turned in either direction, it drives the water before it through one or other of these tubes; at the same time the void left behind it is kept filled by the pressure of the atmosphere on the surface of the liquid in which the lower orifice of the suction-pipe is placed. The edges of the pistons are made to work close to the ends and rim of the cylinder by means of strips of leather screwed to them. Modifications of these pumps have also been used in England as fire engines. Watt patented one in 1782 for a steam engine.

3143.



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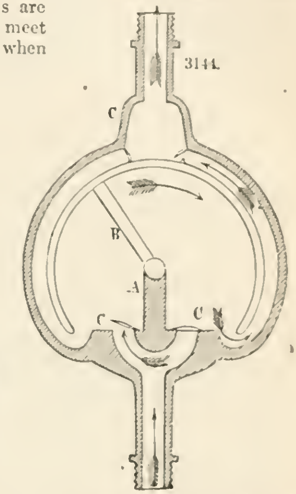
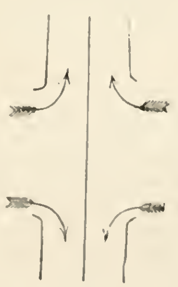


Centrifugal Pumps. If a common blowing fan be immersed in water, and put in operation, the water will be forced to the periphery of the wheel, and may be elevated in a rising main according to the velocity given to the fan. Fig. 3145 represents a side rim of Appold's centrifugal pump as exhibited at the World's Fair in London. It consists of a hollow disk or cylinder, 12 inches diameter and 3 inches wide on the rim, with a circular opening in the centre of 6 inches diameter. This cylinder is inclosed on both sides, excepting the central opening, and is entirely open all round the rim. The disk is placed vertically on a shaft passing through its centre, and on the end of this shaft is fixed a pulley for driving it. In order to raise the water, the disk is placed in the bottom of a vertical trunk, as shown in fig. 3146.

3145



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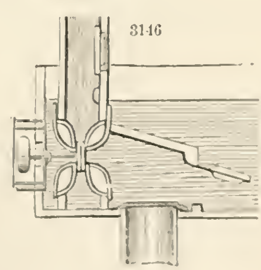


In the centrifugal pump, the velocity of the circumference must be constant for all sizes of pumps for the same height of lift; that is, a pump 1 inch diameter must make twelve times the number of revolutions per minute of one 12 inches diameter, and both pumps will then raise the water to the same height, but the quantity of water delivered will be 144 times greater than the 12 inch pump, being in proportion to the area of the discharging orifices at the circumference, or the square of the diameter, when the proportion of breadth was kept the same, namely, one fourth of the diameter in each case.

In Mr. Appold's pump, a velocity of 500 feet per minute of the circumference raised the water 1 foot high, and maintained it at that level without discharging any; and a double velocity raised the water to four times the height, as the centrifugal force was proportionate to the square of the velocity; consequently,

500	feet per	minute	raised the water	1	foot	without discharge.
1,000	"	"	"	4	"	"
2,000	"	"	"	16	"	"
4,000	"	"	"	64	"	"

The greatest height to which the water had been raised, without discharge, in the experiments with the 1 foot pump, was 67·7 feet, with a a velocity of 4,153 feet per minute, being rather less than the calculated height, owing probably to leakage with the greater pressure.

A velocity of 1,128 feet per minute raised the water 5¼ feet without any discharge, and the maximum effect from the power employed in raising to the same height 5¼ feet, was obtained at the velocity of

1,678 feet per minute, giving a discharge of 1,400 gallons per minute from the 1 foot pump. The additional velocity required to effect the discharge is 550 feet per minute; or the velocity required to effect a discharge of 1,400 gallons per minute, through a 1 foot pump, working at a dead level without any height of lift is 550 feet per minute: consequently, adding this number in each case to the velocity given above at which no discharge takes place, the following velocities are obtained for the maximum effect to be produced in each case:

1,050	feet	per minute,	velocity for	1	foot height	of lift.
1,550	"	"	"	4	feet	"
2,550	"	"	"	16	"	"
4,550	"	"	"	64	"	"

Or, in general terms, the velocity in feet per minute for the circumference of the pump to be driven to raise the water to a certain height, is equal to

$$550+(500\sqrt{\text{height of lift in feet}}).$$

In some situations where it is the most important consideration for a pump to be quickly and readily applied, that would discharge a very large quantity of water, the centrifugal pump is found very advantageous in such cases. In one instance, in putting in the foundations of harbor works at Dover, a large quantity of water of 2,000 to 3,000 gallons per minute was pumped out by one of these pumps. The centrifugal pump had another important advantage for such applications, from having no valves in action when at work, which enabled it to pass large stones, and almost any thing that was not too large to enter between the arms. The largest pump constructed at present on this plan was erected at Whittlesea Mere, for the purpose of draining, and has worked there nearly a year with complete success. The pump is 4½ feet diameter, with an average velocity of 90 revolutions, or 1,250 feet per minute, and is driven by a double-cylinder steam-engine, with steam 40 lbs. per inch, and vacuum 13½ lbs. per inch; it raises about 15,000 gallons of water per minute an average height of four or five feet.

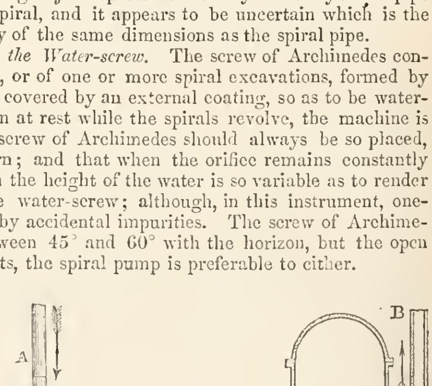
Mr. Appold considers the spiral form of the arms an essential point in his pump, instead of the radial arms in the other centrifugal pumps. He at first tried straight arms inclined at 45°, but he found that the curved arms ending nearly in a line with a tangent to the outer circumference gave the greatest effect.

The comparative value of the different forms of arms was proved by the experiments at the London Exhibition mentioned before; the curved arms gave a duty of 68 per cent., the inclined arms 43 per cent., and the radial arms only 24 per cent.

The Spiral Pump. If we wind a pipe round a cylinder, of which the axis is horizontal, and connect one end with a vertical tube, while the other is at liberty to turn round and receive water and air in each revolution, the machine is called a spiral pump; it was invented, about 1746, by Andrew Wirz, a pewterer in Zurich, and was employed at Florence with Bernoulli's improvement, in 1779. At Archangelsky, near Moscow, a pump of this kind was erected in 1784, which raised a hogshead of water in a minute to a height of 74 feet, and through a pipe 760 feet in length. Eytelwein enters very minutely into calculations of the effect of such a machine under different circumstances; and the results of the theory, as well as of experiment, recommend it for common use, instead of forcing pumps of a more complicated and expensive construction. The water-tight joint presents the only difficulty: the pipe may form either a cylindrical, a conical, or a plain spiral, and it appears to be uncertain which is the most advantageous; the vertical pipe should be nearly of the same dimensions as the spiral pipe.

The Screw of Archimedes, or the Water-Snail, and the Water-screw. The screw of Archimedes consists, either of a pipe wound spirally round a cylinder, or of one or more spiral excavations, formed by means of spiral projections from an internal cylinder, covered by an external coating, so as to be water-tight. But if the coating is detached, so as to remain at rest while the spirals revolve, the machine is called a water-screw. Eytelwein observes, that the screw of Archimedes should always be so placed, as to fill exactly one-half of a convolution in each turn; and that when the orifice remains constantly immersed, the effect is very much diminished. When the height of the water is so variable as to render this precaution impossible, Mr. Eytelwein prefers the water-screw; although, in this instrument, one-third of the water runs back, and it is easily clogged by accidental impurities. The screw of Archimedes is generally placed so as to form an angle of between 45° and 60° with the horizon, but the open water-screw at an angle of 30° only: for great heights, the spiral pump is preferable to either.

Belidor's pressure engine, moved by water.—Fig. 3150: A conveys the descending column of water from its source to the three-way cock F; to one of the openings of which it is united. This cock is connected, at another opening, to the horizontal cylinder C, whose axis coincides with that of a smaller one D. Both cylinders are of the same length; and their pistons are attached to a common rod, as represented in the figure. Two valves are placed in the ascending pipe B—one below, the other above its junction with the cylinder D. The horizontal pipe H connects B and D with the third opening of the cock. By turning the plug of this cock, a communication is opened alternately between each cylinder and the water in A. Thus when the water rushes into C it drives the piston before it to the extremity of the cylinder, and consequently the water that was pre-



3150.

viously in D is forced up the ascending pipe B; then the communication between A and C is cut off, (by turning the cock,) and that between A and D is opened, when the pistons are moved back towards F by the pressure of the column against the smaller piston—the water previously in C escaping through an opening shown in front of the cock and runs to waste, while that which enters D is necessarily forced up B at the next stroke of the pistons. The cock was opened and closed by levers, connected to the middle of the piston-rod, and was thus worked by the machine itself. By the air-chamber the discharge from B is rendered continuous.

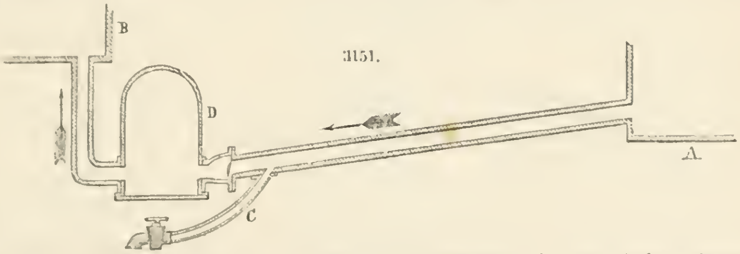
Suppose the water A has a perpendicular fall of thirty-four or thirty-five feet, and it was required to raise a portion of it to an elevation of seventy feet above F; it will be apparent that if both pistons were of the same diameter, such an object could not be accomplished by this machine—for both cylinders would virtually be but one—and so would the pistons; and the pressure of the column on both sides of the latter would be equal. A column of water thirty-five feet high presses on the base that sustains it with a force of 15 pounds on every superficial inch; and one of seventy feet high, with a force of 30 pounds on every inch; hence, without regarding the friction to be overcome, which arises from the rubbing of the pistons, from the passage of the water through the pipes, and from the necessary apparatus to render the machine self-acting, it is obvious in the case supposed that the area of the piston in C must be more than double that in D, or no water could be discharged through B. Thus in all cases, the relative proportion between the area of the pistons, or diameter of the cylinders, must be determined by the difference between the perpendicular height of the two columns. When the descending one passes through a perpendicular space, greatly exceeding that of the ascending one, then the cylinder of the latter may be larger than that of the former; a smaller quantity of water in this case raising a larger one. It, however, descends like a small weight at the long end of a lever, through a greater space.

That the force which a running stream acquires may be made to drive a portion of the liquid above the source whence it flows, is obvious from several operations in nature.

The hydraulic ram raises water on this principle: a quantity of the liquid is set in motion through an inclined tube, and its escape from the lower orifice is made suddenly to cease, when the momentum of the moving mass drives up a portion of its own volume to an elevation much higher than that from which it descended.

The first person who is known to have raised water by a ram, designed for the purpose, was Mr. Whitehurst, a watchmaker of Derby, in England. He erected a machine similar to the one represented in Fig. 3151, in 1772.

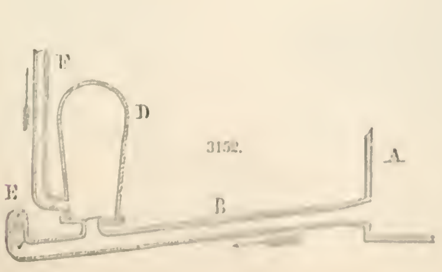
3151.



A represents the spring or reservoir, the surface of the water in which was of about the same level as the bottom of the cistern B. The main pipe from A to the cock at the end of C, was nearly six hundred feet in length, and one and a half inch bore. The cock was sixteen feet below A, and furnished water for the kitchen offices, &c. When it was opened the liquid column in A C was put in motion, and acquired a velocity due to a fall of sixteen feet; and as soon as the cock was shut, the momentum of this long column opened the valve, upon which part of the water rushed into the air-vessel and up the vertical pipe into B. This effect took place every time the cock was used, and as water was drawn from it at short intervals for household purposes, "from morning till night—all the days in the year," an abundance was raised into B, without any exertion or expense.

The *Bélier hydraulique* of Montgolfier was invented in 1796. Although it is on the principle of the one just described, its invention is believed to have been entirely independent of the latter.

3152.



3153.

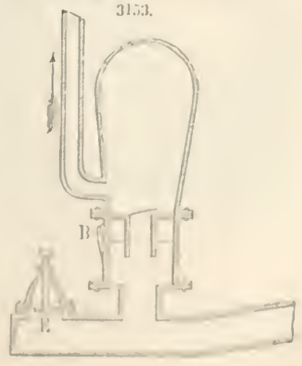


Fig. 3152 represents a simple form of Montgolfier's ram. The motive column descends from a spring or brook A, through the pipe B, near the end of which an air chamber D, and rising main F, are attached to it as shown in the figure. At the extreme end of B the orifice is opened and closed by a valve E, instead of the cock in Fig. 3151. This valve opens downwards, and may either be a spherical one, as in Fig. 3152, or a common spindle one, as in Fig. 3153. It is the play of this valve that renders the machine self-acting. To accomplish this, the valve is made of. or loaded with, such a weight as just to open when the water B is at rest; i. e., it must be so heavy as to overcome the pressure against its under side when closed, as represented in Fig. 3153. Now suppose this valve open as in Fig. 3152, the water flowing through B soon acquires an additional force that carries up the valve against its seat; then, as in shutting the cock of Whitehurst's machine, a portion of the water will enter and rise in F, the valve of the air-chamber preventing its return. When this has taken place the water in B has been brought to rest, and as in that state its pressure is insufficient to sustain the weight of the valve, E opens, (descends;) the water in B is again put in motion, and again it closes E as before, when another portion is driven into the air-vessel and pipe F; and thus the operation is continued, as long as the spring affords a sufficient supply and the apparatus remains in order.

The surface of the water in the spring or source should always be kept at the same elevation, so that its pressure against the valve E may always be uniform—otherwise the weight of E would have to be altered as the surface of the spring rose and fell.

This beautiful machine may be adapted to numerous locations in every country, and is coming much into use in the agricultural districts of this country. When the perpendicular fall from the spring to the valve E is but a few feet, and the water is required to be raised to a considerable height through F, then, the *length* of the ram or pipe B must be increased, and to such an extent that the water in it is not forced back into the spring when E closes, which will always be the case if B is not of sufficient length.

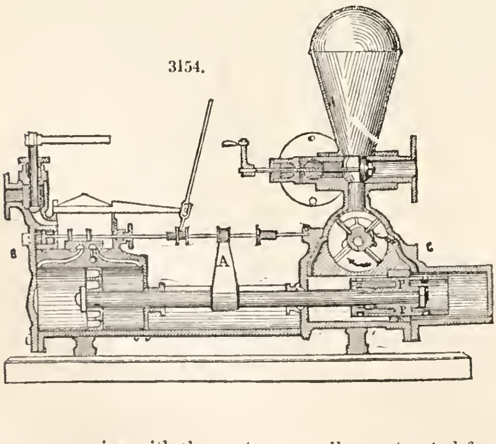
If a ram of large dimensions, and made like Fig. 3152, be used to raise water to a great elevation, it would be subject to an inconvenience that would soon destroy the beneficial effect of the air-chamber If air be subjected to great pressure in contact with water, it in time becomes incorporated with or absorbed by the latter. This sometimes occurs in water-rams; as these, when used, are incessantly at work both day and night. To remedy this, Montgolfier ingeniously adapted a very small valve (opening inwards) to the pipe beneath the air-chamber, and which was opened and shut by the ordinary action of the machine. Thus, when the flow of the water through B is suddenly stopped by the valve E, a partial vacuum is produced immediately below the air-chamber by the recoil of the water, at which instant the small valve opens and a portion of air enters and supplies that which the water absorbs. Sometimes this *snifting*-valve, as it has been named, is adapted to another chamber immediately below that which forms the reservoir of air, as at B in Fig. 3153. In small rams a sufficient supply is found to enter at the valve E.

Although air-chambers or vessels are not, strictly speaking, constituent elements of water-rams, they are indispensable to the permanent operation of these machines. Without them, the pipes would soon be ruptured by the violent concussion consequent on the sudden stoppage of the efflux of the motive column. See *Ewbank's Hydraulics*.

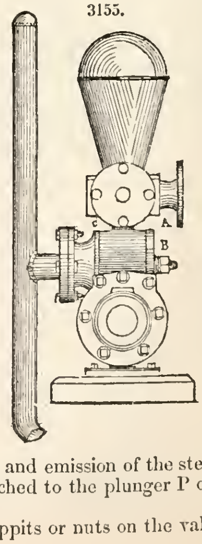
PUMPS, STEAM. Fig. 3154 and 3155 represent an independent steam pumping machine, patented in April, 1849, by Worthington & Baker, of the city of New York, and which is undoubtedly the best pump in use for heavy purposes.

The general principle involved in its construction is the combination of a pump with the steam-cylinder that drives it by direct action, without the intervention of a crank fly-wheel or any other device for producing rotary motion. The steam-cylinder S is in all respects similar to that of an ordinary

3154.



3155.



high-pressure engine, with the parts as usually constructed for the admission and emission of the steam. The rod of the piston which traverses in this cylinder is prolonged and attached to the plunger P of a double-acting pump.

The arm A is fastened to the middle of the piston-rod, and strikes the tappits or nuts on the valve-rod at each end of the stroke, in order to change the position of the steam-valve and admit steam to alternate sides of the piston. The necessary reciprocating motion of the pump-plunger is thus produced in a very simple way, with the least possible amount of friction and loss of power.

The brief space afforded in a notice of this description, will only allow of a glance at the mechanical peculiarities of this machine, designed to overcome the difficulties incident to the direct application of steam, without availing of the controlling power of the crank for regulating the stroke nor of the eccentric for producing the proper motion of the steam-valve. At low speed, more especially, the obvious tendency of the motion is to bring the steam-valve directly over the ports, and exclude the steam from either end of the cylinder. The patentees have obviated this serious difficulty in a manner at once simple and effective. By a peculiar arrangement of the water passages in the pump, the resistance is reduced or relieved at or near the end of the stroke, and thus a momentum is suddenly generated amply sufficient to throw the valve wide open. A modification of the ordinary slide-valve, which the patentees denominate a B valve, is shown in the drawing, and serves to admit the steam in the proper direction, without resorting to levers for changing the motion.

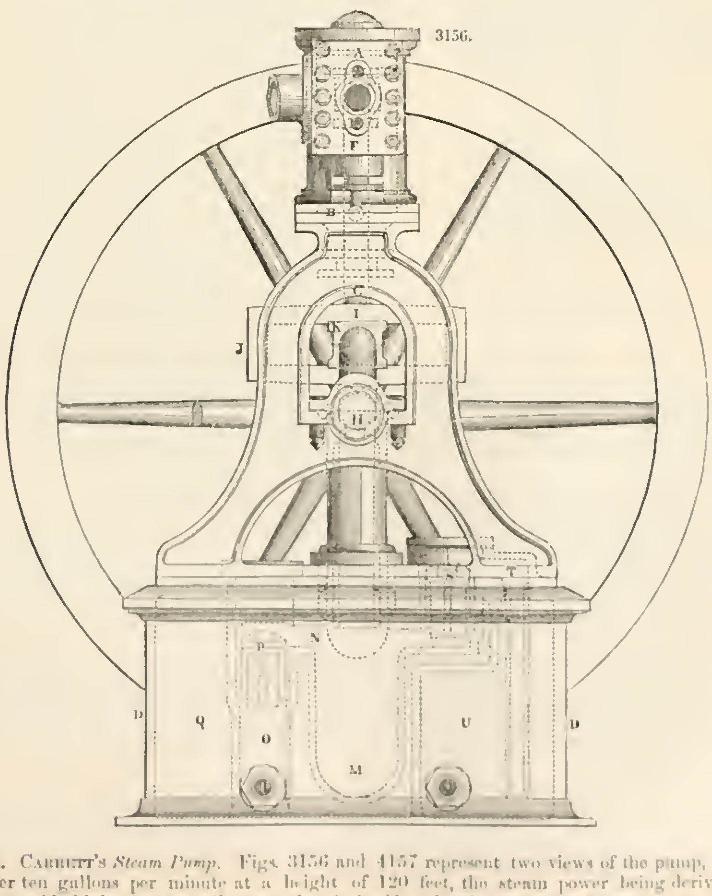
The pump shown at C, called the *double-acting plunger pump*, consists of a plunger or plug P, working through a ring R, which may be made adjustable, if necessary.

The course of the water, as indicated by the arrows, is through a set of valves resting upon seats that radiate from a common centre, and covered in by the cap A, Fig. 3154, which is held firmly in its place by the single bolt B. As all these valves are thus accessible at a moment's warning, a great source of danger from delay in relieving them from impediments is avoided.

This pump is in general use on board of steamboats, and in connection with stationary boilers, both on account of its value as an independent feed-pump, and also as a means of safety against accidents, having been found of great use as a bilge pump, and also as a fire engine.

This pump has also been employed for water supply in the city of Savannah, Ga., and Cambridge, Mass. The duty at the latter place almost comes up to that of the best CORNISH ENGINES. The engines consist each of two cylinders on the Wolf plan, with condensers. The cylinders are concentric, the smaller being interior, and the larger exterior; the piston of the latter being annular with two rods The whole machine is compact and economical, both in first cost and in working.

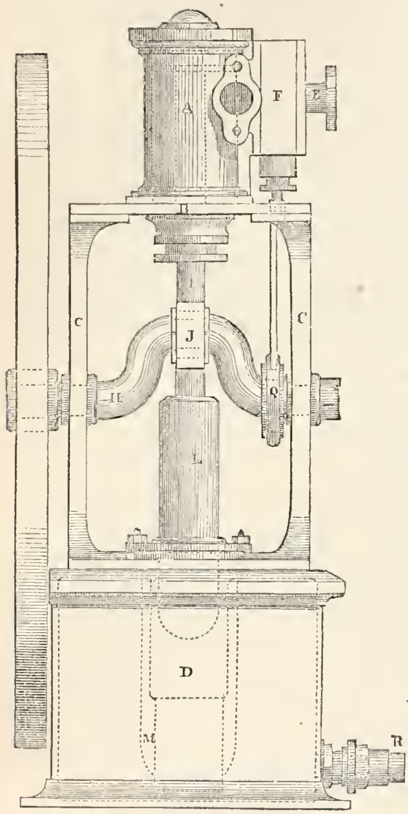
3156.



PUMPS. CARRETT'S *Steam Pump*. Figs. 3156 and 4157 represent two views of the pump, constructed to deliver ten gallons per minute at a height of 120 feet, the steam power being derived from a two-horse portable high-pressure boiler, complete in itself, and weighing under 6 cwt.

Fig. 3157 is a front elevation of the pump and actuating steam-cylinder, and Fig. 3156 is a corresponding side elevation or view, at right angles to the first figure. The steam-cylinder A is inverted upon the horizontal plate B, which is bolted to the top of the two-standards C, forming the framing of the machine. These standards spring from the chest D, which answers as the base of the whole, and contains the influx and efflux vessels for the water. The branch E conveys the steam to the slide-valve chest F, which is arranged in the simplest manner, the slide being worked direct from the eccentric G, on the crank-shaft H. The crank-shaft is carried in two bearings in the cross-piece of the side standards, and is connected to the piston-rod I, of the steam-cylinder, by passing the cranked-portion, fitted with a steel slide J, through the horizontal slotted cross-head K, of the piston-rod. The latter is prolonged below the cross-head, for the purpose of carrying the water plunger L, which is bored out and entered upon the rod, and secured by set screws. When the engine is not required for pumping, the plunges is disconnected by slackening these screws, and the piston-rod then works loose inside the plunger as a guide, the the power of the engine being then devoted to driving other machinery by a belt on the fly-wheel, or by connecting the crank-shaft with the machinery to be driven, by means of a link or universal joint, which, in the figure, is supposed to be broken away. The whole of the pump-work is shown by sectioned dotted lines in the base chest. The pump cylinder or barrel is at M, in the centre, and the passage N, at the top, forms the communication with the vertical influx water-passage O, governed by the conical lift-valve P. The bottom of this passage opens into an air-vessel Q, which, with the corresponding vessel for the discharge on the opposite side, forms the chief feature of improvement in the arrangement. The water is taken in by a pipe attached by a union joint at R, to the base chest. The discharge is by the opposite port, fitted with the lift-valve S, which opens into the top passage T, communicating with the top of the discharge air-vessel U, which has a discharge pipe attached at V.

3157.



It is this neat combination of air-vessels, with the influx and efflux passages, which enables the pump to be worked at an effective speed without injury to the different movements, whilst a constant and regular delivery is completely secured. Without a provision of this nature the barrel of the common pump is only partially filled at each stroke, and the ram is consequently driven against the surface of the water with a serious shock at each down stroke. On the other hand, in Mr. Carrett's pump, the lower valve, at each ascent of the plunger, drains its water supply from the bottom of the induction air-vessel; which again is fully replenished by the suctional power from the reservoir. When the plunger descends, the water in the barrel is driven through the upper valve into the discharge air-chamber, and makes its escape thence in a "continuous stream," under the pressure of the contained air. Thus, the pump has a noiseless and perfectly smooth action, with a uniform delivery.

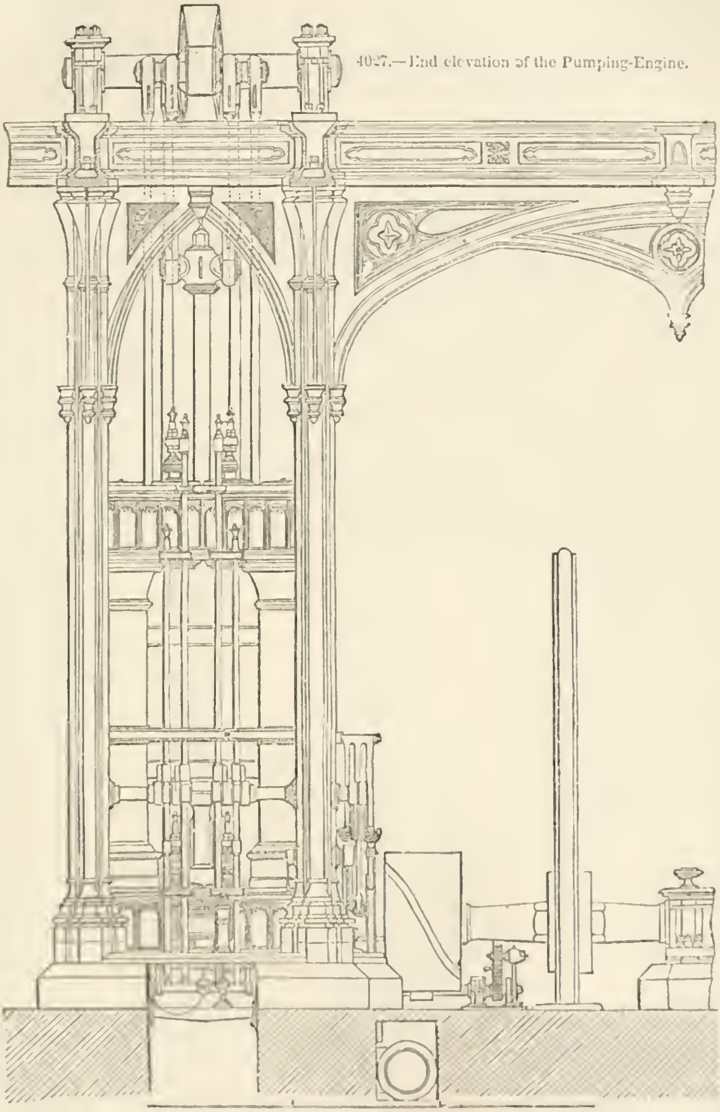
Our plate shows the old slotted cross-head movement as adopted for returning the plunger at each termination of its stroke, and for this purpose, as there is no great strain on the working parts, this simple plan has met with an apt application. For powers of pumps from three horses upwards, a connecting-rod and vertical slide movement is substituted, and this of course is a much more suitable arrangement where the engine is intended occasionally to exert its power through the crank-shaft.

The slotted frame is not, however, a mere aperture, as in the original plan adopted in steam-engines. A thin metal plate is bolted on each side, so as to provide projecting edges as guide flanges for the slide-block, and to retain the lubricating oil on the surfaces where it is wanted.

Pumps like the preceding, with a fly-wheel, are better suited to constant work than to the variable duty of feed-pump to a boiler. They must be run with sufficient velocity that the impetus of the fly-wheel may carry the valve sufficiently far to open the ports. This difficulty, as has already been explained, has been obviated in the Worthington pump, by relieving the pressure on the pump piston near the conclusion of the stroke. In Garrison's pump, also a direct action pump, this throw is effected in the steam chest.

The motion is somewhat similar to the working motion of a planing machine, fig. 3080. The rod x is the valve, and the weight r consists of a small piston working in a cylinder open at the upper end to the steam pressure, the other end connected with the exhaust. In this way the pressure of the steam is made to serve for the weight; other direct engines have been constructed in which the valve is worked by another small engine.

PUMPING-ENGINE, *erected at the new Dry Dock, Brooklyn Navy Yard, New York.* The pumping-engine of the new Dry Dock, at the United States Naval Station, New York, is of the largest class, and possesses many interesting features. It was built at Kemble's West Point Foundry, and affords additional proof of the capability of that establishment to execute the most massive work in the highest degree of perfection.



4027.—End elevation of the Pumping-Engine.

There are but very few specimens of large pumping engines to be found in the United States, those of the government dry docks at Norfolk and Boston being the most important. These, however, are of somewhat antiquated construction, and possess no remarkable qualities of excellence. The new dock at New York being the largest in the country, and at the most extensive naval station, it was deemed important that the machinery for exhausting it should be of the most perfect kind, and of great power and capacity also, as but a very inconsiderable amount of aid is afforded by the recession of the tide.

The "duty" required of the engine was to raise 610,000 cubic feet of sea-water in three hours, distributed through different heights, as follows:

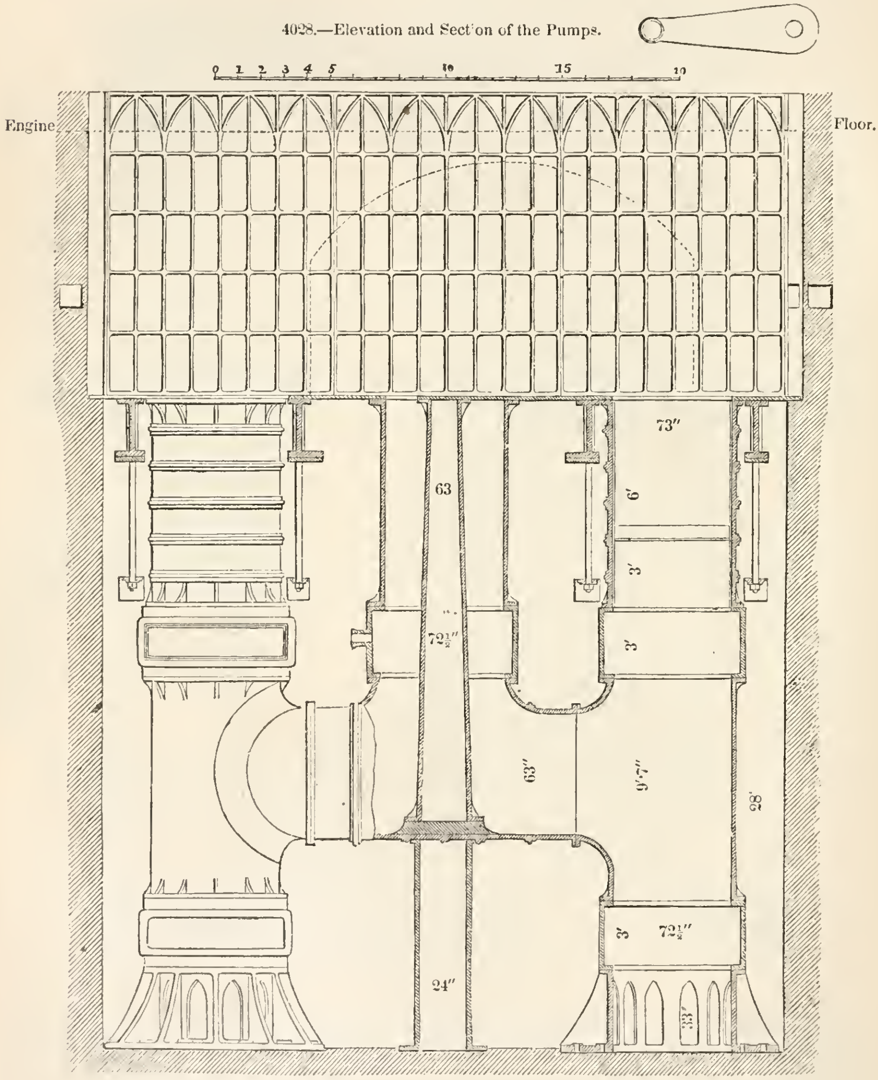
110,000 cubic feet of water raised through an average height of		$2\frac{1}{2}$ feet.
125,000	"	" $7\frac{1}{2}$ "
115,000	"	" $12\frac{1}{2}$ "

110,000 cubic feet of water raised through an average height of			17½ feet.
110,000	"	"	22½ "
40,000	"	"	26 "
610,000			

The commission appointed to devise a plan, unanimously adopted that shown in the accompanying figures, a brief description of which is here given.

The pumps are two in number, of the kind denominated "lifting-pumps," each 63 inches in diameter of cylinder and 8 feet length of stroke. The suction-pipes (also 63 inches in diameter) are extended to the bottom of the well, and terminate in suitable rose-pieces, with ample apertures in the sides for the

4028.—Elevation and Section of the Pumps.

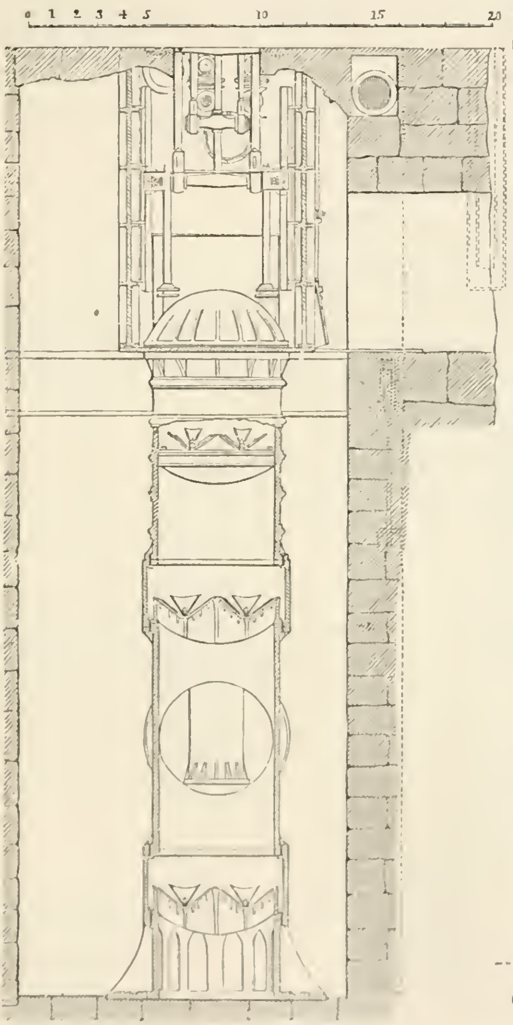


admission of the water. By this arrangement a staunch support is furnished for the insistent weight of the upper works of the pumps and the engine above. Each suction-pipe is furnished with a capacious branch-piece, (63 inches diameter,) forming a connection with an air (or vacuum) chamber, situated centrally between the pumps, and extending up to the bottom of the upper (or engine) bed-plate. This air-chamber, in addition to the support received from the branch pipes, is upheld by a hollow cylindrical pillar resting on the bottom of the well. A continuation of this pillar is carried through the centre of the air-chamber to the under side of the lower (or pump) bed-plate.

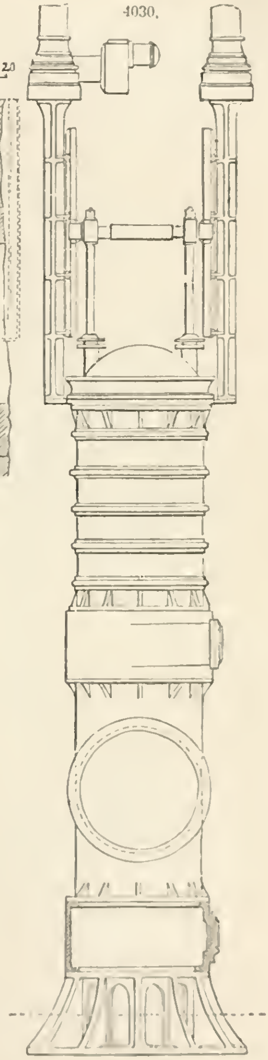
The pump-cylinders, suction and branch pipes, the air-chamber and its support, are of cast-iron, flanged and ribbed, as represented in the figures, the pump-cylinders being lined with composition metal.

The mouths of the pumps are placed at the level of mean low water, in a chamber formed of cast-iron, 8 feet wide, 13 feet high, and 30 feet long,—the bottom of the chamber forming a support to the heads of the pump-cylinders, as well as a bed-plate for the air-pump and condenser of the engine: its sides, strongly ribbed, support the engine bed-plate with the superstructure, and the top is itself a part of the engine bed-plate. A culvert from the bay leads up to one of the sides of this chamber, and serves as a conduit for the water delivered from the pumps. Twelve of the panels of the side of the

4029.—Elevation and Section of the Pumps.



4030.



chamber adjoining the conduit are open, and furnished with flap-valves of vulcanized India-rubber, opening outwardly to prevent the rising tide from flowing into the chamber. Four cast iron girders of ⊥ section, 32 inches deep, are placed transversely across the well, directly underneath the bottom of this chamber, and are held down to the masonry by suitable bolts.

The arrangement of the pump-valves is of somewhat novel character, a suction valve being placed near the bottom of each suction-pipe, in addition to the usual one near the bottom of the pump-chambers. Each of these valves is provided with suitable chests and bonnets, and is composed of vulcanized India-rubber, with the usual metal guard above. A disk of India-rubber, cut to the proper shape, with punctures along its diameter, is slipped over standards, tapped into the valve-seat, and secured by washers and the nuts of the guard; the India-rubber alone, from its flexibility, forming the hinge.

The valve-seats are of composition metal, their faces being indented in such a manner as to require two sets of valves to each chest, and are divided into numerous apertures by narrow but deep bars, crossing each other at right angles. This cross-barring forms a support for the flexible material of the valve, and obviates all the difficulty to be apprehended from the tendency of the valve to collapse on being loaded. A perfectly tight and quiet-working valve is the consequence of this arrangement.

The pump-rods are double, and passing through stuffing-boxes in the floating covers with which the pumps are provided, take hold of cross-heads working in slides below the engine bed-plate. From these cross-heads, double connecting-rods extend directly to the beam of the engine.

The engine is a double-acting condensing one, of 50 inches diameter of cylinder, and 12 feet length of stroke, with an independent adjustable expansion-geer, so arranged, that as the load upon the engine is increased by the lowering of the water in the dock, a proportionate increased amount of steam is admitted into the cylinder.

The working beam is of cast-iron, 31 feet long between the "end centres," and 4 feet deep at the "main centre," strongly flanged and bossed. The piston-rod is attached to the beam by a parallel motion; the main-pump and air-pump rods are connected to it by double rods and links, the air-pump cross-head working in slides attached to the columns of the engine-frame. The balance-wheel is of cast-iron, 25 feet in diameter, a cross section of its rim having an area of about 80 square inches. Its arms (eight in number,) unite in a centre case, having compartments to receive their tapered ends.

The condenser is formed from a portion of the air or vacuum chamber before described, a partition being placed in that portion of it which extends above the engine bed-plate. The air-pump stands level with the condenser. The air-pump rod and bucket, foot-valve and seat, are of composition metal. The length of stroke is 42 inches, the diameter of the cylinder 44 inches. The interior of the cylinder is lined with composition metal.

The piston, cylinder-cover, and steam chests, side-pipes, valves, and valve-geering, are all nearly identical with those used in the best specimens of *American steamboat engines.* The boilers are three in number, 26 feet long, and of 7 feet diameter in the waist, built on the "single return drop flue" plan. They are fed by the direct action steam-pumps of Worthington and Baker of New York.

PUMPING ENGINES. For the water supply of cities the Cornish Engine (*q. v.*) for this purpose affords the highest rate of duty. We know of no others that are remarkable either in construction or duty, except the one at Cambridge, Mass., already spoken of, and one at Hartford, Conn. The peculiarity of the latter consists in the arrangement of the piston in the pump cylinders: there are two pistons in each cylinder, the piston-rod of the lower passing through that of the upper, and so arranged in their alternate movements, that the flow of water is nearly continuous. They are actuated by cams, driven by a vertical steam engine, working very expansively.

PUMP, LEEGHWATER STEAM.—*Drainage of the Haarlem Lake, Holland.* In order to ascertain the most approved method, and at the same time the most economical manner, of draining this lake, the Dutch government appointed a commission of engineers to report upon the best means, and to examine the various plans of drainage adopted in England. After examining a great variety of schemes and proposals, it was determined to adopt the plan submitted by Mr. Joseph Gibbs and Mr. Arthur Dean. It is proposed to have three engines of the same power, and three sets of pumps. The first of these engines is now in operation, and is shown in Figs. 3158 to 3161.

Description of the engines. The Leeghwater Engine, as shown in the figures, has two steam cylinders A and C, one within the other, united to the same bottom X; but the inner one is not attached at the top, a clear space of 1½ inch existing between it and the cover, which serves for both cylinders. The large cylinder A, is 144·37 inches diameter, and 1½ inch thick; and C, the small cylinder, 84·25 inches diameter, and 1⅝ inch thick; both are truly bored out, and the small cylinder is also turned on its outer circumference. B is a steam-jacket for the large cylinder, cast in 13 segments—which is again enveloped in a wooden casing *l*, having 4 inches of peat ashes between them.

Pistons.—The small cylinder C is fitted with a plain piston of 5474·81 square inches area, and the large cylinder A is occupied by an annular piston of 10323·36 square inches area. The areas of the two cylinders, after deducting 472·8 square inches for the thickness of small cylinder, are as 1 to 2·85. The internal and external packings of the pistons consist of hard cast-iron segments at bottom, with gasket above, pressed down by glands, also in segments; the open spaces in the pistons *c c* are filled with cast-iron plates, and the tops of the pistons have movable cast-iron covers.

Cap or cross-head.—The pistons are connected to the great cap or cross-head G, by the main piston-rod Y, of 12 inches diameter, and by four small rods *y*, of 4½ inches diameter, (Fig. 3158.) The great cap G has a circular body 9 feet 6 inches diameter, divided into eight compartments, which can be filled with cast-iron weights; from its centre a guide-spindle *z*, passes through a stuffing-box placed in the centre of a great beam of timber 2 feet square, which passes across the engine-house, and is secured to its walls; there are two other guide-rods *b*, which pass through stuffing-boxes in the arms of the great cap G, and are secured to the upper and lower spring beams.

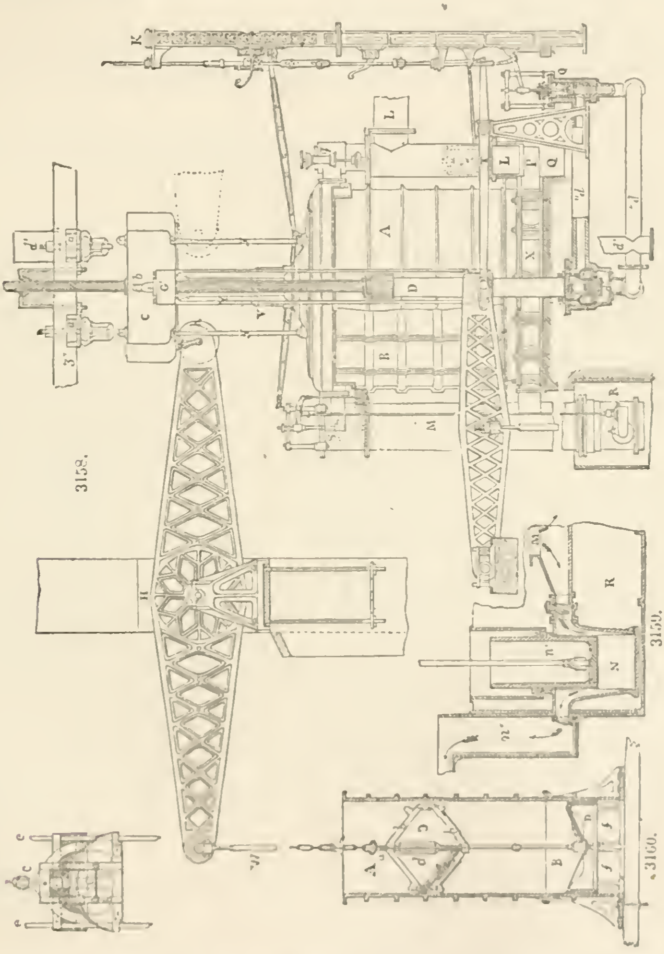
Plungers.—Suspended from the arms of the great cap are two 9-inch plunger-poles F, working in plunger-cases D; attached to D are two valve-nozzles *d''*, connected with stand-pipes *d'*, by two branch pipes *d''*; the valve-nozzles are connected with each other and a hydrostatic equilibrium valve-nozzle O, from the bottom of which a branch piece is connected with the stand-pipes *d'* by the pipes *d''''*. The exterior surfaces of the plunger-cases D are turned truly, so as to allow the rings *e e* to slide up and down freely; the rings are suspended from the great cross-head by rods *v*, and are furnished with cross-bearings, on which the jaws of the two air-pump balance-beams E rest: the inner ends of these balance-beams move in a perfectly vertical line, and the outer ends are furnished with rollers working between guides, to allow for the variation of the beams during the up or down stroke.

Air-pump.—From the centre of the air-pump balances, the two air-pump plunger pistons *n'* are suspended, (Fig. 3159;) diameter of plunger pistons 40 inches, stroke 5 feet; the two air-pumps N are united by a branch piece with the bottom of the condenser M. The condenser has an intermittent in jection by a valve 8 inches diameter, and a constant injection by another valve of 3 inches diameter. R is the condenser cistern.

Pipes and valves.—L is the steam-pipe (2 feet diameter) from the boilers; in it is placed a double beat governer-valve of 16 inches diameter.

P, the induction-valve,	16	inches	diameter	and nozzle.
Q, Equilibrium-valve,	20	do.	do.	do.
S, Eduction-valve,	26	do.	do.	do
q, Equilibrium steam-pipe.				

The induction and equilibrium nozzles are each connected to a separate port cast in the cylinder's bottom. The eduction nozzle is connected by a pipe M, 34 inches diameter, to the branch-pipe M of the condenser. The pipe M is also connected to the bottom of the cylinder, in which a port is cast, which communicates with the space under the annular piston; by this arrangement a constant vacuum is maintained beneath that piston.



3158. 3159. 3160. 3161.

The hand-geer is connected to the weigh post K, and the plug rod is worked by a lever and shaft T, the outer end of which is slotted and worked by a pin on the sliding ring *c*.

Pumps.—The engine works eleven pumps of 63 inches diameter; each pump is furnished with a cast iron balance beam H, (Fig. 3158,) which radiates from the centre of the piston rod; the inner and outer arms are of equal lengths from the centre gudgeon. The inner ends of the balance beams are furnished with cast iron rollers, working against a plate, fitted with guides for each roller, which is screwed up against the under side of the great cap; each beam is connected to the cap by two slotted bridles, to insure simultaneous upward motion during the up-stroke of the engine. From the outer end of the balance-beam the pump piston is suspended by wrought iron rods, 3 inches diameter and 16 feet long, and an additional length of 14 feet of patent chain cable attached to the pump piston. Fig. 3160 shows a section of one of the pumps, and Fig. 3161 an elevation of the piston. A, working barrel, 63 inches diameter; B, windbore and clack piece; C, the piston or bucket; D, bottom valve and seat.

The pump piston C is of a peculiar construction; it is composed of a wrought-iron centre-piece, 1 inch thick; firmly bolted to this piece are two double elbow frames of cast-iron, called "the cradles;" the elbows are faced with gun-metal plates; the cradles serve to support two wrought-iron semi-elliptic valves *c c*, which occupy the whole area of the pump when they fall out, and constitute in fact the piston. These valves are edged with wood, having a piece of leather on the upper side secured by a wrought-iron gland; the valves are hung to the centre-piece at about 3 inches from their lower edges, so that when they open during the down stroke, any dirt or sand which has lodged on the bottom may fall through. Attached to the centre-piece are two plates of cast-iron, which serve as ballast to sink the piston; these ends are cast with a jaw, in which pieces of wood are secured to prevent friction against the sides of the pump, and to give steadiness to the piston. These pistons require a weight of 1·4 lb. per square inch of the area of the pump to sink them with the velocity required upon the down stroke. The pump pistons of the Leeghwater are not furnished with guides, as shown in Figs. 3160 and 3161, and work very well without them: but the pistons for the pumps of the Cruquius and Van Lynden engines (now constructing for the drainage of the lake) will have guides, in consequence of the diameter of the pumps being increased to 73 inches.

Pump valves.—The bottom valves have cast-iron seats secured to the windbore, the valve beats are of wood, and the valves are simply plates of wrought-iron, 1 inch thick; the valves are not hung on fixed joints, but are each fixed to a bar, the ends of which are entered in cast-iron slot-pieces, allowing a rise of 1½ inch, so that the valve can rise altogether from its beat, and give a large water passage all round.

Power of engines.—The steam and pump pistons both perform a stroke of 10 feet in length: each pump by calculation should deliver 6·02 tons of water per stroke, or 66·22 tons for the eleven pumps; but by actual admeasurement of the quantity delivered, it is found to be 63 tons. The loss might be reduced, but probably at the expense of increased friction.

The engine-house is a massive circular tower, concentric to the cylinders; on its walls are placed the eleven pump balances radiating from its centre. The eleven pump balances are so placed as in no way to disturb the equilibrium of the great cap of the engine, under which the inner ends of all the balances are concentrated. If any of the pumps require repairs, the opposite pairs can be easily detached, without causing more than a trivial delay to the working of the engine.

The action of the engine is very simple; the steam being admitted into the small cylinder, the whole of the dead weight and pump-balance beams attached to the great cross-head are elevated with it, and the steam being cut off at such portion of the stroke as may be required, the remainder is effected by the momentum acquired by the dead weight and the pressure of the expanding steam upon the small piston, (the pump pistons at the same time make their down stroke;) at the end of the up stroke a pause of one or two seconds is requisite, to enable the valves of the pump pistons to fall out, so that upon the down stroke of the steam piston they may take their load of water without shock. During this time it is necessary to sustain the great cross-head and its load of dead weight at the point to which it was elevated by the up stroke, as otherwise it would fall back until the expanded steam under the small piston was compressed to a density equal to the pressure per square inch of the load lifted, or would cause a very violent shock upon the pump-valves by suddenly throwing them out against the sides of the pumps. To avoid these evils the hydraulic apparatus D F was devised.

Hydraulic apparatus.—When the engine makes its up stroke, the plunger-poles F (which form part of the dead weight) are lifted, and the water from the stand-pipes and reservoirs *d′* flows through the valves *d″*, and follows up the plunger-poles as fast as they are elevated. At the end of the stroke the spherical valves instantly close, and the dead weight is suspended exactly at the point at which it had arrived—and, of course, if the valves are tight, could be maintained there for any given period; in consequence of all strain being thus removed, there is no pressure to close the valves of the pump pistons beyond their own weight; therefore, they fall out without the slightest shock. To make the down stroke, the equilibrium steam-valve Q, and the hydraulic valve O are opened *simultaneously:* the water from beneath the plungers escapes to the stand-pipes and reservoirs by the pipes *d″″*, and the steam from the small cylinder passes by the pipe *q*, round to the upper side of the small and annular pistons, puts the pressure on the small piston in equilibrium, and presses upon the annular piston, (beneath which a constant vacuum is maintained,) in aid of the dead weight now resting upon the inner ends of the pump balances: by the united effort, the pump pistons are elevated and the water discharged. Before the next stroke is made, the eduction-valve is opened and a vacuum formed over both pistons.

So well does the hydraulic apparatus just described effect the object for which it was designed, that the Haarlem-mer Meer Commissioners have decided to use only eight pumps, but of 73 inches diameter, for the other engines; the chief reason for the adoption of the 63-inch pumps for the Leeghwater Engine having been the fear of the shocks to which such large pump pistons are ordinarily liable.

Boilers.—The Leeghwater Engine is furnished with five cylindrical boilers, each 30 feet long and 6 feet diameter, with a central fire-tube, 4 feet diameter: a return flue passes under the boilers to the front, and then splits along the sides. Over the boilers is a steam chamber, 4 feet 6 inches in diameter and 42 feet in length, communicating with each boiler; from thence a steam-pipe, of 2 feet diameter, conducts the steam to the engine. The steam space in the chamber, boilers, and pipe is nearly 1320 cubic feet, and as the engine draws its supplies from such an immense reservoir of steam, no "primage" takes place, and a very uniform pressure upon the piston is obtained until the induction-valve closes These boilers have produced steam enough to work the engine to the net power of 400 horses. The Cruquius and Van Lynden Engines will have boilers capable of working to 500 horses' power if required.

The drainage.—Prior to the construction of the engine-house, &c., an earthen dam of a semicircular form was thrown out into the lake, to inclose about 1½ acres; after the water was pumped out from within the dam, a strong piled foundation was made, and the masonry commenced at the depth of 21 feet below the surface of the lake: a small steam-engine was erected to evacuate the water from the dam. When the Leeghwater was completed, the commissioners determined to test its merits fully before deciding on the construction of the other engines upon the same model; and as they had the means of evacuating the water within the dam to any level required, the Leeghwater could be tried and worked continuously under any circumstances, precisely similar to those which will occur during the drainage of the lake, if, instead of discharging the water from the pumps into the upper canal, it was allowed to fall back again to the level from whence it was derived.

The average depth of the lake is 13 feet below the general level of the surface water of the canal and water-courses conducting to the sea-sluices; when the communications between those waters and the lake are closed, the engine will at first have only the head of water caused by the discharge from the pumps, and the friction of the machinery, to overcome; in this state, all the filling plates or ballast of the great cap and pistons will be taken out, and counter-balances added to the pump balance-beams "out of doors," so as to take up as much of the dead weight attached to the great cap as may not be required for working the engine: as the lift becomes greater, the dead weight "in-doors" will be gradually added. In this manner the engine was worked for a considerable time, to get all the parts in good working order. A sub-committee of the commission conducted a series of experiments, and satisfied themselves that the Leeghwater will perform a duty of 75 million pounds, lifted one foot high, by the consumption of 94 lbs. of good Welsh coal, whilst exerting a net effective force of 350 horses' power. With a lift of 13 feet, the engine easily worked the eleven pumps simultaneously; the net load of water lifted being 81·7 tons, and the discharge 63 tons, per stroke.

When the bed of the lake is cultivated, the surface of the water in the drains will be kept at 18 inches below the general level of the bottom; but in time of winter floods, the waters of the upper level of the country will be raised above their ordinary height: in which case, to keep the bed of the lake drained to the regulated height, the lift and head may be increased to 17 feet. To test the power of the engine under these circumstances, (and without regard to the consumption of fuel,) the whole of the 11 pumps were worked simultaneously, and the extraordinary quantity of 109 tons net of water was raised per stroke to the height of 10 feet; but, in practice, it will be advisable to work a less number of pumps, and increase the number of strokes per minute.

After numerous and severe trials of the engine, the commissioners were satisfied that it is capable of performing its work under the most difficult circumstances that can arise; and immediately determined on having two more engines constructed, of equal size, and on the same model—the only material alteration being in the arrangement of the pumps; the number being reduced to 8 for each engine, but of 73 inches diameter, placed in pairs opposite each other, and the ends of the balance-beams projecting over the great cap of the engine, (instead of under as in the Leeghwater,) to which they will be connected by stout wrought-iron straps. The boilers also will be increased in number, and in power nearly 100 horses. All the feed-water will be filtered before passing into the boilers.

Advantages of two cylinders.—Many persons imagine that the engines are constructed with two cylinders to obtain a greater expansion of the steam than would be attainable in one cylinder; but such is not the case, as no greater economy of steam can be obtained by the use of two cylinders than by one, although greater steadiness of motion for rotatory engines, and less strain upon the pit-work of a mine pumping engine, may result from the use of two cylinders. In the Haarlem engines two cylinders are used, because if one cylinder only were employed it would sometimes be necessary to use a dead weight of 125 tons to overcome the resistance of the water load and friction of the engine and pumps; such a mass of iron or other heavy material would be unmanageable, and no alteration in the force of the engine could be effected but by taking from or adding to the dead weight, which would be a source of great difficulty and inconvenience, when the varying character of the load, during the drainage of the lake, is considered; particularly as at times the water will be charged with so much foreign matter as greatly to add to the friction of the pumps. By the system adopted the maximum dead weight elevated by the small piston will seldom exceed 85 tons, the additional power required being derived from the pressure of the return steam, at the down stroke, on the annular piston; by varying the expansion and pressure of the steam in the small cylinder, the engineman can add to, or diminish the pressure upon the annular piston, so as to meet any case of variable resistance without the inconvenience and delay attending an alteration of the dead weight; the load is therefore under perfect command at all times.

Quantity of water.—The area of the Haarlem Lake is 45,230 acres, the estimated contents to be pumped out about 800 million tons; but should the quantity be increased by any unforeseen cause even to 1000 million tons, the whole amount could be evacuated by the three engines in about 400 days.

The bed of the lake when drained must be always kept dry by machinery, and observations continued during 91 years show that the greatest quantity of rain which fell upon the area of the lake in that period would give 36 million tons as the maximum quantity of water to be elevated by the engines in one month; to perform this work would require a force of 1084 horses' power to be exerted during that period; the average annual drainage is estimated at 54 million tons.

The cost of the Leeghwater, buildings and machinery, was £36,000; of this amount about £15,000 are due to the buildings and certain contingencies. For the foundations 1400 piles were driven to the depth of 10 feet into a bed of hard sand, and a strong platform laid thereon at the depth of 21 feet below the surface of the lake; upon this platform, at the distance of 22 feet from the engine-house, a strong wall pierced with arches was constructed, and at 7 feet from the coping a stout floor of oak was laid between the wall and the engine-house; the pumps rest upon the platform beneath and opposite the arches, and their heads come through the floor alluded to, and stand about 3 feet above its level: into the canal thus formed between the engine house and the outer wall, the water from the pumps is discharged, and flows off on either side of the boiler-house, through sluice-gates, into the canals conducting to the sea sluices.

The great cost of the buildings, for whatever description of machinery might have been employed, rendered it an object of considerable importance to lessen this expense by concentrating the power to drain the lake in three engines; in addition to which a considerable saving in the wages of enginemen, stokers, and others is effected, as these large engines require very little more attendance than an ordinary mine engine; this is an important feature in the economy of the charge for the permanent drainage of the "Polder," which will be formed by the bed of the lake.

The average consumption of the ordinary land-draining engines applied to scoop-wheels and Archimedian screws, may be taken at 15 lbs. of coal per *net horse-power* per hour; this quantity will be greatly reduced if the horses power of the engines be calculated by the pressure of the steam on the pistons, and not by the net delivery of the water; in a case where the water delivered by a large steam-engine working a scoop wheel, was measured during eight hours, the engine was found to exert a *net* force of 73 horses' power during the first hour, with a consumption of 15 lbs. of coals per *net* horse-power; as the lift increased the power diminished, and the consumption of fuel increased, until at the eighth hour it was found that the engine only exerted a *net* force of 33 horses' power, and consumed 24 lbs. of coal per *net* horse-power per hour. The consumption of fuel by the Leeghwater is 2½ lbs. of coals per horse-power per hour when working with a net effective power of 350 horses.

No *new principle* has been developed in the Leeghwater, but important facts have been demonstrated which must have an immense influence on the progress of agricultural hydraulic engineering: it has proved that with proper attention to well-known principles, steam-engines of the very largest class (the Leeghwater is believed to be the largest and most powerful land engine ever constructed) may be employed to raise great bodies of water from low lifts for the drainage or irrigation of low lands with as great an economy of fuel as was hitherto generally supposed to be confined to the elevation of comparatively small quantities of water to great heights. To the Haarlem-mer Meer Commissioners belongs the merit of having ventured to carry out this bold experiment, and they will reap their reward by an economy of at least £100,000 over the cost of draining the lake by the ordinary system of steam-engines and hydraulic machinery employed to drain land; and of upwards of £170,000 and three years time over the cost of draining the lake by the windmill system hitherto generally employed in Holland.

The Leeghwater is named in honor of a celebrated Dutch engineer, who, from his great success in draining numerous lakes in North Holland, was popularly known by the name of "Leeghwater," or "the drier-up of water," and with him the first proposal to drain the lake originated in 1623.

The engines and pumps were manufactured at the establishment of Messrs. Harvey & Co., of Hayle, and Messrs. Fox & Co., of Perran, Cornwall.

PUNCH, REVOLVING SPRING. Invented by S. Merrick, of Springfield, Mass., and patented February 28th, 1848.

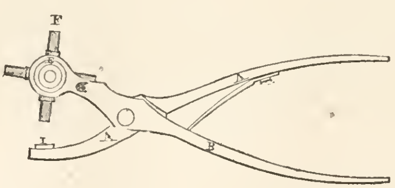
This tool is designed for punching leather and other like material, and contains four punches of varying size, either of which can be instantly brought into use.

In the drawings, Fig. 3162 denotes a side elevation.

Fig. 3163 an end view of the cylinder E, and the series of rotating punches F F F F, showing the right-angular shoulders *b*, on the punches.

In said Figures A denotes the bed-lever of the punches; B, the punch-lever, or that which supports or carries the series of rotating punches F F F F, which are sustained and revolve between spring-jaws D D. I is the bed or blank of copper, in conjunction with which the lower punch acts during the opera-

3162.



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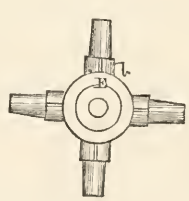
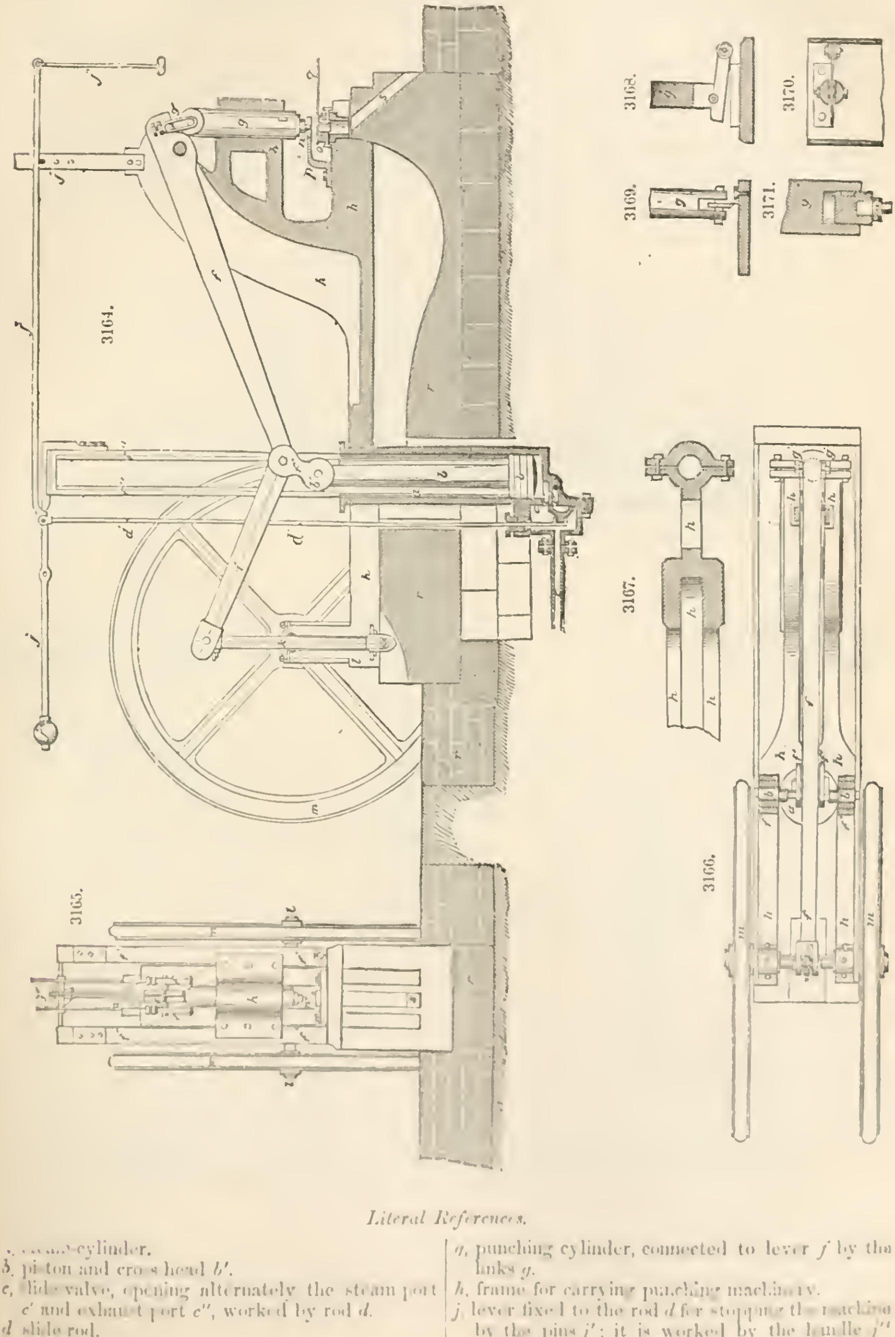


tion of punching; E is the cylinder to which the several punches are fastened: right-angular notches are made in the lower side of the spring-jaws D, which notches are made to fit the projections or right-angular shoulders *b*, made on the sides of the punches; their object is to prevent the lower punch from being moved forward towards the extremity of the lever A during the operation of punching. Each punch of the series is fitted with like shoulders. The notches are made in cam projections, formed respectively on the spring-jaws. For the purpose of effectually discharging the little circles or cylinders of material separated from any article by the cutters, and which pass through the cutters and into the interior of the cylinder E, a cone is arranged with respect to the discharging mouths of the punches, so that after the pieces of leather have passed out of the punches they are forced against the cone, and by it directed laterally and out of the space. Without some such contrivance, the space is very liable so become filled or choked by the pieces which are cut away by the punches.

The remaining parts of the punch will be obvious without further description.

PUNCHING MACHINE, STEAM.—*By M. Cavé, Paris.* Fig. 3164, elevation. Fig. 3165, end view. Fig. 3166, plan. Fig. 3167, sectional plan of punching-frame. Fig. 3168, section of cutter adapted to machine for cutting plate. Fig. 3169, elevation of the same. Fig. 3170, plan. Fig. 3171, section showing the mode of keying the punch.



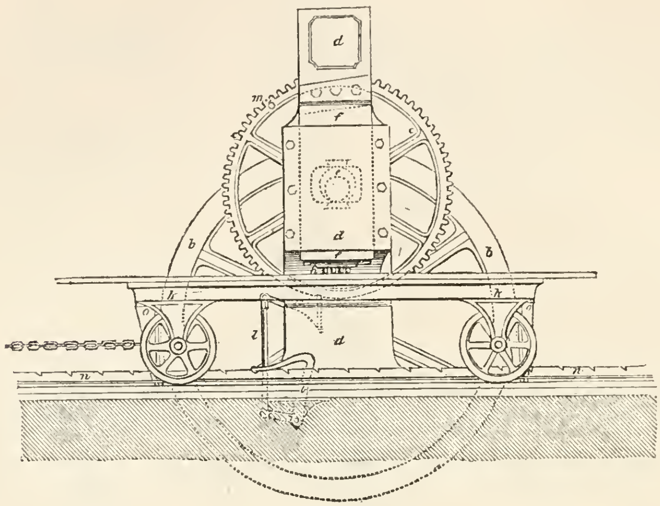
Literal References.

a, steam-cylinder.
b, piston and cross head *b′*.
c, slide valve, opening alternately the steam port *c′* and exhaust port *c″*, worked by rod *d*.
d, slide rod.
e, steam pipe.
f, punching lever, connected to the piston by the links *f′* and cross-head *b′* working in frames *f″*.
g, punching cylinder, connected to lever *f* by the links *g*.
h, frame for carrying punching machinery.
j, lever fixed to the rod *d* for stopping the machine by the pins *j′*; it is worked by the handle *j″* and counterbalance *j‴*.
k, connecting rod.
l, crank and shaft.

m, fly-wheel.
n, punch.
o, dies.
v, stop.
q, plate being punched.
r, foundations.
s, aperture through which the iron plate punched out falls.

PUNCHING AND PLATE-CUTTING MACHINE. *By Messrs. Nasmyth, Gaskell & Co., Manchester* Fig. 3172, front elevation. Fig. 3173, side elevation.

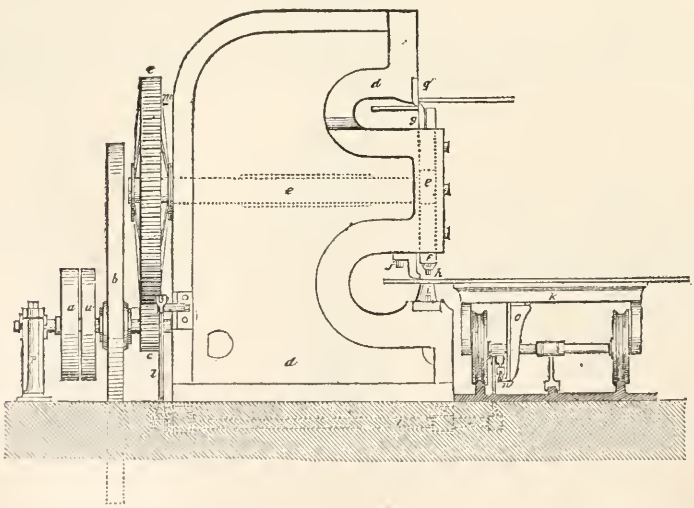
3172.



Literal References.

a, tight and loose riggers.
b, fly-wheel.
c, spur-wheel and pinion.
d, frame for carrying machinery.
e, shaft and eccentric for raising and depressing slide.

3173.



f, slide, the upper end having a steel cutter *g*, and the lower end the punches *h*.
g, steel cutters.
h, punches.
i, die frame.
j, stop for preventing the plate from rising.
k, travelling table for carrying plate to be punched.
l, rods, levers, and spindle for advancing the travelling table by means of tappet *m*, on spur-wheel
m, tappet on spur-wheel.
n, rack-bar attached to brackets *o* of travelling table.
o, brackets fixed to table.
p, carriage for supporting spindle.

PUNCHING AND SHEARING MACHINE. By Caird & Co., Greenock. These figures represent the form and general arrangement of a machine of great importance and utility in the manufacture of steam-engine boilers. The present example is distinguished for its mechanical elegance of design, simplicity of construction, compactness and strength. Although the machine occupies only a very inconsiderable space on the floor of the factory, it is capable of punching and shearing plates of one inch in thickness.

Fig. 3174 is a general side elevation of the machine.

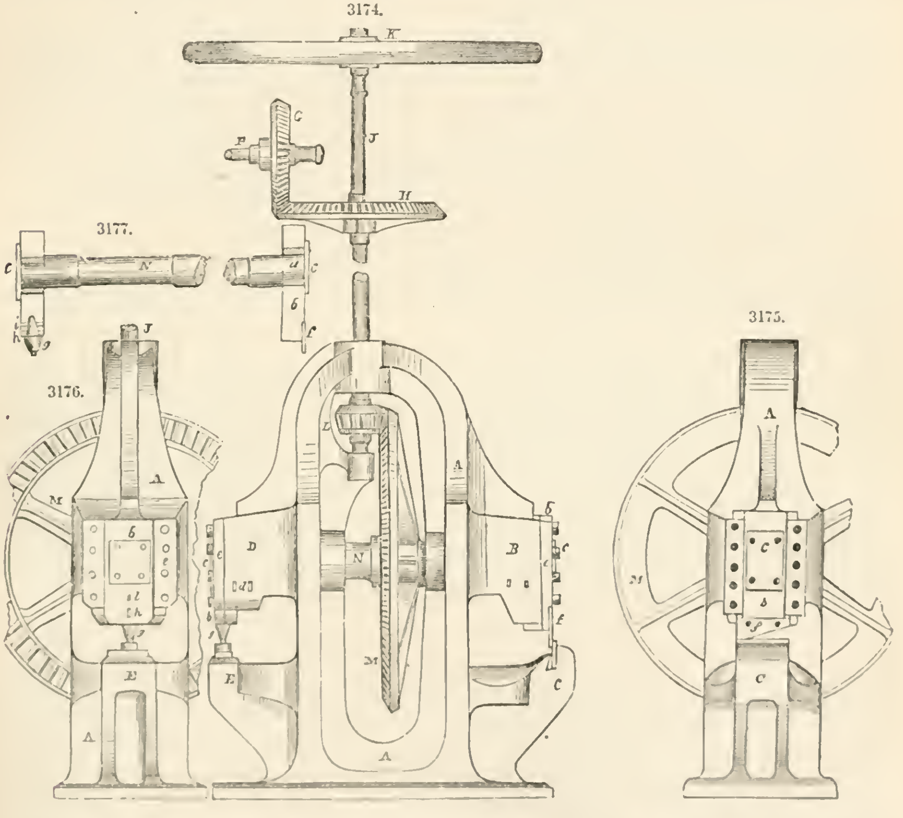
Fig. 3175 is a front elevation, looking upon that face of the machine which is adapted to the operation of shearing.

Fig. 3176 is a corresponding elevation of the opposite end at which the operation of punching is performed.

Fig. 3177 shows the form of the main-shaft and section of the slides.

General description.—The framing consists of a single massive casting A A, having strong brackets B C and D E formed upon it at opposite sides. In the pieces B and D recesses are formed for the reception of the bushes of the shaft N, and of the slides *b b*, to which the shearing cutter and punch are attached respectively. The bushes of the shaft N are adjusted to the proper degree of tightness by the

3174. 3177. 3176. 3175.



cotters *d d*; and the extremities *a a* of the shaft, close to these bearings, are formed eccentrically, as shown in Fig. 3177. These eccentric ends are inserted into the slides *b b*, and work in oblong bushes of such a form as to allow the eccentrics to move freely in a lateral direction, while the full amount of their vertical motion is transferred to the slides. These bushes are retained in their places by thin wrought iron covers *c c*.

The slides move vertically between the parallel dovetail guides *e e*, fixed by screws tapped into the projecting pieces B and D, which are carefully dressed to allow the slides to move freely but without play upon them. On the shearing slide is fixed a steel cutter *f*, acting in contact with the stationary cutter inserted into the table C; the cutting edges form an acute angle with each other, so that during the process of shearing, the action is rendered gradual. The opposite slide carries the punching tool *g*, which is held in its socket by a cotter *h*; the small hole *i*, immediately over it, is for the convenience of driving the punch out of the socket when required. The die-holder is attached to the table E by two screws tapped into the table, and thus admits of being changed at pleasure.

The shaft N derives its motion from the large bevel mortise-wheel M M, keyed upon it between the cheeks of the frame. This wheel geers with, and is put in motion by, the pinion L, on the lower end of the vertical shaft J, which is carried in a step supported in a bracket cast on the [illegible] of one of the cheeks; the upper end revolves in an independent bearing attached to any convenient beam. The power is transmitted to this shaft from the driving-shaft F, by means of the two bevel-wheels G and H. On the upper end of the same shaft J is keyed the fly-wheel K, for equalizing the motion of the machine under the irregular strains to which it is subject.

Action of the machine.—Motion being communicated to the eccentric-shaft N, the slides will be made to travel vertically through spaces corresponding to the eccentricity of the parts *a a*, thereby working the shears and punch alternately; the eccentricity of the two extremities being formed on opposite sides of the shaft, so that while the punch is descending, the cutter of the shears will be ascending, and *vice versa.* The plates under operation are shifted by hand, upon tables of wood erected at the proper levels, and usually with guides fixed upon them for insuring accuracy in the operation of cutting.

Literal References.

A A, the frame of the machine.
B, hollow bracket for the shearing-slide.
C, the fixed table for the same.
D, hollow bracket for the punching-slide.
E, the table upon which the hollow die is set.
a a, eccentric ends of the shaft N.
b b, the shearing and punching slides.
c c, covers fixed upon the slides over the ends of the eccentrics *a a*.
d d, cotters for adjusting the adjusting bearings of the shaft N.
e e, dovetail guiding pieces between which the slides move.
f, the shearing-cutter.
g, the punching-tool.
h, a cotter for fixing the punch in its socket.
i, an oblong hole over the socket of the punch for driving it out when required.
F, the shaft by which the power is led to the machine.
G, a bevel-wheel on the horizontal driving-shaft, geering with
H, a bevel-wheel on the vertical driving-shaft J.
K, the fly-wheel for regulating the motion of the machine.
L, a bevel-pinion on the vertical shaft J, geering with
M, a large bevel mortise-wheel fixed on
N, the main eccentric-shaft.

PYROMETER. An instrument for measuring the degrees of heat. The term *pyrometer* is generally understood to denote either an instrument intended to measure higher temperatures than can be measured by the ordinary thermometer, or an instrument for comparing the expansions of different metals.

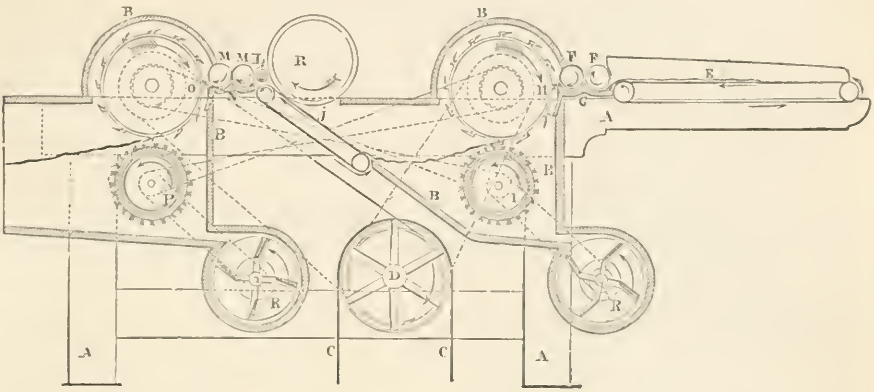
Various contrivances have been employed for the above purposes. Musschenbroek, the original inventor of the pyrometer, adopted the following method: A prismatic rod (about six inches long) of the metal under trial being attached at one extremity to an immovable obstacle, and heated by lamps, the other end is necessarily pushed forward; and this being fastened to the end of a rack playing into a pinion, communicates a revolving motion to an axle to which a train of wheel-work is attached, whereby the minutest expansion of the heated bar is rendered sensible, and measured by an index on a dial. The principle of this apparatus is sufficiently simple; but the uncertainty attending the motion of so many loosely connected wheels and pinions must have rendered its indications of little value; and the method is liable to a still more serious objection, namely, that the temperature communicated to the bar by the lamps is entirely unknown. Desaguliers, and afterwards Ellicott, made several improvements in the construction of the instrument, tending to give it a more equable motion and to increase its delicacy. Graham substituted a micrometer screw for the wheels and levers that had formerly been employed; and on this principle Mr. Smeaton contrived an ingenious apparatus, which is described in the *Phil. Trans.*, vol. xlviii.

RAG AND WASTE PICKER—By C. G. Sargent. It has always been a desideratum, and hitherto unaccomplished in any practical degree, for the manufacturer to be able to reduce waste yarn and poor or worn fabrics to their original condition of fibre, and capable of being again worked into cloth. The above machine accomplishes this object, being capable of reducing 150 pounds of waste woollen yarns, so that they may be easily carded and spun anew. It was invented after trials of several modes, and after much consideration, by Mr. Charles G. Sargent, of Lowell, and he is now constructing them for most of the woollen-mills in that section of the country. The cost of one whose cylinders are 12 inches long, with full rights to use it, is about $300.

The machine and its action may be described by reference to Fig. 3178, which represents a longitudinal section of it. The frame being represented at A A A, &c., the casings at B B B, &c., D being a shaft put in motion by some force, and from which motion is communicated to all moving parts. The yarn, cloth, or other material required to be picked, is spread upon a feeding apron E, which has a slow motion towards the roll F, which has a motion indicated by the arrows, and being fluted or toothed draws in the material between itself and the iron shell G, and passes it forward to the roll F′, which is similar to F, and has a quicker angular motion than it, thereby insuring that it may take all that is presented by the roll F, and at the same time tending to draw the threads or fibres to a position at right angles to its axis, the rolls F and F′ being so supported that they can rise and fall from and towards the shell G, according as there may be large or small pieces between them and the shell.

The material is thrust out from between the roll F′ and the shell G, towards the first picking cylinder H. This cylinder is formed by adding to a plain cylindrical pulley strips of metal, about 1 inch by ¾ inch, and of the same length as the face of the pulley. Parallel to its axis and upon the outer surfaces of these strips, are secured plates somewhat wider than the strips, having fine teeth cut upon one of their edges, and set in such a manner that the points of the teeth will be somewhat further from the centre of the pulley than the other edge, and also projecting forward in the direction of the motion of the pulley, and overlapping the strips to which they are attached. This cylinder being so placed that the teeth of the serrated plates will, when the cylinder is in motion, barely clear the shell G, when the material is projected from between the roll F′ and the shell G the part so projected will be combed and torn to shreds, while the twist of the yarn will be taken out by the rapid action of the serrated plates, while large and long pieces will be prevented from being passed through by being held between the rolls and the shells. The material is taken from the cylinder H by the brush I, which revolves more rapidly, and at the same time is assisted by the fan R, which also keeps the brush clean. By the current of air produced by the fan and brush the material, now partially picked, is blown upon the second feeding apron J, which has a slow movement indicated by the arrows, and is prevented from leaving this apron by the cylinder K, which revolves slowly, being carried by the apron. This cylinder is made by covering a slight frame with wire cloth, thus allowing the air to pass through it and retain the material upon the apron, forming a lap.

3178.



The material now passes under the small roll L, which is a plain cylinder, and for the purpose of leading it to the second pair of feeding-rolls M M′, the cylinder O, the brush P, and fan R, each of which acts respectively the same as the rolls F F′, the cylinder H, brush I, and fan R, except that the teeth of the cylinder O are finer than those of H, and that the material is now blown out of the machine picked, and again ready for the card.

RAILROADS. The limits and scope of this work forbid enlarging upon the history of railroads, or tracing their development from the rude tram-ways of the German mines, to their present highly advanced state of perfection. A great deal has been written on this branch of the subject, easy of access and the reader is referred to Wood, Breese, Dempsey, and others on railroads. We have to do in this place with railroads in the light of machines, and as such describe them as they are; the principles upon which they are projected and located, constructed and worked.

Railroads are roads upon which the carriages travel on iron rails, to which they are confined by projections on their wheels, called *flanges*.

The principles which govern in the location of a railroad are the same as those of a common road; the motor in general use on the former, however, renders necessary a more rigorous observance of these principles.

The resistance to motion on roads is occasioned: 1st. By the want of uniformity in the surface of the road; the weight of the load having to be lifted over the projecting points and out of the hollows or ruts, thus diminishing the effective load which the power may draw to such as it can lift.

2d. *The want of strength of the road bed itself*, let its surface be as even or uniform as it may, adds another impediment to the movement of a load over it, with the additional disadvantage that while the power is endeavoring to lift the load from a cavity or hollow, the fulcrum, which in the first case was supposed to be rigid and fixed, is in the latter yielding and variable, subjecting the power to the constant effort of lifting instead of simply drawing. To these causes of resistance are to be added,

3d. *The grade of the road*, or the quantity by which it differs from a level. This resistance is due to the force of gravity, and unlike the others may be determined from the well known laws of mechanics, whilst the former are determinable entirely by experiment on the road in question or a similar one.

Friction of the axles and resistance of the air.—This, it is true, is a fourth cause of resistance to motion on roads, but its consideration may be neglected for the present, as its effects are constant, and independent of the imperfections of the road.

The first cause of resistance above enumerated, want of uniformity or evenness of the road surface, is attempted to be overcome in the railroad by substituting for the uneven gravel or pavement a hard and smooth iron surface, or the rail. The second cause of resistance is diminished by a system of constructions whose aim is to afford the iron rail a permanent and unyielding support.

The whole art of railroad *building*, then, consists in producing for the carriage to roll on, a hard, smooth surface, upon an unyielding foundation or road bed—in appearance a very simple matter—in reality a very difficult one.

To exhibit at a glance the value of a *smooth* surface—From experiments made upon the best turn pike road in England, and probably in the world, the following was found to be the force of traction, or the weight in pounds which, hanging over a pulley, would draw one ton on a level part of the road—the road-bed as firm as most railways:

On a well-made smooth pavement	33 lbs.
On a broken stone surface (macadamized) over an old flint road	65 "
On a gravel road	147 "
On a macadamized road, on a rough permanent foundation	46 "
On a macadamized surface, on a foundation of cement and gravel	46 "
Average,	67 lbs.
On a good edge railroad, the force of traction on a level is usually taken for one ton at	8 "

or a horse will draw from five to eighteen times as much on a good railroad as upon the best turnpike roads in use, and this is due to the smoothness of the surface alone.

This illustrates the extent of the first cause of resistance to motion on roads.

For the second, it may be sufficient to mention a circumstance within the writer's experience. A locomotive engine, built at Lowell, drew, on trial, on the Lowell and Boston Railroad, up a grade rising 30 feet per mile, the same load which it barely drew on a level part of the inferior railroad upon which it was subsequently worked. The surfaces in the two cases were the same, wrought-iron; but the one road-bed and rail was firm, and the other yielding.

The engine which could draw, say 300 tons gross, on a grade rising 30 feet per mile, the rail perfectly firm, would, in the same condition of rail, draw 475 tons on a level. This illustrates the value of a firm and unyielding road surface.

Location.—In the location of a railroad, the termini are in most cases fixed, and the engineer, having in consideration the nature and amount of the traffic anticipated on the road, must so adjust its alignment, both vertical and horizontal, as with the least expenditure in first cost and in subsequent working, to produce the greatest effect—in this case, the greatest return on the capital invested in the building maintenance, and working of the road.

The perfection of a railroad would seem to be a straight line and a level, and yet there may be controlling circumstances which would render a level road not desirable; such as a very heavy trade of coal, lumber, ores, &c., in one direction: in fact, the trade may be such as to render the weight of the empty return wagons alone the data for limiting the steepness of the grade; and again, when the trade is well balanced, it would be desirable to have the acclivities and declivities balanced, and the profile to be an undulating grade, providing a level road could not be found. In general, however, let what will be the best grade in view of the weight of traffic or other circumstances, it is rarely that these conditions can be rigorously obtained, save at a cost which will defeat its own object; for it is undeniable that a *good* road may cost too much. For instance, a heavy trade in one direction with no return of freight would seem to call for a uniform descending grade, or a grade undulating between level and descending; and yet to obtain these advantages ridges may require tunnelling, and expensive works encountered, to pay the cost of which would require tolls on the traffic for which the road was built, tending to throw the article out of the market in competition with other sources of supply. Between these limits of maximum acclivity and level the engineer is to make his selection, keeping always in view the conditions which he is aiming to fulfil, avoiding a hill here, cutting through a ridge there, again tunnelling in preference to adding to the length of line or to the curvature, or the reverse, increasing the length of the road very materially in some cases in order to avoid encountering heavy expenditures, &c. After he has made a careful reconnoissance of the country between the termini, and an instrumental examination of such lines of route as appear to his judgment the best calculated to fulfil the conditions sought, it will usually be found that one of two things exist: either the true route is indicated beyond all doubt by the features of the country, in which case it remains but to improve the line within narrower limits, or else several lines offer, either of which may, to the unassisted judgment, appear to fulfil all the required conditions. In the latter case, after improving each line in detail in reference to balancing the material to be used, that is to say, where possible, making the cuttings furnish the material for the filling; reducing the amount of curvature as much as possible; selecting the proper crossings of rivers, swamps, ridges, &c.; examining foundations of all kinds; ascertaining the fitness of the material to form banks; examining quarries, timber, price of labor and materials, and, in general, ascertaining the capabilities of the country on each route: the several routes are then compared in view of their first cost, maintenance, and working, and not unlikely a new element will appear of the varying amounts of the local or way business to be anticipated and provided for.

A treatise on railroad engineering would of itself require more space than can be allotted to the whole subject of railroads in a dictionary. This will account for the suppression of much of the detail which would be sought for in a complete treatise on railroad building. We must omit, therefore, the consideration of the preliminary operations of surveying and levelling, as well as the form and character of the respective works which make up the construction of a railroad; such as bridges, culverts, tunnels, foundations, &c., and which, in their principles of construction, are common to many branches of internal improvement.*

In preparing the estimates of the several lines, plans in detail are made of all the mechanical structures from which their cost is deduced: profiles are made exhibiting the grades of the road together with

* These are subjects of but little interest to the general reader, and the student in the science of engineering should look elsewhere than in a dictionary, however comprehensive, for the principles of his profession.

In the first volume of this Dictionary reference is frequently made to "railway engineering;" but the subject is, we conceive, foreign to the character of this work, which is a dictionary of "machines," showing the *principles* of their construction and working, or the "engineering of machinery" simply.—[Ed. 2d. Vol.]

the cuts and fills, and tables exhibiting the cubical contents of the various sections of the work, as also the horizontal alignment, showing the relative amounts of straight line and curves, and the character of the latter. The cost of construction having thus been obtained of the various lines, they are equated for their respective amounts of ascents, descent, and curvature, the ruling grade, or the grade which limits the effective power of the engines to be used, determined, and the lines of routes brought under one general view for comparison.

Equating for grades.—The result of experiments carefully conducted gives as the resistance to motion of one ton, moving on a well-built level railroad, about $8\frac{1}{2}$ pounds, or the weight which hanging freely over a pulley will overcome the friction of one ton. This resistance to motion is a constant fraction of the weight moved, and is its $\frac{1}{264}$th part. This is the friction of the load. If now the plane be elevated from a level to a rise of $\frac{1}{264}$th its length, according to well-known mechanical laws 1 pound will on this plane sustain 264 pounds, (See Inclined Plane and Mechanical Powers,) or $8\frac{1}{2}$ pounds will sustain one ton; and the fraction $\frac{1}{264}$ representing a rise of 20 feet in a mile; it follows that on this grade the effect of gravity is equal to that of friction, and in order to produce motion up this grade, *twice* the power must be applied that would be required were it on a level; and as it is a well-known mechanical law that the same amount of power is expended in raising a weight through a given height, whatever may be the *angle* of the plane upon which the motion is effected, it follows that for every 20 feet in height that we ascend on a railroad, we expend an amount of power equivalent to the transport of that weight over one mile of level; and this holds true whatever the grade may be. Equating for grades with a view to a comparison of lines, then, consists in *adding to the measured distance one mile for each and every twenty feet of ascent on the respective routes.*

Equating for curves.—Direct motions on levels or inclines are affected less by disturbing causes than motion in curves; for in addition to the irregularities growing out of the imperfections of the curved track and the varying elements of the curved motion in practice, is to be added all the disturbing causes which exist in the first case. This has, as yet, prevented that rigorous solution of the latter problem, which is to be desired, and which is essential to a true comparison, *a priori*, of the cost of movement on curved roads. It is as yet entirely an empirical formula deduced from a few experiments, but has been used for the purpose of comparison of routes by distinguished engineers, and is the best we can offer with our present knowledge of the subject.

We find by the experiments referred to above, that a curve of 400 feet radius *doubles* the resistance. In propelling a train, then, through an entire circumference of such a curve, we expend twice the power that would be consumed in travelling an equal distance in a right line.

Taking, then, the analogy afforded by motion on ascents as compared with levels as a guide, and we conclude that the same power would be expended in turning through an entire circle, *whatever may be its radius,* (this, of course, must be understood as confined to certain limits;) hence, for every circle of 360 degrees, we must add for the expenditure of power on a right line of the same length, the circumference of a circle described with the radius of double resistance, found by experiment as above to be 400 feet; this will be half a mile. Equating for curves consists, then, in *adding to the measured distance one half mile for each and every three hundred and sixty degrees of curvature on the respective routes.*

Having explained the principles which govern in reducing the several routes under comparison to a uniform standard in respect to their distance, curvature, and grades, we will introduce an example from actual practice illustrative of the every-day operations of comparing routes preliminary to a selection of one for construction.

The road in question was to connect two points some ninety miles apart, for which seven routes were examined, nowhere distant from each other more than seven miles, and the nature of the country and the anticipated traffic such as to reduce the question of a choice of routes to that of economy of construction, maintenance, and working—independently of any local advantages which one route might possess.

The cost of repairs per mile per year of roads as nearly similarly circumstanced as possible, and with a given traffic, having been obtained from their official returns, as also the cost of working, the former amounting to $600 per mile, was multiplied by the *measured distances of the lines,* and the latter, amounting to $750 per mile, was *multiplied by the distances resulting from equating the lines for curvature and grades* as above described.

A capital which at 6 per cent. will furnish the first amount is shown in the sixth column of the table below; the capital to furnish the second is shown in the seventh column.

Table exhibiting the measured and equated Distances on the Various Lines surveyed for Railroad, with the estimated Cost of each, including Graduation, Masonry, Wooden Bridging, and Railway, with the Capital requisite at 6 per cent. to furnish an annual sum adequate to maintain and work each line.

Description of Lines.	No.	Measured distances in miles and decimals.	Equated distances in miles and decimals.	Estimated cost of construction.	Equivalent capital to maintain.	Equivalent capital to work.	Grand totals.
Upper line	1	92·63	160·13	$1,127,171	$926,375,00	$2,001,636 25	$4,055 182 56
Lower line	2	91·06	157·22	1,067,816	910,632,00	1,965,256,25	3,943,705.17
Lower line B	3	89 61	157·40	1,076,012	896,116,00	1,967,527 50	3 939,985,66
Lower line C	4	90·07	156·60	1,087,689	900,766,00	1,957,513,75	3,946,999 02
Lower line D	5	90·21	155 97	1,073,518	902,178,00	1,949,711,25	3 925,737,62
Lower line E	6	91·65	159·55	1,124,509	916 596,00	1,994,416 25	4 033,522,00
Upper line B	7	93·51	160·79	1,129,097	9[illegible]5,116 00	2,009,911 25	4 074 124,74

Judging the lines by these tests, we find that No 1, or the *upper line*, stands 6th in order of directness, 6th in point of value derived from present actual outlay, 6th in order of working, and of course 6th in the aggregate of them all.

No 2. or the lower line, is	4th	In order of directness.
	1st	In value derived per actual present outlay.
	3d	In order of working.
	3d	In the aggregate of all these considerations.
No. 3 stands	1st	In order of directness.
	3d	In value derived per actual present outlay.
	4th	In order of working, and
	2d	In aggregate of all these.
No. 4 stands	2d	In order of directness.
	4th	In actual present outlay.
	2d	In order of working.
	4th	In aggregate of all these.
No. 5 stands	2d	In order of directness.
	2d	In actual present outlay.
	1st	In cost of working, and
	1st	In aggregate of them all.
No. 6 stands	5th	In order of directness.
	5th	In order of actual present outlay.
	5th	In cost of working.
	5th	In aggregate of all.
No. 7		Is the inferior one in every respect, standing last in all the comparisons.

Simplifying the matter as far as possible, we have four routes, No. 2, 3, 4 and 5, differing from each other, in the extremes of the first respect, rather less than two per cent., and in the latter about ½ per cent.

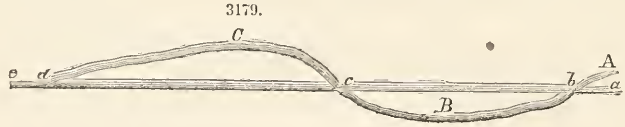
There seems no substantial reason at this stage of the case, founded upon such minute differences, for preferring one line over another, and we must therefore consider what improvements each is susceptible of, when it comes to be definitely staked off for construction.

It is very rare, however, that so small differences appear in the comparison of several routes, but it is introduced here as an example in actual practice, and showing a very proper method of comparison.

The route having been determined on, we proceed to the construction.

Excavation and embankment.—Let A B C, Fig. 3179, represent a profile or longitudinal section of a portion of the line over which the railroad is to pass, and *a b c d* the level at which the road is to be formed,

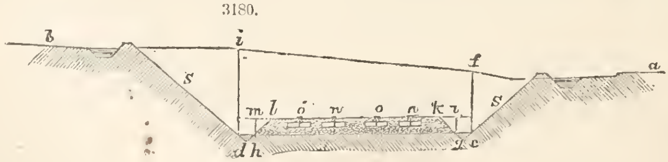
3179.



constituting what is called the *grade line*. All those parts of the section above the line *a b c d* will require to be cut down, and are called *cuttings;* and those portions below this line will require to be filled up, and are designated as embankment, or *fillings*.

Where a trifling variation in the general inclination of the line or of the grades is not of great importance, it is very advisable that the line should be so laid out that the quantity of earth, or material required for making the embankments, should not be greater than what is to be obtained from the excavations. There is, however, an exception to this in cuttings or embankments of great lengths. Cases may occur where the distance between the cutting and embankment is such, that the expense of con-

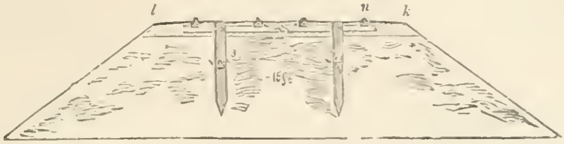
3180.



veying the earth from one part of the line to another is greater than the increased expense of borrowing material alongside the line of railway, or near the embankment, for the purpose of forming the embankment; and of depositing the earth from the cut, which ought to have formed the embankment, upon waste ground alongside such cut, in spoil bank. These are, however, cases to be judged of by the engineer of the work, and are entirely questions of comparative expense between the one mode and the other.

Width of the railway.—Fig. 3180 is a cross section of an *excavation* or cutting, and Fig. 3181 a cross section of an *embankment; a b* being the original surface of the ground, and *g h* the bottom level or extreme depth of the excavation. The first question to determine is the width at the bottom level, as by this the whole of the operations are guided; and this depends upon two considerations: first, the width between the rails; and next, the width between the two lines, if the railway is intended to be a double line.

3181.



Width between the rails.—The first public railway, of any extent, which was executed, was the Stockton and Darlington Railway. The width between the rails of that railway was made four feet eight inches and a half, taking the Killingworth Colliery Railway as a standard. The Liverpool and Manchester Railway, constructed by the same engineer, was formed of the same width; and it was then made a standing order of the legislature in England that, in all public lines of railway, the width, between the rails, should be four feet eight inches and a half. In 1836 this standing order was suspended, and there is now, or was until lately, no standard of width whatever.

The following are the principal gages in use, ranging from 4 feet 6 inches to 7 feet: No. 1.—4 feet 6 inches, originally laid down in Scotland. No. 2.—4 feet 8½ inches, the gage in most general use. No. 3.—of 5 feet, formerly adopted for the Eastern Counties and Blackwall lines, in England. No. 4.—of 5 feet 6 inches, used in Scotland. No. 5.—The New York and Erie Railroad of 6 feet. No. 6.—The Irish gage of 6 feet 2 inches; and No. 7, the Great Western of 7 feet gage, in England.

The confusion actually resulting, and to be anticipated by this want of uniformity in the construction of the "arterial circulation," so to speak, of Great Britain, led to the appointment by government of a commission to inquire into and report upon the most advantageous width to be adopted in the future construction of railroads in that country. The subject was examined with all the minuteness which its importance called for; every evidence was received from the friends of the several widths which it was in their power to furnish, and the result was a report from the commission in favor of the "narrow gage," or four feet eight and a half inches between the rails as affording all the advantages claimed for the "broad gage," and at a diminished expense. It is now the standard gage in that country, but in our own the matter is still left to the caprice of individuals or companies.

We shall, then, assume the width between the rails to be four feet eight inches and a half. The breadth of the bearing part of the rails cannot vary much; about two inches and a half seem to be the width agreed upon by almost, if not all, engineers. The width between the outside of the rails will, therefore, be five feet one inch and a half; or five feet one inch if the breadth of the rail itself be two inches and a quarter.

Width between the two tracks.—The next consideration is the width between the tracks of the railway. Upon the Liverpool and Manchester, the width was made the same as that between the rails, viz., four feet eight inches and a half. On the London and Birmingham, and the Grand Junction Railways, the width is six feet; and less than this is not considered advisable, and is the width almost universally adopted in this country.

Width on the outside of the rails.—The next question to determine is the width required on the outside of the rails, or between the rails and the edge of the embankment, or side of the excavations. This is, to a great extent, determined by what is necessary to keep the ties firm, to preserve the stability of the rails, and to effect the passage of the engines and carriages along the railway with every possible security. Where economy of construction has been a primary object, a width of three feet and a half from the rails to the outer edge of the embankment or footpath of the excavation, or from *n* to *k*, or *o* to *l*, Figs. 3180 and 3181, has been found sufficient to secure adequate firmness and stability to the blocks, or cross-ties and rails.

But there is another very important object to effect,—the width necessary to secure the safety of the engines and carriages passing along the railway, and which is more difficult to determine, without going into the subject, in a speculative point of view. The width necessary to prevent the cars running off the bank will vary very materially, according to the circumstances of the case; the speed, the weight, the dimensions, and the shape of wheels, the material forming the road bed, the method of laying the rails, the alignment of the road, whether straight or curved, &c., all having more or less bearing on this dimension to insure safety. It has been attempted to investigate this question mathematically, but it is one of the few questions wholly beyond such method of determination. Its solution can only be arrived at by practical observation and experience. A standard writer on railroads has calculated that this dimension should, when the road is travelled at a speed of twenty miles per hour, never be less than the distance between the rails of the two tracks. This, it appears to us, is unnecessarily great, and failing a more rigorous solution of the question, we will assume as the proper distance outside of the track, the distance very generally adopted in this country, as well as on some foreign roads, and which is found to answer sufficiently well, viz., three feet.

Supposing the width of gage to be 4 feet 8½ inches, or to outside of rails to be five feet one inch between the tracks six feet; and the breadth on the outside of the rails three feet on each side; we have, then, the width of the entire road, at the level of the rails, or, between *k* and *l*, Figs. 3181 and 3180, twenty-two feet two inches. The only remaining questions for consideration, are the slopes *g k*, *h l*, required for the filling of the road, and the width required for the drainage of the excavations. The depth of the filling is usually two feet or two feet three inches, and a slope of one foot horizontal, to one foot perpendicular, is found to be sufficient.

The width of the drainage *c g*, *h d*, Fig. 3180, will vary, according to the quantity of water required to be conveyed off; but one foot and a half on each side, at the bottom level, is generally found sufficient.

We have, then, the width of the excavations at the bottom level, as follows:

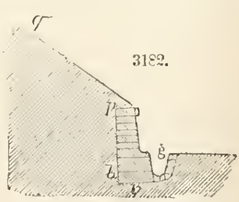
	feet.	inches.
Two lines of railway, including rails	10	2
Width between the two lines	6	0
Width on the outside of rails	6	0
Width required for the slopes	4	0
Width for the drainage	3	0
	29	2

which will be the width *f i'*, *c d*, Fig. 3180.

And for the embankments, or *l k*, Fig. 3181, which require no width for drainage, three feet less, or twenty-six feet. And where the slope of the embankments is one and a half to one, the width at the bottom level, so called, (two feet three inches below grade,) is thirty-three feet nine inches.

Slopes of the excavations and embankments.—Having now ascertained the width, it is next necessary to determine the angle to be given to the slopes of the excavations and embankments. These depend, in some degree, upon the depth of the excavation, or height of the embankment; in the former, when the material is sand, gravel, or gravelly clay, a slope of one and a half horizontal, to one perpendicular, is quite sufficient; and in excavations, up to thirty or forty feet, this slope has been found to stand very well. In some descriptions of clay a greater slope is given, sometimes as much as two to one. The embankments are generally made with the same slope as that of the excavations; and it is presumed that, with whatever slope the excavation will stand, the embankment formed of the material from such excavation will stand with the same angle of slope.

On the English railways the slopes are covered with a layer of soil, which is procured from the base of the embankments, or from the top of the cuttings; this layer of soil is spread over the face of the slope about six inches thick, or of the thickness which the soil from those places will yield. It is of great importance to the security of the slopes, that the soil should be laid on as soon as possible, after the excavation is made, or the embankment consolidated; and sown with grass or clover, or both, to get a turf upon it before the slopes are affected by the action of the weather. By doing so slopes will often stand, where, without the soiling and turf, or when exposed to the action of the weather, they will not stand. This is very much neglected in this country, and the consequence is, the cuts are in general either badly drained, or a gang of hands are constantly at work to keep the ditch free from the wash of the slopes; and it is a good practice to sow the slope with some hardy grass-seed, or defend it from washing by loose stones thrown over the bank.


3182.

In these figures we have shown the slope of the excavation to run down to the bottom of the drain. In some cases, where stone is plentiful, and where there is an excess of cutting, side walls, similar to Fig. 3182, are built, to retain the sides of the excavation, the line *p q* showing, in that case, the line of the slope. In such cases, stone drains, similar to that shown at *g*, are made to still further diminish the width of the railway. The propriety of doing this is, however, entirely a matter of calculation.

Foundations for the cross-ties.—The line having been formed to the proposed inclination longitudinally, it is then levelled transversely. But, as the material constituting the base of the railway, in the excavations and embankments, is rarely a proper material for a road-bed, it is necessary to cover these surfaces over with some material which will allow the water to drain off from the bottom of the ties, and which will likewise form a sufficiently firm foundation for the ties to rest upon. This is generally done by a layer or coating of broken stone, or clean gravel, whichever is found the least expensive.

The drainage having been effected, and the under coating of broken stone having been all spread upon the line, the next operation is setting the blocks or ties.

On all the excavations where stone blocks can be had at a moderate cost, and on the embankments which are perfectly consolidated, which, by the way, is never sufficiently the case on a *new* road, they may be used; but upon high embankments made of clay, and which are constantly settling down, it is found most advisable, in the first instance, to lay down wooden sleepers or ties, stretched across from one rail to the other.

It has been the custom in England to lay the rails on stone blocks, which rest on a layer of broken stone about nine inches thick, and the whole filled in afterwards or "ballasted," as it is called, with gravel. If broken stone be used, about one foot in depth will be sufficient; but if gravel be used, it is customary to lay a greater depth, about two feet. This serves as a drain to take off the surface water and prevents its freezing at the bottom of the ties or blocks.

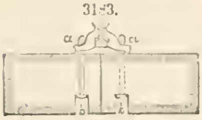
The American system, however, is beginning to prevail to a great extent; viz., the use of cross-ties of wood instead of stone blocks, upon which to rest the rail. In our country, where the frost is so severe, the difficulty and expense of setting and preserving the stone blocks is very great, and they have long since been abandoned for the wood ties; and even in England, some roads originally laid with stone blocks have been taken up and wood cross-ties substituted in lieu of the stone blocks. And in fact, it the experience in this country be worth any thing, this may be considered the proper method, as most modern works are now projected on this plan.

These wooden sleepers are made from eight to ten feet long, eight to ten inches broad, and about five inches thick.

When the blocks are set, or sleepers laid, as the case may be, the space between the blocks, and on the outside of the rails, is filled up to about three inches above the top of the blocks, or about the same depth below the top of the rails.

Seating the chairs upon the blocks.—A seat is first made upon the top of the block, perfectly level, and in the same plane as the base of the block, upon which the chair, of cast-iron, and weighing from 20 to 40 pounds, is to be set. Holes are drilled into the stone, about two inches in diameter, into which oaken plugs are driven, Fig. 3183; these plugs are then bored with a three-eighth inch auger, and the chair, having been properly seated upon the top of the block, an iron pin is driven through the ho[illegible] the chair into the wooden plug, and which, having a head, fastens the chair to the sleeper.

3183.



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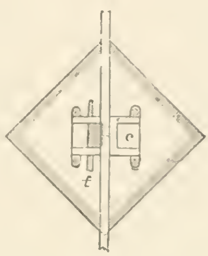

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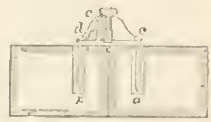
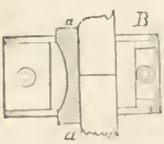


Keying the rails to the chairs.—Various methods have been devised for fastening the rail to the chair. Iron wedges, keys, and pins, and sometimes a union of all three, have in their turn had their advocates; but all metal fastenings are objectionable, as all are found to work loose. Wooden keys or wedges are beginning to be in favor. Fig. 3184 is the rail used on the London and Birmingham Railway, and weighs sixty-five pounds per yard; and which is the form of rail used upon the Grand Junction Railway.

3184.



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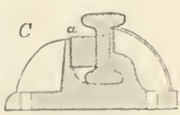

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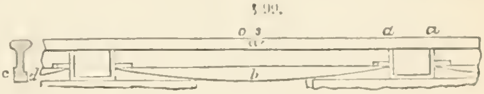
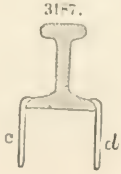


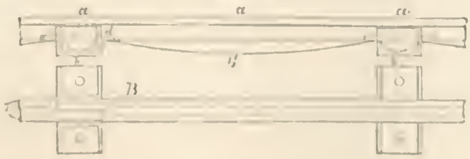
3187.



3188.

These rails are secured to the chair by a wooden key, *a a*, Figs. 3184 and 3185. One side of the chair is bevelled vertically, against which the wedge acts, and pressing against the upper side of the base of the rail, forces it downwards into the chair, while it, at the same time, forces the rail against the other cheek of the chair. These keys are made of oak and well dried, so that when driven, and exposed to

3205.



the humidity of the atmosphere by expanding, they act with very powerful effect in fastening the rail to the chair; so much so as in some cases to split the chair. The plan B of Fig. 3184 shows the form of the wedge *a a* longitudinally; by this it will be seen that the side of the chair is convex; when therefore, the wedge, being quite dry, is driven between the rail and chair, and expanding by the damp of the atmosphere, it is very tightly compressed by the convexity of the chair, which produces a corresponding expansion at the ends, and thus fastens the wooden wedge so securely that no working takes place between it and the rail or chair. This key has, of course, no tendency, except the mere friction or pressure of its sides, to prevent the ends of the rails at the joint from separating.

Fig. 3186 represents the form of chair in use on the New York and Erie Railroad, in this State, which is found to answer a good purpose. The chair is complete in itself, and the rail fastened by means of it and the spikes to the cross-ties, independent of the oak wedge, which is driven in to prevent the rattling of the rail in its seat, from the vibration caused by the passage of the train. It will be perceived that the action of the wedge forces the rail down in the chair and firmly against its opposite cheek.

The effect of the expansion and contraction of the rails, by the variation of temperature, amounts to about the fifteenth part of an inch in a rail fifteen feet in length. It has been attempted to obviate this shock by forming the ends into a half-lap joint, but with partial success only. The best thing that can be done at present is to preserve the parallelism of the upper surface of the rail; but the opening of the joint is inevitable, as, from the expansion and contraction of the rail, an open joint must be left, dependent in its dimensions upon the temperature at the time of laying the rails.

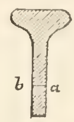
3188.

3189.

3190.

3191.

3192.



3193.

3194.

Fig. 3187 is a plan of rail laid down on some of the railroads in this country; with this rail chairs are dispensed with, the base of the rail being very broad, and being laid upon the longitudinal sills or cross-ties, is fastened to them by the brad-headed spikes *c* and *d*, which are driven into the sills. A notch is cut near the end of the rail on each side, somewhat longer than the width of the spike which is driven through the notch, thus permitting the rail to expand or contract, while the flat head of the spike confines it firmly to the cross-ties. This has become a favorite mode of fastening rails in this country, and may be said to be universal, sometimes without any chair at the ends, and sometimes with a mere plate to prevent the ends of the rail from bedding themselves into the wood. This form of rail is now known in Europe as the "American rail." The following are a few of the various patterns of rail in use:

Fig. 3188 is the section of an experimental fish-bellied or elliptical rail, rolled by the Newcastle and Carlisle Railway Company, for the purpose of ascertaining the comparative rigidity of this kind of rail, and parallel rails of the same weight per yard; the weight of this rail was about fifty pounds per yard; the figure shows the extreme depth, and the dotted line *a b* the smallest depth.

Fig. 3189 is the section of the parallel rail, rolled for the purpose above described, the weight of which was as nearly fifty pounds per yard as it could be rolled. The area of the wearing or top part of the two rails is precisely the same, as likewise the breadth of the base; but they differ in the depth and thickness of the middle part of the rail.

Fig. 3190 is the section of a parallel rail, used upon the Liverpool and Birmingham, or Grand Junction Railway, and weighing about sixty-two pounds per yard. The top and base of this rail are the same section.

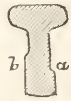
Fig. 3191 is the section of a rail used on the Dublin and Kingston Railway, and which is a parallel rail, weighing about forty-five pounds per yard.

Fig. 3192 is a fish-bellied rail, made by Mr. Stephenson, and weighing about forty-four pounds per yard. The entire section on the drawing shows the extreme depth in the middle, and the line *a b* the depth at the bearing parts. This rail does not swell out at the base, being intended to be keyed into the chair.

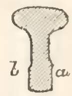
Fig. 3193 is the section of a parallel rail, of the weight of fifty pounds per yard, a few of which are laid down on the Liverpool and Manchester Railway.

3197.

3198.



3200.



3201.

3202.

3203.

3204.

Fig. 3194 is the section of a rail intended for the Great North of England Railway, the weight of which is about sixty pounds per yard. This is likewise a parallel rail; the mode of keying this rail differs from any of the preceding plans, and is shown in Figs. 3195 and 3196, Fig. 3196 being a section, and Fig 3195 a plan. One side of the chair is cast to fit the rail; on the other side of the chair a loose intermediate wedge slides between the cheeks of the chair, shown at *e*; this intermediate wedge is keyed against the rail by the driving-key *f*, which may be driven with any degree of tightness; the intermediate key prevents the vibration of the rail from loosening the key *f*. This chair, it will be seen, has four pins to fasten it to the block.

Fig. 3197 is the section of a parallel rail, laid down on the Liverpool and Manchester Railway, and weighing sixty pounds per yard. In all the preceding figures of rails, both sides of the top or wearing part of the rail, whereon the wheels roll, is the same; but as it is only on one side of the rail that the flanch of the wheel rolls against it below the plane of the top of the rail, the wheel on the other side rolling along the plane of the surface, it is evident that there is no necessity to have both sides the same. In this case the side of the top, acted against by the flanch of the wheel, is of the same outline as that part of the wheel; while, on the opposite side, the section is at right angles to the plane of the top. This plan, however, prevents the rail from being turned with the opposite side to the flanch of the wheel, which it is sometimes found requisite to do.

Fig. 3198 is a section of the thirty-five pounds per yard fish-bellied rail, originally laid down upon the Liverpool and Manchester Railway; the entire figure showing the extreme depth in the middle, and the line *a b* the depth in the bearing parts of the rail. The mode of keying this rail is shown in Fig. 3199.

Fig. 3200 is a section of a fifty pound per yard elliptical, or fish-bellied rail, laid down on the Liverpool and Manchester Railway: the section of this is nearly similar to the preceding figure, except in the area and weight; the keying is precisely similar; the line *a b* shows the depth at the bearings.

Fig. 3201 is a parallel rail, weighing seventy-five pounds per yard, and laid on the London and Birmingham Railway. The mode of keying is similar that shown in Fig. 3199; the distance of the supports, five feet.

Fig. 3202 is the section of the parallel rail, laid down upon the Liverpool and Manchester Railway, weighing seventy-five pounds per yard. The top of this rail is made of the shape explained in Fig. 3197.

Fig. 3203 is another sixty pounds per yard parallel rail, which has been laid down upon the Liverpool and Manchester Railway.

Fig. 3204 is the section of the rail laid down upon the Newcastle and Carlisle Railway; it is an elliptical or fish-bellied rail, shown in Fig. 3205, with a convex projecting knob at the bearing points. The entire figure in the plate shows the extreme depth of section at *a′ b′*, Fig. 3205, and the line *a b*, Fig. 3204, the depth near the knob, the latter swelling out the depth of half an inch more within the chair. These rails weigh forty-two pounds per yard, and are laid in fifteen feet lengths, with five bearings of three feet each.

The compound rail, designed with a view to correct the defect experienced in the simple rail at the joint, is now receiving a good deal of attention from engineers. Several plans have been devised, but all of them want the results of experience before they can be recommended for general adoption. Undoubtedly the defects of the joints are, to a great extent, remedied by the compound rail, but it is questionable if in this country greater evils would not result by increasing the number of parts of a machine already so complicated and difficult to keep in repair as a railroad.

Curves on the line of railway.—It has been usual to construct the wheels for railway carriages so that the outside rim is conical, or enlarged in diameter next the flanch; when, therefore, the carriages are passing round a curve, the wheels being connected together by the axle, forms, as it were, a conical roller, running upon the rails with different radii; the larger radii being on the outside curve of the rail. This increase in the diameter of the wheel running on the outside compensates, to a certain extent, for the increased length of the outer curve of the rail; and if the radius of the curve is not less than the line which the two wheels of unequal radii would describe, the wheels will travel along the line of the curve without rubbing against the flanches. But if the curve is more acute than such a line, then the flanches of the wheels are the only guides to keep the carriages on the rails.

The degree of cone generally given to the tire of the carriage wheels is to make the diameter next the flanch one inch larger than the diameter next the outside of the tire, the breadth being 3½ inches. In practice, it is likewise usual to keep the wheels at such a distance from each other upon the axles, that, when travelling upon a straight line, the flanches on each side are about one inch from the rail. With a view to provide against the centrifugal force of the carriages when running in a curve, it has been customary to elevate the outer rail of the track.

The following table will show the elevation to be given to the outside rail, of different radii, above that of the inner rail; so that the whole amount of centrifugal force is balanced by that of the gravity of the load, towards the inside of the curve.

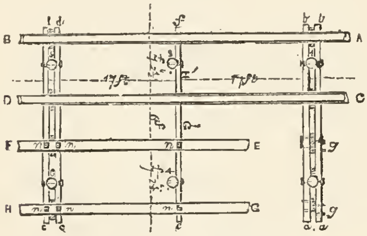
Description of wagon and width of railway.	Radius of the curve in feet.	Surplus of elevation in inches, the velocity in miles per hour being:			
		10 miles.	15 miles.	20 miles.	30 miles.
	250	1·16	3·04	5·67	13·
Diameter of wagon wheels 3 feet;	500	·58	1·52	2·83	6·57
width of railway 4 feet 8 inch.;	1000	·29	·76	1·42	3·30
inclination of the tire of the	2000	·15	·38	·71	1·65
wheel ⅕ inch in the breadth,	3000	·10	·25	·17	1·10
viz., 3½ inches.	4000	·07	·20	·36	·83
	5000	·06	·15	·29	·67

It was a few years back the custom in this country, as it still is to a great extent in England, to *cone*, as it is called, the tires of the wheels with a view to prevent the rubbing of the flanches of the wheels in passing the curves. The above calculations of the elevation of the outer rails includes, as an element, this coning of the wheels. Theoretically and practically, with a given speed, this is correct but the passenger, express, and freight trains, travelling at very different speeds without their wheels are coned at different angles—which in practice would be very inconvenient, if not wholly impracticable—the different elevations of the outer rail would not meet the necessities of the particular case as a speed of 30 miles per hour requires an elevation some 11 times greater than a speed of 10 miles. It is now, in this country, the custom to disregard this coning of the wheels to the extent which the theory would call for, and simply cone them to the amount of the draft (as it is called) of the casting, about $\frac{1}{8}$ inch on the tread of the wheel; and engineers differ very much as to the proper amount of elevation which should be given to the outer rail. The actual amount to meet a given speed is easily estimated; but whether it is expedient to give more or less than this, or to provide for the freight or passenger trains, is as yet an unsettled question.

As there can be no doubt that the higher velocities of passenger trains, even with their less load, is productive of greater injury to a road than the freight trains, it would seem desirable to adjust the rail with the surplus elevation due the higher velocity; if the road were essentially a passenger road, or in other words, without the freight trains were largely in excess of the passenger trains, to suit the curves to the latter traffic, having in view the diminution of "wear and tear" of both wheels and rail, rather than an economy of motive power.

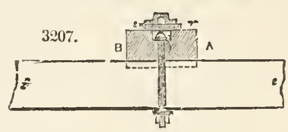
Great Western Railroad in England—Mr. Brunel's plan.—Figs. 3205, 3206, and 3181, (p. 519,) show a plan and different sections of Mr. Brunel's plan of railway. A B C D E F and G H are the longitudinal rails forming the railway; these longitudinal rails are 14 to 15 inches broad and 6 or 7 inches thick, and are made of American pine. *a b′ a b′* and *c d′ c d′* are double transverse ties or sleepers, which are each six inches in breadth and seven inches deep; and *e f* single transverse ties or sleepers, which are six inches in breadth and nine inches deep. These sleepers are stretched across the line of railway, and to them the longitudinal rails are secured. 1 2 3 4 5 and 6 are piles which, in the cuttings, are from nine to fourteen feet in length, according to the nature of the material, and in the embankments 12 to 30 feet, or of such a length as that they will reach from the base or formation line of the railway 6 to 8 feet into the original surface of the ground. The cross-ties are American pine, and the piles of beech.

3205.

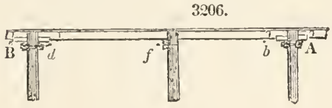


3208.

3207.



3206.



The plan of construction, or of forming the railway, is as follows: the piles are driven at intervals of every fifteen feet, as shown in the drawing, and in the middle between the longitudinal rails. In cuttings, they are driven from eight to ten feet into the ground, below the level of the cross-sleepers; and on embankments they must be of such a length as to be driven about the same depth, or seven or eight feet into the original ground. Upon an embankment of three feet they must be, therefore, ten or twelve feet long, and so on, according to the height of embankment, and the kind of subsoil into which they are to be driven. These piles are always to be driven to the exact depth required; no part of the head is allowed to be cut off; but if the pile does not drive to the proper depth, it must be drawn and driven again. This is for the purpose of being certain that they have sufficient hold of the ground; near the head of these piles, as shown at 1 2 3 4 5 6, Fig. 3205, and at *b b′ f* and *d d′*, Fig. 3206, a square shoulder, of $1\frac{1}{2}$ inch, is made on one side of the piles for the single ties, and on both sides of the piles 1 2 5 6 for the double ties. The ties or cross-timbers are let into these shoulders, and they are firmly bolted to the piles, as shown in the drawings. The double cross-timbers are laid down thirteen inches, and the single timbers nine inches below the line of the rails. Between the double timbers, as shown at *g g*, Fig. 3205, and also at all the other points where the longitudinal rails intersect the cross-timbers, a piece of wood is interposed, which is pinned to the cross-timbers, and upon which the longitudinal rails rest.

The longitudinal rails are then laid down upon the cross-timbers, the upper surface of which is three inches below the surface of the iron rails; they are bolted to the cross-timbers with screw-bolts and washers, as shown at *n n n n*, Fig. 3205, and by a larger scale in Fig. 3207, *e f* being the cross-timber, and A B the longitudinal timbers; the latter, it will be seen, is let into the cross-timber a little, the single cross-timbers being deeper than the double cross-timbers. The head of the bolt and washer is countersunk into the upper surface of the longitudinal rail, as shown in the figure. One of these bolts is put in at each of the points of intersection of the longitudinal rails with the single cross-timbers, and two bolts at each of the points of intersection with the double timbers.

When the piles are firmly driven, the cross-timbers bolted to them, and the longitudinal timbers bolted to the cross-timbers, then sand, or finely screened gravel, is beat or packed underneath the longitudinal timbers, until a base or bed is made for them to rest upon, perfectly firm, solid, and compact.

Fig. 3208 shows a section of the rail used, which weighs from 43 to 44 pounds per yard, and which rests upon and is secured to the hard-wood plank and timbers of the longitudinal sills, and is of the description known as the U or bridge rail.

As shown in the figure, the rails have a slight bevel inwards.

The width or gauge of the railway is 7 feet 2½ inches, from centre to centre of the rails; and the width between the centres of the inside rails is 6 feet.

A few instances occur in this country of the use of stone blocks for the support of the rail; but they form the exception, it being found that the wear and tear of machinery on the stone track is much greater than on the wood, and in consequence, the use of the latter material for the support of the rail has become universal. Upon this depends in a great measure the perfection of the road. The point in which our roads present a great inferiority when compared with the English, is in the want of complete preparation of the foundation. All the refinement of science, applied to the form and dimension of rails, chairs, engines, &c., is useless, if the foundation be liable to be thrown by frost, or to displacement from any cause. To prevent this, too much care cannot be given to the nature of the material forming the road-bed, and to the position and preservation of the ditches. All material impervious to water should be excavated from the bed of the road to the depth at least of two feet, and its place supplied by clean gravel. The sleepers or cross-ties of chestnut, cedar, oak or other durable wood, according to the locality, are laid transversely, at intervals of about two feet. These ties should be at least 6 inches deep by 7 or 8 inches wide, and for the narrow gauge 8 feet long. Upon these cross ties are to be spiked the iron rails.

The rail is usually secured in the chair by the brad-headed spikes which hold the latter to the ties, the notch in the rail for the spike being elongated so as to permit the expansion and contraction of the rail, or else the chair is fastened independently of the rail, and the latter prevented from rising out of the chair by the latter being made to conform to the shape of the rail, so that it cannot be removed from its chair but by drawing it out in the direction of its length. At the intermediate cross-ties the rail is secured inside and out by the brad-headed spike driven into the tie on each side, and lapping over the base of the rail. The rail may be further secured in the chair by a wooden wedge, sawn to a taper, and driven into the chair against the bottom, side, and top of the rail, one side of the chair being cast to receive it. It is not advisable, however, to make the fastening of the rail in the chair dependent entirely upon the wedge. The chair should be safe against accident, were the wedge to drop out; but the use of the latter should be to perfect the joint, and prevent the small motion in the chair occasioned by the vibration of the rail, which in the end might prove the destruction of the chair. The spikes should be machine-made, with chisel points, and weigh at least half a pound each, and occupying in length the depth of the cross-tie. After the rails—we have supposed the H or U section, of about from 60 to 80 pounds per yard—are laid and spiked, and the line of rails adjusted to their proper adjustment, the ballast of clean gravel is brought into the road and deposited between and around the cross-ties, packed well underneath them with the shovel and rammer, and levelled off to the plane of the bottom of the rail, nearly. This is the method, with some modification, which prevails pretty generally in the construction of the modern railroad. A longitudinal bearing under the rail, into which the cross-ties are framed something similar to the Western Railroad in England, is occasionally adopted; but its want of simplicity, as well as other defects, has occasioned its disuse.

ROLLING STOCK. Under this term are included the locomotives and cars. The distinctive feature of the American locomotive will be found under its appropriate head. Our cars are still more peculiar. Whilst the English, adopting the stage coach as their model, made their cars with compartments resembling coach bodies, generally three to each car, and supported on but two sets of wheels, we, adopting a new and distinct construction, have adopted a long undivided car, supported near the ends by trucks like the forward trucks of our locomotives. Each truck has not less than two sets of wheels, sometimes three, and in very rare instances four. Passenger cars are provided with seats for from 40 to 60 passengers. Most of the cars are entered at the ends from the end platforms, but in some, as in the Jersey Railroad cars, the entrance for passengers is in the centre.

The freight cars are in general construction similar to those for passengers, but shorter. On a few roads the short four-wheeled cars are adhered to, and when slow speeds are preserved they are more economical, less dead weight in proportion to the weight carried, and easier moved at the stations. Freight cars are either open or boxed; ballast cars are usually two wheeled, and arranged so as to be capable of being dumped.

The chief objection to our present system of cars, resulting in part from unnecessary speed, is the amount of dead weight drawn in proportion to their freight; and even this is disproportionately increased by the often unnecessary hauling of empty or far from full cars. We annex the following table from the Report of the New York Commissioners for 1856.

The following tabular statement gives the average cost per mile, for building and manning the road; also the average amount of freight in tons, and the number of passengers for one year:

Average cost per mile of road, .	$50,792 88
Of equivalent single track, . .	36,833 73
Average cost of locomotive engines and fixtures, ...	9,625 50
Average cost of passenger and baggage cars, ...	2,011 50
Average cost of freight cars, .	631 50
Average number of miles of road for one locomotive, ...	3.13 miles.
Average number of miles of road for one passenger car, . . .	2.75 "

Average number of miles of road for one freight car, ...	0.26 miles.		
Average number cars per train, passenger, ...	4.5	freight,	18.2
Average number per train of passengers, ...	72.6	" tons	71.2
Average number per car, of passengers, ...	16.13	" "	3.91
Average number of tons of non-paying weight per passenger, ...	1.17	" "	2 75

PROGRESS OF RAILROADS IN THE UNITED STATES FROM 1828 TO 1857.*

[Our Railroad history has had two eras—the first from 1820 to 1848 when there was in the number of miles built an average increase of 268 miles per year; and the second, from 1848 to 1856, having an average increase of 2350 miles per year. In many of the States, the development of the Railroad system is quite equal to the wants of the people; but in many others, Kentucky being the most notable instance, it is much less.]

STATES.	First Era—1828 to 1848.																			
	1828.	1829.	1830.	1831.	1832.	1833.	1834.	1835.	1836.	1837.	1838.	1839.	1840.	1841.	1842.	1843.	1844.	1845.	1846.	1847.
Maine	....	....	....	....	....	....	....	....	....	12	12	12	12	12	37	64	64	64	64	64
New Hampshire	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	3	19	38
Vermont	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Massachusetts	3	3	3	3	3	3	3	49	126	126	126	144	144	219	435	465	465	467	626	718
Rhode Island	....	....	....	....	....	....	....	....	....	....	50	50	50	50	50	50	50	50	50	50
Connecticut	....	....	....	....	....	....	....	....	....	....	36	36	36	212	238	238	238	238	238	238
New York	....	....	....	....	17	39	39	39	74	230	325	325	404	496	590	722	722	796	873	878
New Jersey	....	....	....	....	....	34	34	77	77	108	108	123	148	186	186	186	186	186	186	186
Pennsylvania	....	25	25	32	52	212	311	318	343	424	562	562	562	893	893	893	893	893	893	946
Delaware	....	....	....	....	....	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Maryland	....	....	13	13	20	80	88	88	128	128	181	181	181	202	223	238	254	268	285	324
Virginia	....	....	....	....	....	12	33	93	93	125	125	125	125	147	223	223	223	223	223	270
North Carolina	....	....	....	....	....	....	....	....	....	....	....	....	53	87	87	87	87	87	87	87
South Carolina	....	....	....	6	33	88	137	137	137	137	137	137	137	204	204	204	204	204	204	204
Georgia	....	....	....	....	....	....	....	....	....	7	57	100	185	271	323	368	452	516	576	609
Florida	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	38
Alabama	....	....	....	....	....	46	46	46	46	46	46	46	46	46	46	46	46	46	36	91
Mississippi	....	....	....	....	....	....	....	....	....	....	....	....	....	14	14	26	26	42	42	60
Louisiana	....	....	....	....	....	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Texas	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Missouri	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Tennessee	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Kentucky	....	....	....	....	6	6	15	15	22	22	22	25	28	28	28	28	28	28	28	28
Ohio	....	....	....	....	....	....	....	....	....	....	....	....	....	36	84	84	84	84	84	129
Michigan	....	....	....	....	....	....	....	....	....	....	....	....	....	138	138	174	206	238	238	270
Indiana	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	30	30
Illinois	....	....	....	....	....	....	....	....	....	....	....	....	....	22	22	22	22	22	22	22
Wisconsin	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Iowa	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
California	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Total	3	28	41	54	131	576	762	918	1,102	1,421	1,843	1,920	2,167	3,319	3,877	4,174	4,311	4,511	4,870	5,336

STATES.	Second Era—1848 to 1857.									
	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.
Maine	64	87	175	224	283	394	410	422	442	474
New Hampshire	38	134	309	414	463	582	506	646	646	654
Vermont	....	93	243	302	369	427	480	516	518	556
Massachusetts	790	948	1,095	1,145	1,153	1,153	1,175	1,207	1,285	1,285
Rhode Island	50	50	50	50	50	50	60	78	85	101
Connecticut	228	326	434	549	570	627	596	596	601	661
New York	902	953	1,070	1,404	1,946	2,123	2,400	2,668	2,701	2,731
New Jersey	195	195	231	267	290	290	350	448	472	529
Pennsylvania	981	981	981	1,133	1,326	1,326	1,700	2,038	2,407	2,602
Delaware	16	16	16	16	16	16	50	84	120	120
Maryland	324	324	324	324	355	355	355	372	378	430
Virginia	303	303	303	413	548	624	900	1,252	1,480	1,558
North Carolina	87	154	302	249	249	249	400	483	612	612
South Carolina	204	204	241	263	383	599	650	677	706	842
Georgia	609	609	609	665	804	857	910	1,002	1,062	1,187
Florida	54	54	54	54	54	23	23	26	26	128
Alabama	91	113	113	113	135	236	290	317	484	540
Mississippi	60	60	60	60	95	95	210	255	410	484
Louisiana	40	66	66	117	117	117	190	222	264	266
Texas	....	....	....	....	....	32	36	36	57	147
Missouri	....	....	....	....	....	....	....	144	189	317
Tennessee	....	....	....	....	134	185	300	366	509	652
Kentucky	28	28	28	55	93	93	150	198	307	320
Ohio	274	274	299	531	890	1,385	2,500	2,641	2,869	2,880
Michigan	270	270	344	379	474	474	474	474	601	664
Indiana	42	86	86	215	538	755	950	1,438	1,807	1,862
Illinois	22	22	22	148	271	296	1,200	2,135	2,534	2,598
Wisconsin	....	....	....	....	20	50	200	276	630	688
Iowa	....	....	....	....	....	....	....	88	153	256
California	....	....	....	....	....	....	....	23	23	23
Total	5,682	6,350	7,355	9,090	11,631	13,213	18,265	21,128	24,376	26,107

Courier and Enquirer.

The great weight of the locomotive and of the carrying stock generally, has led to various expedient. to avoid this difficulty. Rope railways, that is railways in which the cars were drawn by ropes or chains by means of stationary engines, had long been used in mining districts to overcome steep gradients. This system was adopted with some ingenious modifications, to propel cars on a level track, on the London and Blackwall railway. But it was found uncertain and expensive and given up. In fact, at present there are but few inclines in this country worked by stationary power, it being found more economical to work with the locomotive on zig-zag or Y tracks to overcome steep gradients.

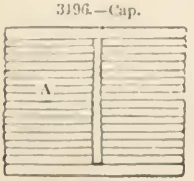
As an improvement on the rope railway, Clegg and Samuda introduced the atmospheric railway upon the Dublin and Kingstown road, where it worked so successfully for a series of years, that it was introduced on the London and Croydon Railroad, but it proved a failure. As an expedient it was very ingenious, and may perhaps in some form be serviceable on very short lines. Suppose a large pipe to be laid down on a road, and that at one end of this pipe were placed an air-pump for withdrawing the air, and at the opposite end a piston, working accurately in the pipe. On pumping out the air from the pipe, the atmospheric pressure upon the piston would drive it along the tube. In order that the piston and the carriages might travel together, much in the same way as the short tube, or pencil-holder inside a pencil-case, travels with the outer tube or ring,—some connection is necessary between the piston within and the cars without the tube. The arrangement employed on the line from Kingston to Dalkey, a distance of 1¾ mile, is as follows:

In this railway the vacuum-pipe was about 15 inches in internal diameter; it was of cast-iron, and was laid down in the same way as the large water mains, between the two rails of the railway. After the pipes were cast, a cutter was passed through them in the direction of their length: they were then raised to the temperature of melting tallow, and a mop dipped in that material was passed through them, and being followed by a wooden piston, the inside became coated with a thin surface of tallow, which soon acquired great hardness. This was found to be an excellent surface for the piston to travel against. On the top of the tube was a narrow opening extending the whole length, closed by a valve so as to render the tube air-tight. This valve was a continuous flap of leather, on the upper and under sides of which plates of iron were riveted, the inner surface of the lower plate formed to the curve of the pipe, the upper plate and the leather being made a little wider than the opening or slot, and extending over it on each side. This continuous valve was hinged on one side to a projecting rib, and the other edge fell into a groove containing a composition of wax and tallow, which, when melted, sealed up the pipe, and made it sufficiently air-tight for the working. A flap called the *weather-valve*, protected the apparatus from the weather. The piston contained within the tube was furnished with a rod 14 or 15 feet in length, to which were attached rollers for opening the air-tight valve behind the piston as it advanced along the pipe. The piston was connected with the first carriage, or *driving-car*, by means of a *coulter:* to the driving-car was attached a copper vessel, several feet in length, heated with coke, for the purpose of melting the wax and tallow when the valve had been pressed down by the apparatus.

It will be understood, then, that the train of carriages moved on rails as in the ordinary railway: but between the rails the tube with its enclosed piston was situated; and that an air-pump worked by a stationary steam engine exhausted the air in the tube in front of the carriages. The speed of the train would evidently be in proportion to the rapidity with which the air could be pumped out. It was found that an exhaustion of 15 inches could be produced in about 2 minutes, and that a speed of 50 or 60 miles an hour could be produced.

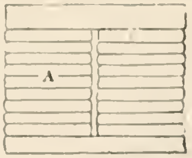
RAILWAY BARS.—*On the manufacture and form of.* The mass out of which the rail is rolled is called a "pile," and is composed of a number of plates cut from rolled bars to a length suitable to the convenience of handling, and the dimensions of the close-furnace in which the piles are placed to receive a welding heat. The piles have a bed and cap plate of double the width of the other plates, which keep the pile together, and are mostly of superior iron. See Fig. 3196, in which A represents the cross-section of the pile.

3196.—Cap.



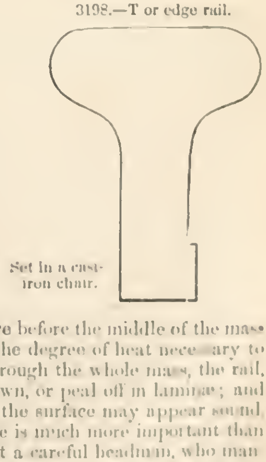
Bed.

3197.—Cap of hammered iron



Bed.

3198.—T or edge rail.



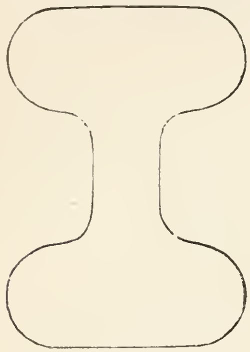
The furnace is closed up to prevent the iron from burning on the surface before the middle of the mass is brought to a welding heat. It requires skill and practice to judge of the degree of heat necessary to insure a sound rail. If the heat is not sufficient for an effectual weld through the whole mass, the rail, when put to the severe action of the locomotive wheels, will crush down, or peal off in laminæ; and when the rail is finished it is not easy to see a defect in the welding, as the surface may appear sound. For this reason a close and competent superintendence of the manufacture is much more important than the most careful inspection after the work is done. It often happens that a careful headman, who manages the rolling, will send back a pile to the furnace, before or after passing it once through the rolls, to receive a better heat. The good quality of a rail is as much dependent on effectual welding as on the quality of the metal.

To obtain a more solid and durable surface on the top of the rail, it has been proposed to use a *hammered* bar of *double* the usual thickness for the cap-plate of the pile, which would remain a solid material of considerable body after the rail is finished. See Fig. 3197, in which A represents the cross-section of the pile.

In the composition of the pile no scraps or short pieces should be admitted, for the reason that the process of rolling and extending the mass lengthwise is *adverse* to welding the cross-joints between the pieces, and so far the rail is diminished in strength and solidity. Scraps and trimmings had better be wrought into common bars, to be worked over again in the smith-shop. The heavy rail is a finished piece of work, and so expensive that its efficiency should not be endangered by the use of improper materials.

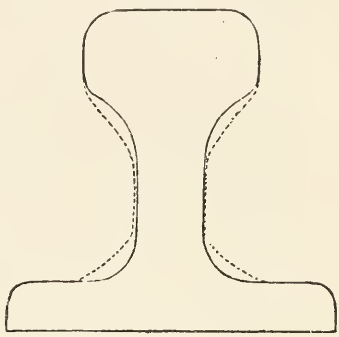
The pile should always be of sufficient weight to afford a surplus in length, so as to cut the rail of the desired length entirely clear of the fag-ends. Rails are often defective and give way at the ends while other parts remain sound, for the want of due attention to this matter.

3199.—Double-headed rail, to be reversed.



Set in a cast-iron chair.

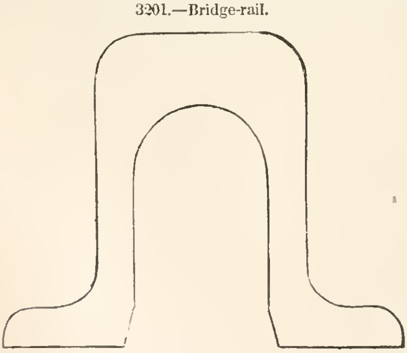
3200.—H-rail.



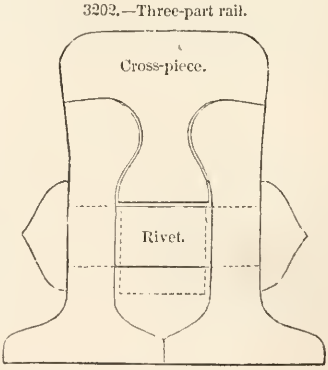
Great care should be taken in the straightening and trimming; and the first step is to see that the large cast-iron plate upon which the rail is laid while hot from the rolls is straight and out of wind—as the rail, being lifted and slammed down while soft, will conform to its surface, and retain a twist when cold if the plate should be in wind. This is a most mischievous fault, and can never afterwards be perfectly corrected. Though the surface may be brought to a line longitudinally, and the base adjusted on the bearings, the pressure on the top, varying from side to side, will produce a rocking action, tending constantly to loosen the rail.

Close attention should also be paid to accurate straightening, as even a slight undulation on the surface will produce, at the ordinary velocity of the train, (30 miles per hour,) a sensible vibration, unpleasant to the passenger, and injurious to the road and train.

3201.—Bridge-rail.



3202.—Three-part rail.



To prevent rails having these defects from being brought into use, a severe inspection should be applied to them. Each rail should be placed on a strong bench, in length equal to that of the rail, and the surface plated with iron in several places; these plates should be dressed to a correct line and out of wind, which will at once detect any twist or crook that may be in the rail.

The circular saw is now generally used in trimming, which is a great improvement over the chisel, as it leaves the section of the rail undisturbed—a very important matter in making even joints.

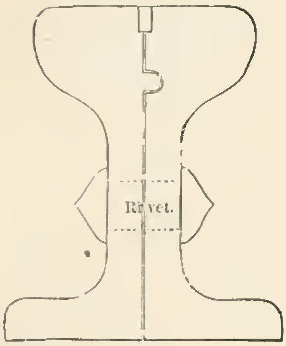
In considering the *form* of the railway bar, it may be first observed that the more simple and compact the section, the more sound will be the rail. It is obvious in viewing a section of the pile, (see Fig. 3196,) that there are a number of joints between the plates to be welded, and that each plate must of necessity be reduced to a thin lamina in extending the mass to the length of a rail, and that the strain on the weldings and materials will be much less in one form of section than another; therefore, in designing a form, it is well to give to this matter its due consideration.

The ┳ or edge rail, set in chairs, and the double-headed rail, Figs. 3198 and 3199 have been extensively used in Europe; but it is said that the H, and *bridge* or U rails, American designs, are coming into favor there. They have long been the favorite patterns in America, and do now divide the opinions of professional men and railway companies, so that the two are placed in competition on extensive divisions of the same line, and on different roads. Each has its peculiar merits.

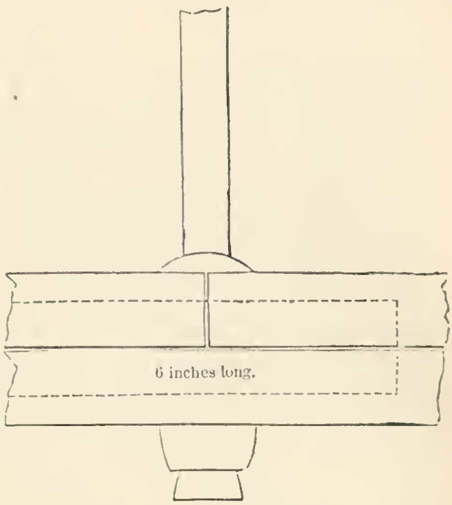
The H-rail has the advantage in simplicity and beauty of form, and *may* have in solidity, by a modification of the section. The head and base are generally made too light, (see Fig. 3200.) It also affords a better base for its support on the bearings.

The U or bridge rail has the advantage of perpendicular sides to support the head, without projections subject to be split off, like the H-rail. It also offers better facilities in its hollow form to secure strong and even joints, by the insertion of an iron core at those points. See Fig. 3201.

3203.—Two-part H-rail.



3204.



But, after all the exertion of talent and skill for the last twenty years to perfect a line of road with the usual form of rails, it still remains very deficient in smoothness and stability at the joinings, and it is feared will continue to be so while the rails are made in independent, separate, solid pieces

The perfection of a rail would be one of sufficient and uniform strength—rolled, or made by other means—in one piece, without joints the whole length of the line; but this being impracticable, the effort is now to approach it by a new device, which is to form the rail of two or more pieces, say 20 feet in length, and to splice them together, breaking joint, so that each part shall act as a splicing-plate to the others where their ends meet.

A three-part compound rail of cast and wrought iron has been on trial for some time on a line of heavy traffic, and stands the test of heavy engines remarkably well. It is more elastic than a solid rail of the same weight, and the line is more uniform in strength, and of course more easy to the passenger, the train, and the road. It is apparently so far a considerable advance towards theoretic perfection. See Fig. 3202.

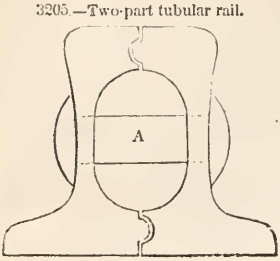
The next attempt, having the same object in view, is a compound rail of two parts, bolted together with a vertical joint, and each part breaking joint with the opposite part. It is now under trial in a section of an important road, and is said to promise well. See Fig. 3203.

The third plan, which yet exists only in model, is also a compound rail of two parts, having a vertical joint, and breaking joint. But each part is concave on the inner side, so that when they are combined they form a tube, in which, at each cross-joint, is inserted an iron core which fills the tube for a short space, and is designed to compensate the loss of strength occasioned by the semi-cross joint, and to prevent vertical slipping between the two parts. The edges of this compound rail are precisely alike, which renders it capable of being twice reversed, thus possessing *two* surfaces to be worn out in succession, thereby doubling the durability of the rail. But without actual trial it is questionable whether this presumed advantage will compensate the expense of the stancheons intended to support the rail in its proper position. The form, however, may readily be modified, (see Figs. 3201 and 3205.) Fig. 3206 shows the break-joint on the top, the dotted lines representing the core.

A fair statement of the distinguishing properties of these three new American devices will now be attempted, leaving a comparison of their merits to those competent to make it, and to the test of experiment.

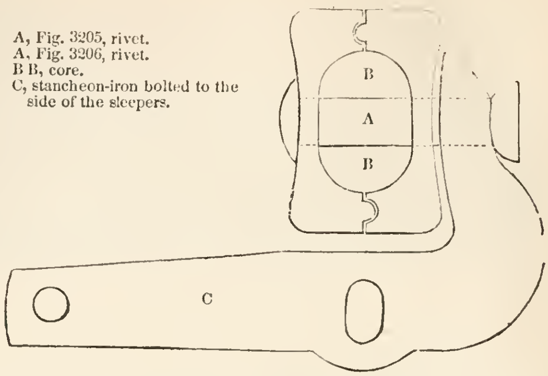
The leading property in the three part rail is, that the cap piece is the only part subject to renewal and being but about one third of the whole weight, must greatly reduce the cost of repairs. The means of securing the cap piece against endwise movement under the stroke of the locomotive wheels is by

A, Fig. 3205, rivet.
A, Fig. 3206, rivet.
B B, core.
C, stancheon-iron bolted to the side of the sleepers.



3205.—Two-part tubular rail.

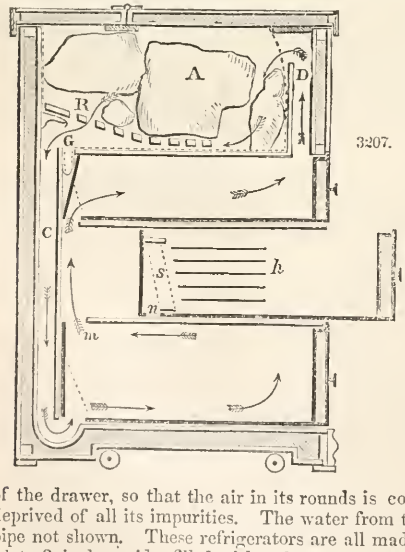
3206.



passing keys through the tongue of the cap-piece and fitting in stop-notches cut in the top of the bearing-rails. A better mode of security in this important matter is suggested by the inventor, which is to let the tongue of the cap-rail project downwards sufficiently low that the bolts which hold the base-rails together may pass through it also. This compound rail loses about one-third of its strength at each cross-joint; but the objection may be relieved to a considerable extent by inserting an iron core at each cross-joint under the tongue of the cap-piece. This form of a composite rail necessarily carries with it one great objection in view of a perfect surface, as the latter is broken at the end of each cap-rail by a thorough cross-joint, presenting a notch for the wheels to pass over of more or less extent, producing more or less jar at all those points.

The two-part H-rail, the second noticed, and the two-part tubular rail each equally possess the advantage of a surface but partially broken, as the cross-joint extends only to the middle of the surface, leaving the other part a bearing to the wheels in passing over. They also equally possess a provision against end-thrusts, in merely combining the two parts. When the surface is worn out, the *whole* rail is lost in each case. The two-part H-rail loses *half* its strength at each cross-joint; the tubular rail, in consequence of the core, is of nearly equal strength in all parts of the line.

REFRIGERATOR, *The Dry, for Family Use.* A. S. Lyman's. Fig. 3207 is an interior view. The ice is placed in the chamber A, and the air in contact with it being cooled and condensed, and therefore rendered heavier, flows down through the grate R, and the descending cold air flue C, in the direction of the arrows. It is discharged up through the opening in the back part of the bottom of the lower drawer. The warmer air in this drawer rises up through the opening M, in the division board above and onwards, finally passing up the flue D, and over again upon the ice: thus a current is formed, as shown by the arrows.



3207.

For the purpose of showing more clearly its internal arrangement, the middle drawer is represented as partially open. This shows the opening M, through the division board on which that drawer rests, and the opening N, through the back end of the bottom of that drawer. This opening N, is now closed by the division board. When the drawer is closed, these openings M and N coincide, and the air flows freely through them, as it is forced from the lower to the upper drawers by the superior weight of the column of cold air in the flue C. The back end of the drawer cuts off all connection with the refrigerator, so that no air can flow out when it is open. The cold air in this drawer being heavier than the air outside, remains in it, unless there are currents in the room, which at most can only sweep the air from this drawer.

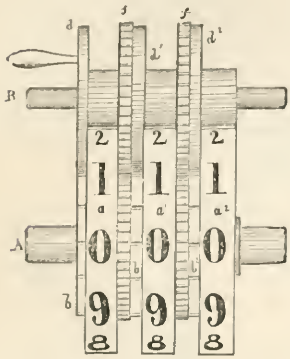
Some of the gases set free in refrigerators are absorbed by ice, or rather by the pure water as it is dissolving from ice; but that alone will not absorb all impurities, nor prevent a refrigerator from accumulating bad odors, as is known practically by all who have used refrigerators for a sufficient time.

In order that the air may be rendered perfectly pure, the charcoal filter S, is placed in the back part of the drawer, so that the air in its rounds is constantly being filtered through the charcoal, and thus deprived of all its impurities. The water from the melting ice runs into the gutter G, and off by a trap pipe not shown. These refrigerators are all made double as represented, and the spaces, which are from $1\frac{1}{2}$ to 3 inches wide, filled with pulverized charcoal; this increases the weight and cost somewhat, but it is essential to practical success.

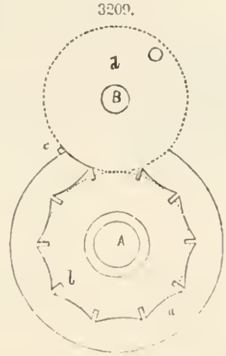
REGISTERING AND NUMBERING MACHINE, Baranowski's *patent.* The several machines patented by Mr. Baranowski are all dependent on one particular arrangement of wheels or disks, of which he gives the following preliminary description:

The wheels or plates d and b, Fig. 3209, turn on their centres B and A, and when the tooth e falls into one of the notches in b, it moves b round one-tenth of its circumference, as there are ten notches in the wheel b. The spaces between the notches in b are arcs of the same circle as d, so that b is always stationary and fixed, except when moved by the tooth in d once for each revolution of d. b is fixed to a, the edge of which is engraved with the figures from 0 to 9, as shown in Fig. 3208. The cogged-

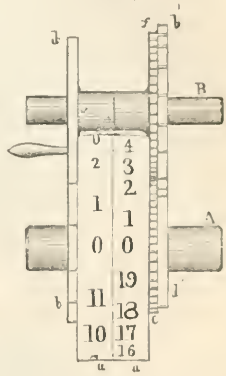
3208.



3209.

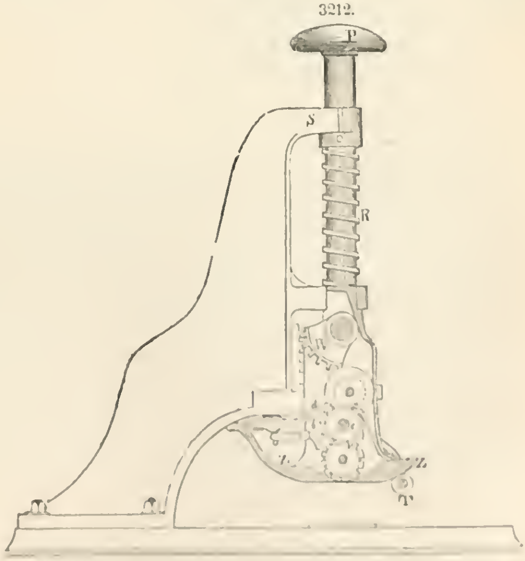


3210.

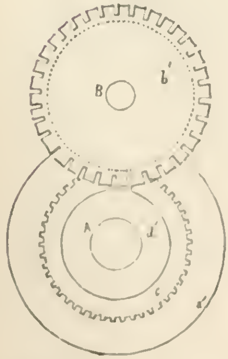


wheel c is also fixed to a, and works into a cogged-wheel of the same size f, turning on the same centre as d, the edge of which is also shown in Fig. 3208. d^1 is fixed to this last cogged-wheel f, and is of the same form and size as d. b^1 is fixed to a^1, the edges of which are shown in Fig. 3208, and is of the same form and size as b. Again: Fig. 3208, b^2 is fixed to a^2, and is turned by d^2, which is fixed to f^1, working into the cogged-wheel c^1: b^2 and d^2 are also of the same size and form as b and d. a^1 and a^2 have also the figures from 0 to 9 engraved upon their edges. All the plates or wheels move freely on their cylinders or centres, A and B respectively, although it will be seen that no one of them can move without moving all the others, at intervals of time dependent upon the number of notches in the wheels b, b^1, and b^2, respectively, and also upon their respective distances in the arrangement from the first mover d. The operation of counting proceeds thus:—The first revolution of d moves a one-tenth, or puts the unit in the place of the cipher on a; ten revolutions of d, or one of a—that is, one revolution

3212.



3211.

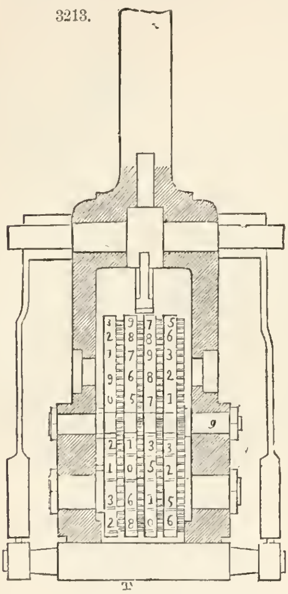


of d^1 (for the cogged wheels are equal in size)—moves a^1 one tenth, or puts unity in the place of the cipher on a^1, or shows ten where there is 0, 0, 0, in Fig. 3208. One revolution of a^1, that is, one revolution of d^2, (for the cogged wheels are of the same size,) moves a^2 one-tenth, or puts unity in the place of the cipher on a^2, or shows one hundred where there is 0, 0, 0, in Fig. 3208, and so on till the arrangement shows 9, 9, 9, where is 0, 0, 0, in Fig. 3208.

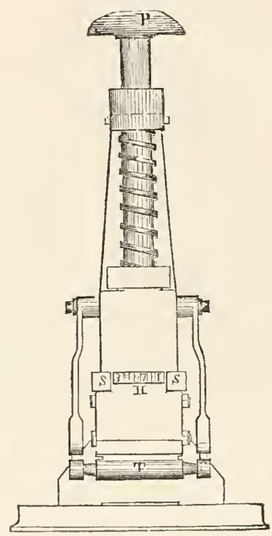
It is obvious that the notches in b b^1 and b^2 need not be each ten in number, nor need there be precisely such three wheels; but there may be, for instance, only two, (see Figs. 3210 and 3211,) b having twelve notches, and b^1 twenty notches; and in such a case the numbers on the edges of a and a^1 might represent shillings and pounds. It will also be seen, by examining the Figs. 3208 and 3210, that Fig 3210 differs slightly from Fig. 3208, without affecting the peculiar character of the arrangement. The same letters show the same parts in both figures. b, the unit wheel a, and d^1 are all fixed to the axle A, which turns upon its centres. In Fig. 3208 the corresponding wheels are loose on A; d^1 works into b^1, as in Fig 3208; and as f is fixed to b^1, and c to a^1, and f and c are of the same size, and work into each other, every complete revolution of a is attended with a partial revolution of a^1 through a space measured by the distance between any two notches in b^1, Fig. 3211. The object of this variation in the Figs. 3208 and 3210 is to bring the numbers on the edges of a and a^1 close together.

Again: if d had two teeth, two notches of b would be moved round at each revolution of d, and the odd or even numbers on a would be presented from time to time where there is now 0, 0, 0, Fig. 3208, according as the arrangement was started with 1 or 2. If started with 1, it would skip 2, 4, 6, &c., and show 1, 3, 5, &c.; if started with 2, it would skip 1, 3, 5, &c., and show 2, 4, 6, &c. The Roman method of notation, or any other signs or symbols expressive of numbers, can be substituted for the Arabic figures, and can, by means of this arrangement, (modified so as to facilitate and vary its application,) be made to appear at 0, 0, 0, Fig. 3208.

3213.



3214.

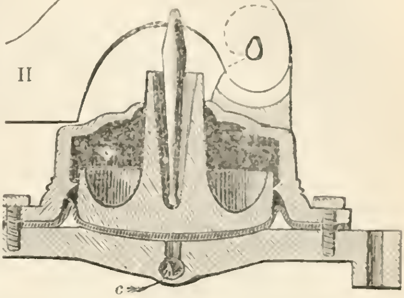


The manner in which this simple and ingenious arrangement is applied to the numbering, stamping, and registering railway tickets, for example, is thus described:

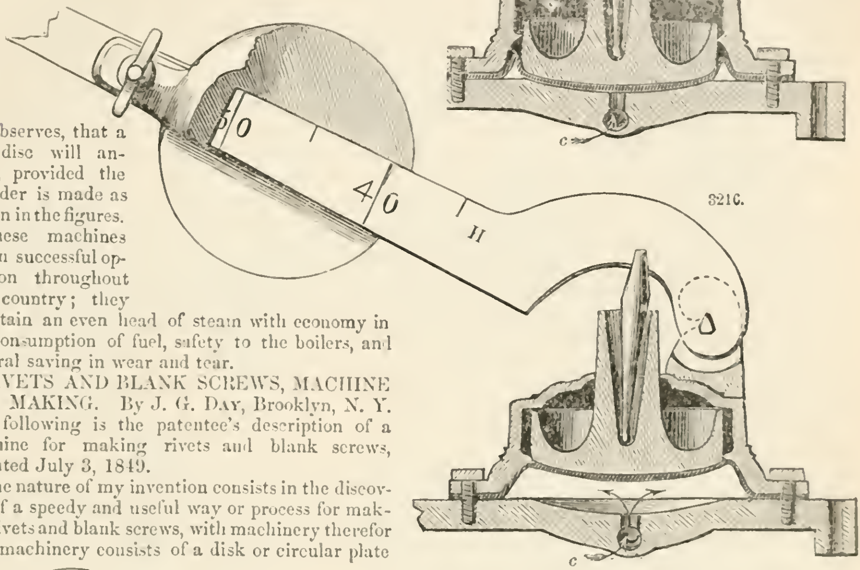
Fig. 3212 is a sectional view of the side of a machine of this description. R R is a cylinder which is movable up and down in the frame S S. The top P, upon which the blow with the hand is to be given, is always kept up some distance above S S by a spiral spring upon R R. The whole of the machinery forms part of R R, and moves up and down with it, except the rack X, and the clicks b and b, which are fixed to S S. When R R is struck down, a tooth of the wheel c passes beyond b, and when R R rises again to its place, the wheel c is turned one tooth by the position and resistance of b; d is a click to keep c fixed, as R R descends. The arrangement here is the same as shown in Fig. 3208, only there are four wheels with figures on them instead of three, as the number shown is any short of ten thousand. There are also two sets of figured or marked wheels, one above the other, and made to move at the same time by the cogged-wheels on the middle axle g, Figs. 3212 and 3213. On the lower set the numbers project to be used as stamps, the neighboring parts being cut away, as shown in the wheels h, Fig. 3212. The upper set appear at H, Fig. 3214, so that each number from time to time is both stamped and registered. The segment of a wheel W, Fig. 3212, to which is fixed an arm carrying a small elastic roller T, works into the rack X, and at each descent of R R is thereby carried over the under side of the apparatus Z Z; and this surface being charged with printing-ink, the roller T inks each projecting figure before it reaches the paper below.

REGULATORS. *Clarks' Patent Steam and Fire Regulator.* Even in the earliest application of steam, regulators were contrived for controlling the draft of the fire by the pressure of the steam in the boiler, by which an even pressure may be maintained and no greater quantity of fuel consumed than may be necessary to maintain the desired pressure. Figs. 3215, 3216, illustrate the most successful and practical of these contrivances, patented by Patrick Clark, in January, 1854. Both figures are in section. The construction can be readily understood. The steam from the boiler is introduced beneath a vulcanized rubber diaphragm, upon which rests a piston F, weighted like a common safety valve to its lever H, as rod K is attached, which connects with the damper in the chimney or flue. Fig. 3215 shows the position of the diaphragm and piston when the pressure in the boiler is below that required; when the pressure exceeds the desired pressure, the diaphragm and piston are forced up, and the damper begins to close, till it attains the position, fig. 3216, when the draft is entirely shut. The amount of pressure is controlled by the sliding weight or pea on the steelyard arm H, as shown in fig. 3216. The diaphragm is composed of a cup or cylinder, and the patentee claims "the combination of a cylindrical diaphragm with a cylinder and piston," by which any desired amount of motion may be given from one inch to ten feet, but for a movement not greater than an inch,

3215.



3216.



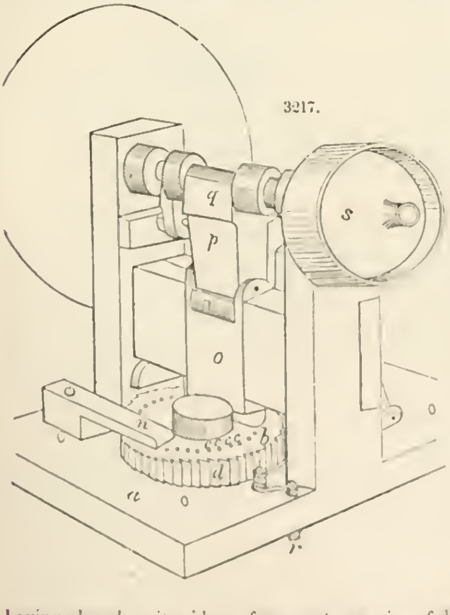
he observes, that a flat disc will answer, provided the cylinder is made as shown in the figures.

These machines are in successful operation throughout the country; they maintain an even head of steam with economy in the consumption of fuel, safety to the boilers, and general saving in wear and tear.

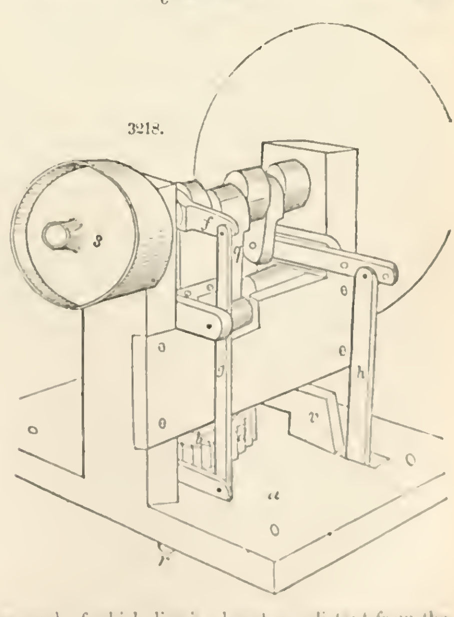
RIVETS AND BLANK SCREWS, MACHINE FOR MAKING. By J. G. Day, Brooklyn, N. Y. The following is the patentee's description of a machine for making rivets and blank screws, patented July 3, 1849.

The nature of my invention consists in the discovery of a speedy and useful way or process for making rivets and blank screws, with machinery therefor This machinery consists of a disk or circular plate

3217.



3218.

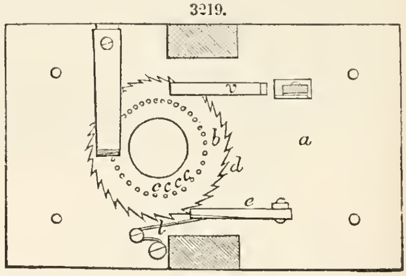


having placed on its side or face a set or series of dies, each of which dies is placed equidistant from the axis of the disk and from each other, and are intended to be brought, one to the place of feeding and another to the place of heading, and one to the place of discharging, all at one and the same time while at an intermediate and alternate time the disk may revolve, and by such revolution bring the next set of dies to the respective points for the before named operations to be performed, the disk to maining at rest for the purpose of allowing such operations to take place, but cutting off the wire or rod that has been fed in as the disk and dies revolve, and holding and conveying it until the work is complete; that is, until the rivet is headed and discharged, and so continuing their operations in succession so long as it shall be desired.

I arrange a table *a* upon which I place a disk *b* having its several dies *c*, and its outer edge being in the form of a ratchet *d*, and which may be caused to revolve by the pawl *e*, or any equivalent mechanism. This may be understood more clearly by referring to Fig. 3219 of the drawings, this being a plan oi these parts, although the same parts are known by the same references in all the drawings. Above the table is the main shaft, from which is conveyed motion to all parts of the machine. A double-acting crank, by an intermediate connecting lever *g*, acts upon the pawl *e* to cause the disk to revolve at the proper time, and to the proper distance; while a somewhat similar arrangement bears a like relation through its connecting-rod *h* to the discharger *i*, worked by an intermediate lever *k*. At the back of the pawl *e'* is a spring *l*, which keeps the pawl up to its work at all times; there is, besides, a strong coiled spring, designed to keep the disk in its place firmly to the table; a planing-board *n* is used to plane off and level the head after the header or meshing tools have done their work. This tool may be constructed with a projecting point or lip to fit in a recess in the face of the disk, and this lip will cut the nick in the head of the screw. This planing tool is placed immediately in front of the discharger; behind the discharger is a stop or gage piece *v* placed in an oblique position, which serves the double purpose of a gage for the length of wire to be cut off, and as a clearer to throw off the work from the disk after it has been discharged from the dies. I will here add, that I have intended to use, if necessary, a lock-up for my disk; this would regulate the disk by stopping its motion at one precise place at each stop, in case it should fall a trifle short or overreach the desired point by the inaccurate action of the pawl. This lock-up may be applied in many ways, but can be well applied by attaching a wide piece to the end of the discharging lever, and upon it placing two pins instead of one; one of these could have a long bevelled or taper point to enter one of the dies, and thus, as it is pushed in to the full size, will bring the disk to the exact place to receive the other, (the discharging pin;) this discharging pin is for operating upon a headed rivet to discharge it.

Fig. 3217 shows the action of the heading hammer. This hammer has several hammer-faces, to act upon as many rivets or blank screws, and gives by this means as many blows upon each one as there are of these faces; that is, one acts upon the head of the rivet in one die at one blow, and the same one acts upon the next rivet after one move of the disk, and so on, while the one acted upon first is acted upon by the second hammer-face, and so on to the finish. This hammer is shown at *o*, and is worked by a connection *p* to an eccentric or crank *q*, by which it is raised and lowered in its operation, and presses or crushes down the metal, and forms a head in the rough where a flat head is to be formed, while the round head is produced by a hollow or concave in the face of the hammers.

3219.



I have used two, three, or more of these hammer-faces as before stated, for the more perfectly pressing and consolidating the metal, as it might not be perfectly solid by a single blow, particularly when the metal is used in a cold state, as is generally the case for blank screws, while heated metal is most generally used for rivets. I also use one hammer having a chisel-face, which may be pressed into the head and form a nick, when it is desired to form nicks.

I provide a tube *r* through which the wire or rod may be fed to the die in the disk, and which does the further duty of one-half of the shears for the cutting off the wire or rod, the die itself being the other half of said shears. The rods or wire may be fed in by hand, or by any convenient machinery, in many ways, such apparatus being common to machines for these purposes.

The operation of my machine will be better understood by saying that the machinery is set in motion by power applied at the pulley *s*. We commence feeding wire or rods through the tube into the dies, while the disk is at rest; next, the disk of dies move round (always in the same direction) and cut off the wire, which has been fed in until it meets the herein-before-named gage *v*. This revolving action brings a second die which is also fed in, and so on until each die will be filled as intended. As the dies continue to fill and cut off, they pass on, and one after the other meets the header and subsequently the discharger, when one after the other is discharged—all the other operations being performed in the progress, and between the feeding and discharging.

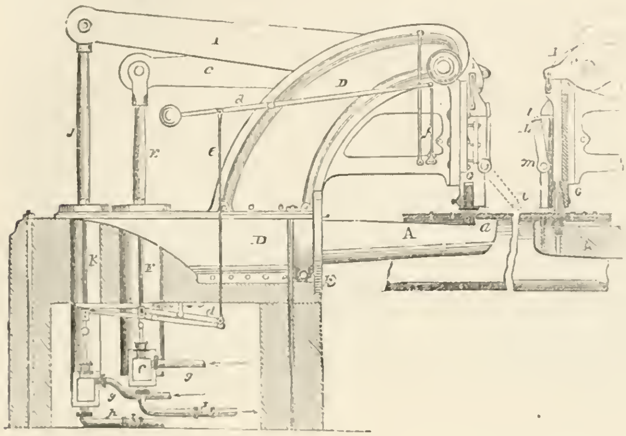
RIVETING AND STEAM PUNCHING MACHINE. By M. Lemaitre, Paris. The principle on which the motive power of the steam-engine is applied in the machine now before us, is widely different from that which characterizes most of those of which we have yet treated, and, simple and obvious as it may appear, it is only beginning to be appreciated by mechanicians as we think it deserves.

In those machines in which a rectilinear motion, whether in a horizontal or vertical direction, is required to be produced, that object has hitherto, in most cases, been accomplished by means of mechanism, more or less complicated and expensive, for converting the rotary motion transmitted through long trains of shafts from the fly-wheel of a steam-engine, into a rectilinear motion. In establishments in which a great number of machines, small as well as great, have to be kept in motion, we believe that no improvement upon this *roundabout* method could be recommended; but for single and independent machines, where great power acting in a rectilinear direction is required, we believe that the *direct* action of the steam-engine, as exemplified in the machine now to be described, will supersede the more circuitous, expensive, and, on many accounts, objectionable method hitherto practised.

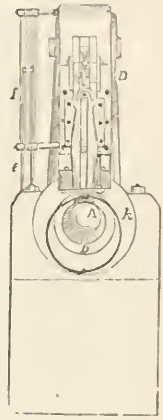
Another very important peculiarity in the machine now under consideration, deserves to be specially noticed. In riveting by hand the workman finds it necessary to bring the plates upon which he is operating into close contact, by striking them with his hammer while closing and finishing the head of the rivet. The necessity of this will be obvious when we consider that the iron pin, which is to form the rivet, tends, by the compression to which it is subjected by the blows of the hammer, to *stave up* throughout its whole length, as well as at the end, and that, consequently, unless the plates are brought into very close contact during the operation, an obstacle to their perfect junction is interposed by the very means employed to bring them into intimate contact. In M. Lemaitre's machine this difficulty is obviated by a very ingenious and effective contrivance which we shall now proceed to describe.

Fig. 3220 is an elevation. Fig. 3221 a plan. Fig. 3222 an end view, and Fig. 3223 a partial section of the steam punching and riveting machine.

3220.

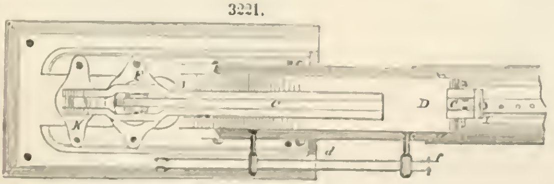


3222.

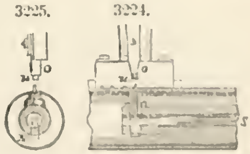


The plates to be operated upon are, in this machine, placed horizontally between the fixed and movable dies *a* and *b*. The matrix of the fixed die *a* is at the extremity of a strong malleable-iron stem or riveting-block A, fixed firmly into the sole and foundation of the machine, and serving as the point of resistance against the action of the punch *l*, the compressing ferule *i*, and the riveting-die *b*. This last, which, as well as its corresponding fixed die *a*, is made of hard-tempered steel, is fixed into a malleable iron stock or tool-holder B, accurately planed and adjusted to slide in a vertical direction, and without lateral motion, in a socket G, the further purpose of which will hereafter be described. The tool-holder B has an alternate rectilinear motion of ascent and descent communicated to it by a malleable-iron lever C, which has its centre of oscillation at the upper extremity of a strong frame D, cast in a piece with the sole or base by which the machine is fixed to its foundations. The opposite end of the lever C is connected by the rod E, to a piston working in the cylinder F. This cylinder, which is open above, and close beneath the piston, is furnished with a valve inclosed in the valve-box *c*, and by this valve high-pressure steam is alternately admitted under the piston, through the steam-pipe *g*, and allowed to escape through the exhaust-pipe *h*. The valve is raised or depressed by means of the combination of rods and levers *d e f*, which are disposed so as to place the machine within the command of the workman who superintends the operation. The mechanism by which the plates are compressed during the process of riveting consists of a cylindrical steel ferule *i*, Fig. 3223, through the centre of which the riveting-die *b* passes, and which again is fitted into a strong cast iron socket G, sliding exactly and without play, between two planed guides H H. The socket G is made hollow for the purpose of forming the guide to the tool-holder B, as we have already mentioned, and receives a motion similar to, though independent of, the latter, from the two malleable-iron levers I I, which have their centre of oscillation at the same point as the lever C, and are connected at their opposite extremities by the rod J to a piston contained within the cylinder K. This latter cylinder is of smaller diameter than that used for riveting and like it, is provided with a valve *c'* for the admission and escape of steam. The rods and levers *d*, *e' f*, for opening and shutting this valve, are arranged in the same way as those already described.

3221.



3223. 3224.



This machine is adapted for punching as well as riveting iron plates. For this purpose two strong parallel guides M M are fixed to the movable frame which carries the compressing ferule *i*. To the centre of these guides a socket or tool holder L is attached by means of a pin *m* passing through its upper extremity and the guides. The punch *l* is fitted to the opposite end of the socket L, and its position, when brought into operation by turning it downwards upon its pivot m and securing it between the guides M M, coincides exactly with that of the matrix a', upon the extremity of the riveting-block A The matrix a' is sunk into a circular recess cast upon the riveting-block, and for the sake of accurate adjustment, is acted upon by three small screws passing through the sides of the recess. Under these circumstances, it is obvious that the operation of punching will be performed by the same mechanism, by which, in riveting, the compressing ferule is made to descend. When not required to be used, the punch and its socket are turned into the position represented in Figs. 3222 and 3223.

Action of the machine.—The plates to be united by riveting, having been previously punched, are placed together, as shown in the drawings, upon the horizontal stem or riveting-block A. The heated rivet is then placed into its appropriate hole, with the head inside, and the plates are shifted till the rivet-head falls into the matrix a. The attendant workman by pulling down the handle f' depresses the valve inclosed in the steam-chest c', and thus opens a communication through the pipe g', between the steam in the boiler and the under side of the piston working in the cylinder K. The piston ascends, and its motion being communicated through the rod J to the levers I I, causes the ferule i to descend, and compress the plates firmly together. The same workman then, by pulling down the handle f, opens the valve of the large cylinder F, taking care that the pressure is still kept upon the plates. This causes the tool-holder B, and riveting-die b, to descend, and thus the rivet is finished. The valve of the cylinder F is then first moved so as to shut the communication between the boiler and the piston, and allow the steam to escape through the pipe h. The weight of the rod E and lever C causes the piston to descend and the die b to rise. The handle f' is then released, and by a similar process the ferule i rises to admit of the plates being shifted for the fixing of the next rivet.

The action of the machine in punching is obviously so similar to that already explained as to require no further description. As it is of importance that the rivet-holes should be pierced with as little delay as possible, at the same distance from each other, and in the same line, M. Lemaitre makes use of a marker which serves as a guide to the workman in placing the plates under the action of the machine. This contrivance consists of a small arm n formed into a socket, so as to admit of being adjusted and fixed upon the axis o, which has its bearings in one of the cheeks or guides M. Into the arm n is fixed a small piece of sheet-iron, shaped at the outer extremity into a circle, the diameter of which is equal to that of the punch, and its centre, when turned towards the punch, coinciding with it. In making use of this contrivance the handle p of the axis o is turned round till the extremity of the arm n is brought directly under the punch. The plates are then shifted so that the place where the hole is to be pierced is covered by the circular end of the sheet-iron marker, and thus the accuracy of the work is insured.

Figs. 3224 and 3225 represent a very ingenious and most useful contrivance which M. Lemaitre has adapted to this machine, for the purpose of riveting long and narrow tubes from the interior, a problem which, at first sight, is of very difficult solution. The stem or riveting-block N is made hollow throughout its whole length, and incloses a long rod S, terminated by a steel wedge r. This wedge acts upon the movable matrix t, which passes through the upper side of the riveting-block N, in such a way as to cause it to rise or fall according as the rod S is pushed in or drawn out. The die u and its holder or stock O are of the same form, and are connected with the machine in the same manner as those already described. In using this form of the machine, the rivets are inserted from the outside of the tube, the dies t and u receive simultaneously a motion in opposite directions, the lower one t being made to rise by pushing in the rod S, and the upper one u descending by the action of the steam-piston upon the lever, and thus the rivet is formed.

M. Lemaitre has been enabled, by this contrivance, to rivet tubes of considerable length and small diameter; a work which it was impossible to perform either by hand or by any machine formerly in existence.

Literal References.

A, the malleable-iron stem or riveting-block.

B, the stock or tool-holder into which is fixed the riveting-die b, and which is made to move in a vertical direction by the great lever

C, by which the pressure necessary for forming the rivet-head is conveyed from the steam-piston.

D, the frame and sole or base of the machine.

E, the connecting-rod between the piston inclosed within the cylinder F and the lever C.

F, the steam-cylinder in which the power required for forming the rivet-head is generated.

G, a socket or tool-holder, to the lower end of which is fixed the compressing ferule i, and which moves vertically between the two planed guides

H H, bolted firmly to the fixed frame of the machine.

I I, a double malleable-iron lever, by which the pressure necessary for keeping the plates firmly together is conveyed from the piston inclosed within the cylinder K, to the compressing ferule i.

J, the connecting-rod between the piston inclosed within the cylinder K and the lever I.

K, the steam-cylinder in which the power required for compressing the plates is generated.

L, the stock or socket into which the punch l is fitted.

M M, the guides for confining the tool-holder L, laterally.

a, the matrix or die on the end of the riveting-block.

a', the matrix of the punching-tool.

b, the cylindrical stock into which the riveting-die is fixed, and which works up through the compressing ferule i.

c, the valve-box fixed to the lower extremity of the steam-cylinder F.

c', a similar valve-box fixed to the lower extremity of the cylinder K.

$d\,e\,f$, rods and levers for working the valve attached to the cylinder F

$d'\,e'\,f'$, similar rods and levers for working the valve attached to the cylinder K.

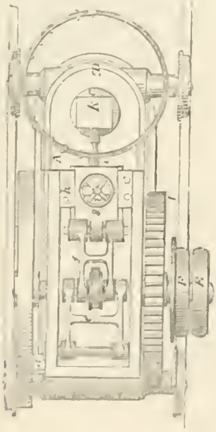
$g\,h$, pipes for the admission and escape of steam into and from the valve-box c.

g' h', pipes for the admission and escape of steam into and from the valve-box *c'*.
i, the compressing ferule.
k, a strengthening piece by which the foundations, frame, and riveting-block are held together.
l, the punching-tool.
m, a joint by which the punch-holder L may be turned upwards or downwards, as required.
n, a small sheet-iron arm which may be used as a marker.
o, the axis upon which this marker is fixed.
p, a handle by which it may be turned out or in as required,
N, the hollow riveting-block used for riveting tubes internally.
O, the stock or die-holder used in the same operation.
S, a long rod terminated in a wedge *r*, by which the riveting-die *t* is made to ascend.
r, a steel wedge moving in the interior of the riveting-block N.
t, the internal riveting-die moving upwards and downwards by the action of the wedge *r*.
u, the external riveting-die moving upwards and downwards by the action of the steam.

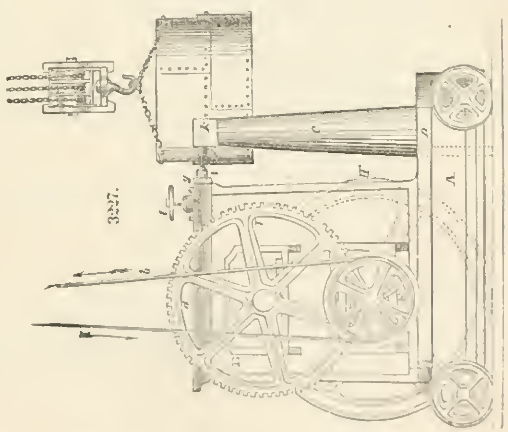
RIVETING MACHINE—By WILLIAM FAIRBAIRN & Co., Manchester. In the manufacture of steam-engine boilers, however varied and important the improvements which have, from time to time, been effected in the form and arrangement of their parts, no attempt has, until a very recent period, been made to facilitate the means of their construction, or, by the introduction of machinery, to supersede the necessity for manual labor. It is true, the punching and shearing machine has, under various modifications, been long in use, but it is only within the last few years that machines for bending plates, for making rivets, and still more recently for *riveting*, have been introduced.

For this last purpose, a variety of ingenious and effective combinations have been proposed, and although, as yet, none of them has come into very general use among boiler-makers, there can be little doubt that the laborious and expensive process of riveting by hand will be superseded by some form of this machine. The first idea of the riveting machine is due to Mr. Fairbairn, of Manchester, who, in 1838, patented a machine in many respects similar to the common punching machine, but having the great lever of such a form as to communicate a horizontal motion to the dies or tool for forming the head of the rivet. The machine represented is a modification which Mr. Fairbairn has since made, in which he has introduced several improvements, and remedied several defects to which the former was subject.

3126.



3127.



The principle of Mr. Fairbairn's machine consists in its performing by almost instantaneous pressure, what could formerly only be done by a long series of impacts. Every mechanic is aware that the operation of riveting, in all ordinary cases, requires the services of three men, one to hold a hammer or other mass of iron inside the boiler, against the head of the rivet, while the other two beat the protruding end into the conical form given to the rivet on the outside of the boiler. For this operation very expert and skilful workmen are required, that the rivets may be fixed soundly and firmly without injury to the plates, and that all unnecessary hammering, which has only the effect of weakening the rivets, may be avoided. By means of the riveting machine, the process is accomplished with much greater rapidity and regularity, without producing the stunning and disagreeable noise unavoidable in hand riveting. Besides these advantages, the operation being, as we have before said, performed almost instantaneously by the machine, the danger of injuring the rivets by hammering them when too cold is avoided and the hemispherical, which we think greatly preferable to the conical form, is more easily impressed upon them.

Fig. 3127 represents an elevation, and Fig. 3126 a plan of Mr. Fairbairn's machine in its most improved form, and as it is now constructed by him. It possesses the advantage over his first proposed form, of being more compact and portable, and is capable of more extensive application, being adapted to rivet angle-iron, and finish the corners of boilers and cisterns.

The sole or base of the machine A is made of cast iron, and mounted upon wheels adapted to rails, for the convenience of shifting it to any required place. The framing B B is cast in a piece with the sole A, and consists of an oblong box, open at the top, and furnished with bearings for the movable parts of the machine; C, a strong upright stem of malleable iron, fitted firmly into the base A, which is secured against the effect of undue strains, arising from the dies coming in contact with a cold rivet or other hard substance, by a malleable-iron strap D passing round its upper edge, and secured by nuts at *a a*. The stem or riveting-block C is the point of resistance to the action of the dies, and against it is placed that part of the boiler which is to undergo the process of riveting. It is made of malleable-iron, in order that it may possess a certain amount of elasticity, which is necessary to the prevention of such accidents as we have just alluded to. Its upper extremity is formed into an oblong block *k*, and in this the matrices for receiving the dies are placed.

The moving parts of the machine consist of a shaft carrying the fast and loose pulleys E and F, driven by the belt *b*. To give the requisite power and velocity to the machine, a pinion G is fixed upon this shaft, and works into a wheel I, keyed upon another and stronger shaft situated directly over the former. On the pinion-shaft is placed the fly-wheel H, for giving a uniform motion to the working parts of the machine, and at each revolution of the wheel I the machine performs one stroke. The ratio of the pinion G to the wheel I is as 1 to 6; consequently, when the pulleys are driven at the rate of 42 revolutions per minute, the machine performs 7 strokes per minute, and this is found to be the most suitable velocity. On the axis of the wheel I is fixed a cam *c*, of the form denoted by the dotted lines in Fig. 3127. This cam, in its revolution, alternately raises and suffers to fall by its own weight the friction-pulley *d*, which runs loose upon the centre pivot of a knee-joint composed of the arms *e e* and *f f*. The arms *e e* working upon a fixed centre, as shown in the plan, the elevation of the pulley *d* by the cone *c* necessarily impresses a horizontal motion upon the corresponding extremities of the arms *f f*. These extremities are connected by a joint to the slide *g*, the motion of which is guided into a perfectly rectilinear and horizontal direction by the dovetail pieces *h h*, planed true and screwed firmly to the frame of the machine. The sliding piece *g* is furnished at its outer extremity with three holes or matrices for receiving the die *i*, which forms the head of the rivet. These matrices are so placed that their centres coincide exactly, both in the horizontal and vertical planes, with the centres of similar ones in the upper extremity of the stem or riveting-block *c*, already described. Into these latter is fitted the die *j*, against which the head of the rivet is placed during the process. The centre matrix in which the dies are represented in the figure is used for riveting every description of flat or circular work, while those at each side are required for finishing the corners of the boilers. Thus the machine is adapted for riveting vessels of almost every shape within the given depth.

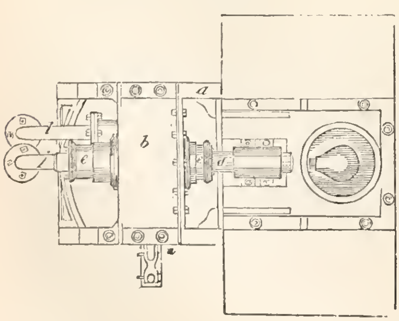
Action of the machine.—The plates to be riveted together, having been previously punched in the usual way, are suspended by a block and chain, as shown in Fig. 3127. The heated rivet is then inserted into its appropriate hole, and the attendant workman shifts the plates, so that the head of the rivet falls into the recess on the point of the die *j*. The machine is then put in motion by changing the position of the strap *b* from the loose to the fixed pulley. This motion is transmitted by the mechanism above described, to the sliding tool-holder *g*, and its projecting-die *i*, in its advance, forms the head and finishes the rivet. The velocity of the machine is so calculated as to allow time between each stroke for the insertion of another rivet and the readjustment of the plates, and thus the work proceeds without interruption.

It is stated by Mr. Fairbairn that, with two men and two boys attending to the plates and rivets, his machine can fix, in the firmest manner, eight rivets of three-quarters of an inch diameter in a minute, whereas, by the common process of hand riveting, three men and a boy can only rivet up 40 per hour. Thus the quantity of work done in the same time in the two cases is in the proportion of 480 to 40, or as 12 to 1, exclusive of the saving of one man's labor.

RIVETING MACHINERY—GARFORTH'S PATENT, for riveting metallic plates, for the construction of boilers, and other purposes.

These improvements in machinery or apparatus for connecting metallic plates for the construction of boilers, consist in the direct application of the expansive force of steam to the dies for riveting such plates together, and in an arrangement of machinery whereby such force is brought into action.

3228.



3229.

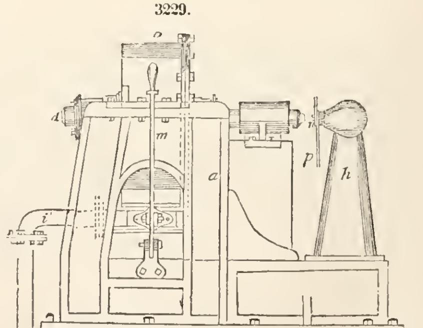


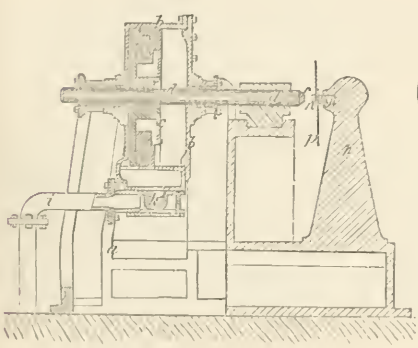
Fig. 3228 represents a plan or horizontal view of an arrangement of machinery or apparatus designed for connecting or riveting metallic plates for the construction of steam-boilers; Fig. 3329 is a side view; and Fig. 3230 a section, taken longitudinally through about the centre of the apparatus. *a a* is the frame-work for supporting the steam-cylinder *b b*, in which a steam-tight metallic or other piston *c c* works; this piston *c c* is mounted upon the rod *d d**, which passes out through stuffing-boxes *e e* at each end of the cylinder *b b*; in the end *d** of the piston-rod the die *f* is fixed, the other die *g* being mounted in the pillar *h*, which is fast to the frame-work. Steam being admitted through the entrance or feed-pipe *i*, it passes onwards through a common slide or other valve *k*, to the cylinder; and after having performed its office, is allowed to pass out through the pipe *l*. The slide-valve *k* is worked by hand, by means of the lever *m*, so as to admit the steam on either side of the piston as required.

The operation of the apparatus is as follows: Steam of a sufficient pressure being admitted (by means of the slide-valve *k*) at the back, or as it appears in Fig. 3230 at the left-hand side of the piston *c c*, that piston will be forced, together with the piston-rod *d d**, in the direction of the arrow, and form the ends of the rivet *n*, between the two dies *f* and *g*; thus firmly connecting the plates *o* and *p*, and thereby producing a perfectly steam, air, or water tight joint.

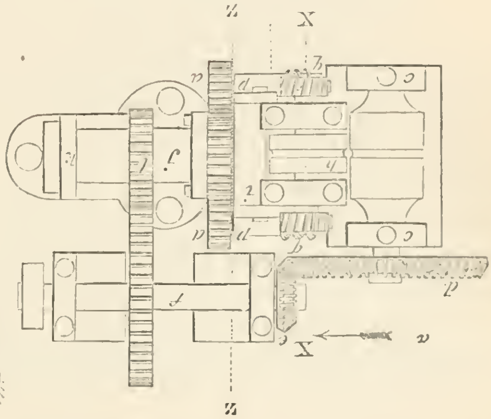
The head of the rivet is formed at one or more blows, as required; the intensity of the blow depending upon the area of the piston, the length of the stroke, and the pressure of the steam employed. The valve *k* is then reversed, to admit the steam in front of the cylinder; which movement will withdraw the die *f*, when another rivet may be put in, and the operation proceeds as before.

The patentee remarks that he does not intend to confine himself to the use of steam alone for such purposes, as the direct pressure of water, air, or other elastic medium may be similarly employed, without departing from the principle of his invention. He states that he does not claim the exclusive use of the several parts of the above-mentioned apparatus, when taken separately, but only when employed for the purpose of his invention, which consists in the riveting of metallic plates by dies driven by the power of steam, water, &c.

3230.



3231.



ROLLING MACHINE, for rolling iron, specially intended for railroad bars and locomotive tires—a new method, invented by Horatio Ames, of Falls Village, Connecticut.

We are induced to publish the entire specification and drawings of this invention, not only on account of the value and merit which it presents, but because of the deep interest which must be felt in all such improvements by those who are engaged in the manufacture of iron, and in railroads. The great rivalship now going on in this country and in England, in the manufacture of iron, renders every improvement which looks either to the reduction of the cost of manufacture, or to the amelioration of the quality of the iron, of the highest importance. And as the cost of repairs on railroads arises in a great measure from the wear of railroad bars and locomotive tires, by exfoliation and splitting, any invention which promises to avoid this evil must be looked upon with interest. The invention in question has already excited a deep interest in England, where the inventor has secured it by patent.

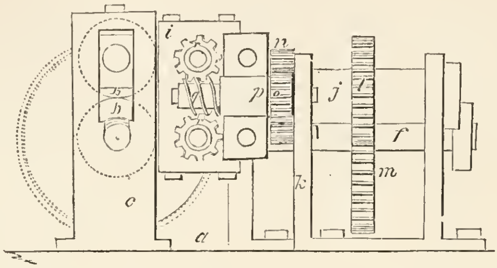
Fig. 3231 is a plan of the machine; Fig. 3232, a side elevation; Fig. 3233, a longitudinal vertical section, taken at the line X X of Fig. 3231; and Fig. 3234, a like section, taken at the line Z Z of the same figure. The same letters indicate like parts in all the figures.

In the manufacture of iron, either by rolling or hammering, the fibres are all drawn longitudinally, which, for the rails of railroads, for the tires of railroad wheels, and for a variety of other purposes, renders it liable to break off in thin leaves or scales, or to split lengthwise—this state of things being very common in the two instances specified. The object of my invention is so to treat the iron, either in the original manufacture thereof, or afterwards, as to avoid this defect, and thereby render the iron for these purposes more durable, by laying the fibres in such form and direction as to prevent it from scaling off or splitting. And my invention consists in twisting the iron in, or before, or after, the operation of rolling or hammering, so that the fibres shall wind around one another, in a manner somewhat similar to the fibres of hemp in a twisted rope or strand.

And the second part of my invention relates to the machinery by which I carry into effect my improved process, and consists in combining two or more sets of rollers, one or both of which are to be draw-rollers, and one set turning in the usual permanent bearings, and the other set or sets working in a frame or chuck that rotates on an axis at right angles to the axis of the rollers, to twist the bar of iron between the two sets of rollers.

To enable any one skilled in the art to apply my improved process of treating iron, and to construct and use the machine which I have invented therefor, I will describe the mode of procedure which I have essayed, as well as the manner of constructing and raising the machine therefor. The bloom of iron, or a bar previously formed, is taken while in a heated state, and twisted while undergoing the operation of hammering, which may be done by securing one end of the bloom or bar in a clamp and rotating it while the hammer rests on the other end; or by securing the two ends in separate clamps and twisting one of them, or both, in opposite directions, until the required twist has been given, and then subjecting it to the operation of hammering. But when the bar is to be drawn by rolling, the bar is to undergo the operation of twisting while passing between the rollers, or after it has passed between one set, and before it passes between the second set; and when it is twisted on its way to the rollers, one end of the bar may be secured to a clamp, which is to be rotated as the bar passes between the draw-rollers.

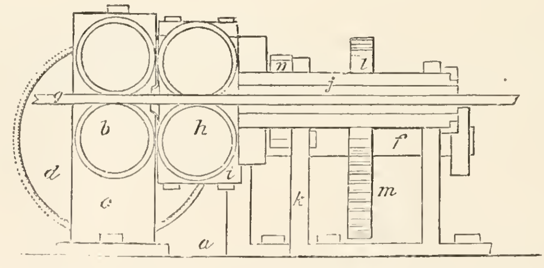
3232.



As the bars thus prepared are, in most instances, to be reworked to receive the required form or forms, according to the purposes which they are to be applied to, it will be evident that they may be twisted as they pass from the hammer or the rollers, instead of giving the twist before the hammering or rolling; and to effect this, the end of the bar may be clamped as it leaves the hammer or rollers, and the required twist given; but it is better to give the twist before the iron has undergone the operation of rolling or hammering, as it is then more highly heated, and the fibres will not be so severely strained as they would be after the metal has been partly cooled.

When iron has been treated and worked according to this process, the fibres, instead of running in the bar longitudinally, in straight lines, will run in the direction of a helix, gradually approaching to a straight line from the circumference to the axis of the bar, so that when used for making tires, or for other analogous purposes, the bar will be prevented from splitting along its length by the tenacity of the fibres, which cross the bar in the direction of a helix, instead of the mere adhesion of the fibres together; and when used for the rails of railroads, or similar purposes, none of the fibres can be separated from the mass longitudinally, as heretofore, nor can the iron be stripped off in scales until they have been cut off on each side, for, by their direction, they pass diagonally from one side, over the surface, and down the other side, whereby they are completely tied together.

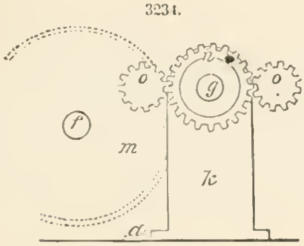
3233.



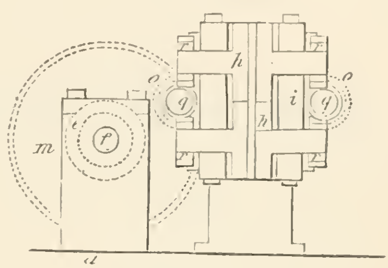
Of the machinery for working iron in accordance with the foregoing process.—In the accompanying drawings *a* represents a frame properly adapted to the purpose, and *b b* two grooved rollers, such as are used in rolling-mills for rolling bars of iron—the groove in each being semicircular, or nearly so, that the two together may form a cylindrical bar. These two rollers are placed one above the other, with their journals in appropriate boxes in the two standards *c c*. The shaft of the lower roller extends out beyond one of the standards, and is provided with a level cog-wheel *d*, which mashes into a level pinion *e* on the main driving-shaft *f*, which turns the lower roller to feed in the bar of iron *g*—the upper roller being carried by the motion of the lower one. Just back of the first set of rollers above described, there is another pair *n n*, similar to the first, except that the grooves in them are smaller, to draw the iron slightly, after passing the first set—they are mounted in a hollow chuck or frame *i* on the forward end of a hollow shaft or mandrel *j* that has its bearings in two standards *k k*, and which is provided with a cogged pinion *l*, the teeth of which engage with a cog-wheel *m* on the main-shaft, by which the second set of rollers are made to rotate at right angles to their axes, and on an imaginary line passing through the bight of the two sets of rollers, and in the centre of the two holes formed by the grooves in the rollers at the bight of each set, the axis of the hollow shaft or mandrel being in this imaginary line. Back of the clutch, and attached to the front face of the forward standard *k*, there is a wheel *n*, the cogs of which mash into the cogs of two pinions *o o* on two short arbors *p p*, one on each of the two opposite sides of the chuck, the other end of these short arbors being provided each with a short screw *q*, the threads of which engage with the cogs of two pinions *r r*, one on the end of each of the rollers of the second set, so that the cog-wheel *n*, being permanently attached to the standard when the hollow shaft with its chuck, and the second set of rollers, is turned, the two cogged pinions *o o* travel about this wheel, which turns the arbors to which they are attached, in the direction of the reverse of the rotation of the chuck, and the threads of the screw in turn engaging with the cogs of the pinions on the shafts of the second set of rollers causes these to rotate on their axes, and in the same direction with the first set, and with a velocity, relatively to the rotation of the first set, proportioned to the amount of drawing action which they are intended to exert on the bar that is to pass between.

In this way it will be obvious that when the machine is put in motion, and a bar of iron fed in, it will pass between the first pair of rollers and be partly drawn, and then pass between the second pair, which having two motions, one on their axis and another at right angles thereto, and on the axis of the bar of iron, it (the bar) will in consequence be twisted between the two pairs of rollers, and also drawn by them, and the fibres compressed.

3234.



3235.



From the foregoing it will be obvious that the extent of drawing action of either or both sets of drawing-rollers can be regulated at pleasure, by simply varying the size of the grooves and relative motions of the draw-rollers on their axes, and their rotation on the axis of the bar of iron.

It will be equally obvious that the number of draw-rollers can be increased without changing the principle of my invention. It is to be understood that the iron, when subjected to the compound action of drawing and twisting, is to be in a heated state, such as practised by and known to iron-masters in the manufacture of iron.

Claim.—What I claim as my invention is, first, the method herein described of treating iron to increase its toughness or durability for certain purposes—such as railroad bars and tires, &c.—by subjecting it, in a highly heated state, to the compound operation of drawing and twisting, substantially as herein described.

I also claim in the machinery above described, giving to one set of rollers the rotary motion on their axes, and a rotary motion at right angles thereto, on the axis of the bar of iron, when this is combined with another pair of rollers that have simply a rotary motion on their axes, whereby the bar of iron, in a highly heated state, is drawn and twisted.

ROPES, STIFFNESS OF, or the resistance of ropes to bending upon a circular arc. The experiments upon which the rules and table following are founded were made by Coulomb, with an apparatus the invention of Amonton, and Coulomb himself deduced from them the following results:

1. That the resistance to bending could be represented by an expression consisting of two terms, the one constant for each rope and each roller, which we shall designate by the letter A, and which this philosopher named the natural stiffness, because it depends on the mode of fabrication of the rope, and the degree of tension of its yarns and strands; the other, proportional to the tension, T, of the end of the rope which is being bent, and which is expressed by the product B T, in which B is also a number constant for each rope and each roller.

2. That the resistance to bending varied inversely as the diameter of the roller.

Thus the complete resistance is represented by the expression

$$\frac{A + B\,T.}{D}$$

where D represents the diameter of the roller.

Coulomb supposed that for tarred ropes the stiffness was proportional to the number of yarns, and M. Navier inferred, from examination of Coulomb's experiments, that the coefficients A and B were proportional to a certain power of the diameter, which depended on the extent to which the cords were worn. M. Morin, however, deems this hypothesis inadmissible, and the following is an extract from his new work, "*Leçons de Mécanique Pratique*," December, 1846:

"To extend the results of the experiments of Coulomb to ropes of different diameters from those which had been experimented upon, M. Navier has allowed, very explicitly, what Coulomb had but surmised—that the coefficients A and B were proportional to a certain power of the diameter, which depended on the state of wear of the ropes; but this supposition appears to us neither borne out, nor even admissible, for it would lead to this consequence, that a worn rope of a metre diameter would have the same stiffness as a new rope, which is evidently wrong; and, besides, the comparison alone of the values of

A and B shows that the power to which the diameter should be raised would not be the same for the two terms of the resistance."

Since, then, the form proposed by M. Navier for the expression of the resistance of ropes to bending cannot be admitted, it is necessary to search for another, and it appears natural to try if the factors A and B cannot be expressed for white ropes, simply according to the number of yarns in the ropes, as Coulomb has inferred for tarred ropes.

Now, dividing the values of A, obtained for each rope by M. Navier, by the number of yarns, we find for

$$n=30 \quad d=0^{m\cdot}200 \quad A=0{\cdot}222460 \quad \frac{A}{n}=0{\cdot}0074153$$

$$n=15 \quad d=0^{m\cdot}144 \quad A=0{\cdot}063514 \quad \frac{A}{n}=0{\cdot}0042343$$

$$n=6 \quad d=0^{m\cdot}088 \quad A=0{\cdot}010604 \quad \frac{A}{n}=0{\cdot}0017673$$

It is seen from this that the number A is not simply proportional to the number of yarns.

Comparing, then, the values of the ratio $\frac{A}{n}$, corresponding to the three ropes, we find the following results:

Number of yarns.	Values of $\frac{A}{n}$.	Differences of the numbers of yarns.	Differences of the values of $\frac{A}{n}$.	Differences of the values of $\frac{A}{n}$ for each yarn of difference.
30	0·0074153	From 30 to 15. 15 yarns	0·0031810	0·000212
15	0·0042343	" 15 to 6. 9 "	0·0024770	0·000272
6	0·0017673	" 30 to 6. 24 "	0·0056400	0·000252

Mean difference per yarn, 0·000245.

It follows, from the above, that the values of A, given by the experiments, will be represented with sufficient exactness for all practical purposes by the formula

$$A=n\,[0{\cdot}0017673+0{\cdot}000245\,(n-6)].$$
$$=n\,[0{\cdot}0002973+0{\cdot}000245\,n].$$

An expression relating only to dry white ropes, such as were used by Coulomb in his experiments.

With regard to the number B, it appears to be proportional to the number of yarns, for we find for

$$n=30 \quad d=0^{m\cdot}0200 \quad B=0{\cdot}009738 \quad \frac{B}{n}=0{\cdot}0003246$$

$$n=15 \quad d=0^{m\cdot}0144 \quad B=0{\cdot}005518 \quad \frac{B}{n}=0{\cdot}0003678$$

$$n=6 \quad d=0^{m\cdot}0088 \quad B=0{\cdot}002380 \quad \frac{B}{n}=0{\cdot}0003967$$

Mean..................0·0003630

Whence

$$B=0{\cdot}000363\,n.$$

Consequently, the results of the experiments of Coulomb on dry white ropes will be represented with sufficient exactness for practical purposes by the formula

$$K=n\,[0{\cdot}000297+0{\cdot}000245\,n+0{\cdot}000363\,T]\ \text{kil.}$$

which will give the resistance to bending upon a drum of a metre in diameter, or by the formula

$$R=\frac{n}{D}\,[0{\cdot}000297+0{\cdot}000245\,n+0{\cdot}000363\,T]\ \text{kil.}$$

for a drum of diameter D metres.

These formulæ, transformed into the English scale of weights and measures, become

$$R=n\,[0{\cdot}0021508+0{\cdot}0017724\,n+0{\cdot}00119096\,T]\ \text{lbs.}$$

for a drum of a foot in diameter, and

$$R=\frac{n}{D}\,[0{\cdot}0021508+0{\cdot}0017724\,n+0{\cdot}00119096\,T]\ \text{lbs.}$$

for a drum of diameter D feet.

With respect to worn ropes, the rule given by M. Navier cannot be admitted, as I have shown above because it would give for the stiffness of a rope of a diameter equal to unity the same stiffness as for a new rope; and it is from having adopted, with other authors, this rule without investigation, that I have been led to this inadmissible result, in calculating the table of the stiffness of ropes inserted in the third edition of my *Aide Mémoire de Mécanique Pratique*, p. 328.

The experiments of Coulomb on worn ropes not being sufficiently complete, and not furnishing any precise data, it is not possible, without new researches, to give a rule for calculating the stiffness of these ropes.

Tarred ropes.—In reducing the results of the experiments of Coulomb on tarred ropes, as we have done for white ropes, we find the following values:

$$
\begin{array}{llll}
n = 30 \text{ yarns} & A = 0{\cdot}34982 & B = 0{\cdot}0125605 \\
n = 15 \quad \text{“} & A = 0{\cdot}106003 & B = 0{\cdot}006037 \\
n = \ \ 6 \quad \text{“} & A = 0{\cdot}0212012 & B = 0{\cdot}0025997
\end{array}
$$

which differ very slightly from those which M. Navier has given. But, if we look for the resistance corresponding to each yarn, we find

$$n = 30 \text{ yarns} \quad \frac{A}{n} = 0{\cdot}0116603 \quad \frac{B}{n} = 0{\cdot}000418683$$

$$n = 15 \quad \text{“} \quad \frac{A}{n} = 0{\cdot}0070662 \quad \frac{B}{n} = 0{\cdot}000402466$$

$$n = 6 \quad \text{“} \quad \frac{A}{n} = 0{\cdot}0035335 \quad \frac{B}{n} = 0{\cdot}000433283$$

Mean..............0·000418144

We see by this that the value of B is for tarred ropes, as for white ropes, sensibly proportional to the number of yarns, but it is not so for that of A, as M. Navier has supposed.

Comparing, as we have done for white ropes, the values of $\frac{A}{n}$ corresponding to the three ropes of 30, 15, and 6 yarns, we obtain the following results:

Number of yarns.	Values of $\frac{A}{n}$.	Differences of the numbers of yarns.	Differences of the values of $\frac{A}{n}$.	Differences of the values of $\frac{A}{n}$ for each yarn of difference.
30	0·0116603	From 30 to 15. 15 yarns	0·0045941	0·000306
15	0·0070662	“ 15 to 6. 9 “	0·0035327	0·000392
6	0·0035335	“ 30 to 6. 25 “	0·0081268	0·000339

Mean..................0·000346

It follows from this that the value of A can be represented by the formula

$$A = n\,[0{\cdot}0035335 + 0{\cdot}000316\,(n - 6)]$$
$$= n\,[0{\cdot}0014575 + 0{\cdot}000316\,n]$$

and the whole resistance on a roller of diameter D metres, by

$$R = \frac{n}{D}\,[0{\cdot}0014575 + 0{\cdot}000316\,n + 0{\cdot}000118111\,T]\ \text{kil.}$$

Transforming this expression to the English scale of weights and measures, we have

$$R = \frac{n}{D}\,[0{\cdot}01051112 + 0{\cdot}00250309\,n + 0{\cdot}001371889\,T]\ \text{lbs.}$$

for the resistance on a roller of diameter D feet.

This expression is exactly of the same form as that which relates to white ropes, and shows that the stiffness of tarred ropes is a little greater than that of new white ropes.

In the following table the diameters corresponding to the different numbers of yarns are calculated from the data of Coulomb, by the formulæ

$$d^{\text{cent}} = \sqrt{0{\cdot}1338\,n} \text{ for dry white ropes, and}$$

$$d^{\text{cent.}} = \sqrt{0{\cdot}186\,n} \text{ for tarred ropes,}$$

which, reduced to the English scale, become

$$d^{\text{inches}} = \sqrt{0{\cdot}020739\,n} \text{ for dry white ropes, and}$$

$$d^{\text{inches}} = \sqrt{0{\cdot}02885} \text{ for tarred ropes.}$$

Note.—The diameter of the rope is to be included in D; thus, with an inch rope passing round a pulley, 8 inches in diameter in the groove, the diameter of the roller is to be considered as 9 inches.

Number of yarns.	Dry White Ropes.			Tarred Ropes.		
	Diameter.	Value of the natural stiffness, A.	Value of the stiffness proportional to the tension, B.	Diameter.	Value of the natural stiffness, A.	Value of the stiffness proportional to the tension, B.
	ft.	lbs.		ft.	lbs.	
6	0·0293	0·0767120	0·0071457	0·0347	0·153376	0·00823133
9	0·0360	0·1629234	0·0107186	0·0425	0·297647	0·01234700
12	0·0416	0·2810384	0·0142915	0·0490	0·486976	0·01646267
15	0·0465	0·4310571	0·0178644	0·0548	0·721357	0·02057834
18	0·0509	0·6129795	0·0214373	0·0600	0·000795	0·02469400
21	0·0550	0·8268054	0·0250102	0·0648	1·325289	0·02880967
24	0·0588	1·0725350	0·0285831	0·0693	1·694839	0·03292534
27	0·0622	1·3501682	0·0321559	0·0735	2·109444	0·03704100
30	0·0657	1·6597051	0·0357288	0·0775	2·569105	0·04115667
33	0·0689	2·0011455	0·0393017	0·0813	3·073821	0·04527234
36	0·0720	2·3744897	0·0428746	0·0849	3·623593	0·04938800
39	0·0749	2·7797375	0·0464475	0·0884	4·218416	0·05350367
42	0·0778	3·2168888	0·0500203	0·0917	4·858303	0·05761934
45	0·0805	3·6859438	0·0535932	0·0949	5·543242	0·06173501
48	0·0831	4·1869024	0·0571661	0·0980	6·273287	0·06585067
51	0·0857	4·7197647	0·0607390	0·1010	7·048287	0·06996634
54	0·0882	5·2845306	0·0643119	0·1040	7·868393	0·07408201
57	0·0908	5·8812001	0·0678847	0·1070	8·733554	0·07819767
60	0·0926	6·5097733	0·0714576	0·1099	9·643771	0·08231334
n	$\sqrt{0·000144\, n}$	$0·0021508\, n + 0·0017724\, n^2$	$0·00119096 n$	$\sqrt{0·00020\, n}$	$0·01054412\, n + 0·00250309\, n^2$	$0·001371889 n$

Application of the preceding tables or formulæ.—To find the stiffness of a rope of a given diameter or number of yarns, we must first obtain from the table, or by the formulæ, the values of the quantities A and B corresponding to these given quantities, and knowing the tension, T, of the end to be wound up, we shall have its resistance to bending on a drum of a foot in diameter by the formula

$$R = A + B\,T.$$

Then, dividing this quantity by the diameter of the roller or pulley round which the rope is actually to be bent, we shall have the resistance to bending on this roller.

Example.—What is the stiffness of a dry white rope, in good condition, of 60 yarns, or ·0928 diameter which passes over a pulley of 6 inches diameter in the groove, under a tension of 1000 lbs.? The table gives for a dry white rope of 60 yarns, in good condition, bent upon a drum of a foot in diameter,

$$A = 0·50977 \quad B = 0·0714576$$

and we have $D = 0·5 + 0·0928$; and consequently,

$$R = \frac{6·50977 + 0·0714576 \times 1000}{0·5928} = 128 \text{ lbs.}$$

The whole resistance to be overcome, not including the friction on the axis, is then

$$Q + R = 1000 + 128 = 1128 \text{ lbs.}$$

The stiffness in this case augments the resistance by more than one-eighth of its value.

SAWS.* Saws may be considered in two groups, namely, rectilinear saws, and circular saws. The blade of the rectilinear saw is usually a thin plate of sheet steel, which in the first instance is rolled of equal thickness throughout: the teeth are then punched along its edge, previously to the blade being hardened and tempered, after which it is smithed or hammered, so as to make the saw quite flat. The blade is then ground upon a grindstone of considerable diameter, and principally crossways, so as to reduce the thickness of the metal from the teeth towards the back. When, by means of the hammer, the blade has been rendered of uniform tension or elasticity, the teeth are sharpened with a file, and slightly bent, to the right and left alternately, in order that they may cut a groove so much wider than the general thickness, as to allow the blade to pass freely through the groove made by itself. The bending, or lateral dispersion of the teeth, is called the set of the saw.

The circular saw follows the same conditions as the rectilinear saw, if we conceive the right line to be exchanged for the circle; with the exception that the blade is, for the most part, of uniform thickness throughout, unless, as in the circular veneer saws, it is thinned away on the edge.

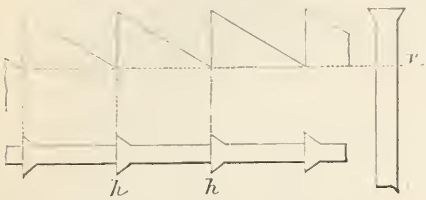
It is to be observed that the word *pitch*, when employed by the saw maker, almost always designates the inclination of the face of the tooth, up which the shaving ascends; and not the interval from tooth to tooth, as in wheels and screws. The teeth of some kinds are usually small, and seldom so distant as ½ an inch asunder: these are described as having 2, 3, 4, 5, to 20 points to the inch; such as are used

* Holtzapfel.

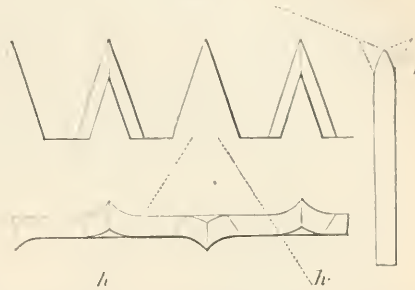
by hand, are commonly from about ½ to 1¼ inch asunder, and are said to be of ½ or 1¼ inch *space* although some of the circular saws are as coarse as 2 to 3 inches and upwards from tooth to tooth.

The processes denominated *sharpening* and *setting* a saw, consist, as the names imply, of two distinct operations: the first being that of filing the teeth until their extremities are sharp; the second, that of bending the teeth in an equal manner, and alternately to the right and left, so that when the eye is directed along the edge, the teeth of rectilinear saws may appear exactly in two lines, forming collectively an edge somewhat exceeding the thickness of the blade itself.

3235.



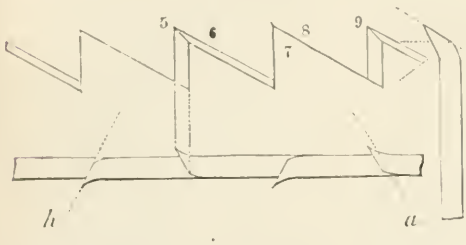
3236.



In general the angles of the points of the saw teeth are more acute, the softer the material to be sawn, agreeably to common usage in cutting tools; and the angles of the points, and those at which the files are applied, are necessarily the same. Thus in sharpening saws for metal, the file is generally held at 90 degrees both in the horizontal and vertical angle, as will be shown; for very hard woods at from 90 to 80 degrees, and for very soft woods at from 70 to 60 degrees, or even more acutely. The vertical angle is about half the horizontal.

Fig. 3235 represents in plan and two elevations the saw-teeth that are the most easily sharpened, namely, those of the frame-saw for metal, commonly used by the smith: the teeth of this saw are not set or bent in the ordinary manner, owing to the thickness and hardness of the blade, and the small size of the teeth.

3237.

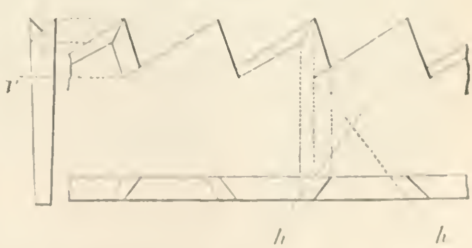


The smith's-saw blade, when dull, is placed edgeways upon the jaws of the vice, and the teeth which are placed upwards, are slightly hammered; this upsets or thickens them in a minute degree, and the hammer face reduces to a general level those teeth which stand highest. They are then filed with a triangular file held perfectly square, or at ninety degrees to the blade, both in the horizontal direction *h*, and the vertical *v*, until each little facet just disappears, so as to leave the teeth as nearly as possible in a line, that each may fulfil its share of the work.

The most minute kind of saws, those which are made of broken watch springs, have teeth that are also sharpened nearly as in the diagram, but without the teeth being either upset or bent; as in very small saws the trifling burr, or rough wiry edge thrown up by the file, is a sufficient addition to the thickness of the blade, and is the only *set* they receive.

Fig. 3236 illustrates the peg-tooth; but it may also be considered to apply to the M tooth, and, in part, to the mill-saw tooth. The points of the cross-cutting saws for soft woods are required to be acute or keen, that they may act as knives in dividing the fibres transversely.

3238.



The left sides of each alternate tooth, are first filed with the horizontal angle denoted by *h*, and then the opposite sides of the same teeth with the reverse inclination, or *h'*. Fig. 3237 may be considered to refer generally to all teeth the angles of which are 60 degrees, (or the same as that of the triangular file,) and that are used for wood. The most common example is the ordinary hand-saw tooth; but teeth of upright pitch, such as the cross-cut saw, or of considerable pitch, are treated much in the same manner. The teeth having been topped, the *faces* 5, 9, are first filed back, until they respectively agree with a dotted line *a*, supposed to be drawn through the centre of each little facet produced in the topping; the file is then made to take the sides 6 and 7 of the back until the second half of the facet is reduced, and the point of the tooth falls as nearly as may be on the dotted line *a*. The first course takes the face only of each alternate tooth; the second course the back of the former and face of the next tooth at one process; and the third course takes the tops only of the second series, and completes the work. This order of proceeding is employed, that the faces of the teeth may be in each case completed before the tops or backs.

Fig. 3238 exhibits also in three elevations a somewhat peculiar form of tooth, namely, that of the pruning-saw for green wood. The blade is much thicker on the edge than the back, so that the teeth are not set at all. The teeth are made with a triangular file, applied very obliquely as to horizontal angle, as at *h*, sometimes exceeding 45 degrees, but without vertical inclination, as at *v;* and the faces of the teeth are nearly upright, as in the hand-saw. The large sides of the teeth are very keen, and each vertical edge is acute like a knife, and sharply pointed; in consequence of which it cuts the living wood with a much cleaner surface, and less injury to the plant, than the common hand-saw tooth.

3239.

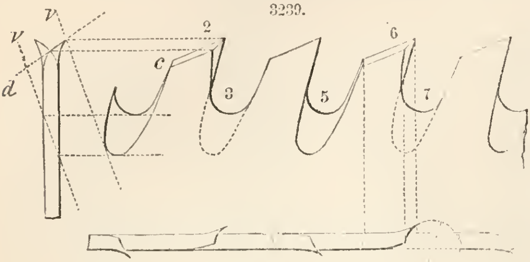


Fig. 3239 explains the method employed in sharpening gullet or briar-teeth; in these there are large curvilinear hollows, in the formation of which the faces of the teeth also become hollowed so as to make the projecting angles acute. The gullets 3, 7, are first filed, and from the file crossing the tooth very obliquely, as at *v v* in the section, the point of the tooth extends around the file, and gives the curvature represented in the plan. The file should not be so large as the gullet; it is therefore requisite that the file be applied in two positions, first upon the face of the one tooth, and then on the back of the preceding tooth. The tops of the teeth, 2, 6, are next sharpened with the flat side of the file, the position of which is of course determined by the angles *c* and *d;* the former varies with the material from about 5 to 40 degrees with the edge, and the latter from 80 to 60 degrees with the side of the blade; the first angles in each case being suitable for the hardest, and the last for the softest woods. The alternate teeth having been sharpened, the remainder are completed from the other side of the blade requiring in all four ranges.

After sharpening, the saw is to be *set*, that is, an uniform bend is given to the teeth alternately to the right and to the left. This is often done by a hammer and set punch, but usually by a saw *set* which consists of a narrow blade of steel, with notches of various widths, for different saws. The saw is firmly held in clamps, the alternate teeth are inserted a little way into the proper notch, and are then bent over by raising or depressing the handle of the blade. Some sets are arranged with a guide by which the bends shall be uniform.

The method of sharpening and setting circular saws is very similar to that employed for rectilinear saws. The teeth of circular saws are in general more distant, more inclined and more set, than those of rectilinear saws. They are more distant on account of the greater velocity given to the saw, whereby the teeth follow in such rapid succession that the effect is almost continuous. They are more inclined because such teeth cut more keenly, and the extra power required to work them is readily applied. The harder the wood, the smaller and more upright should be the teeth, and the less the velocity of the saw. The teeth are more set in order to produce a wider kerf, since the large circular plate cannot be made so true, nor keep so true as the narrow straight blade. The setting must be very uniform, as one tooth projecting beyond the general line will score or scratch the work. "It is generally politic to use for any given work a saw of as small diameter as circumstances will fairly allow, as the resistance, the surface friction, and also the waste from the thickness, rapidly increase with the diameter of the saw. But on the other hand, if the saw is so small as to be nearly or quite buried in the work, the saw-plate becomes heated, the free escape of the dust is prevented, and the rapidity of the sawing is diminished." As a general rule the diameter of the saw should be about 4 times the average thickness of the wood; and the flange on the spindle should be as nearly as possible flush with the platform or saw-table.

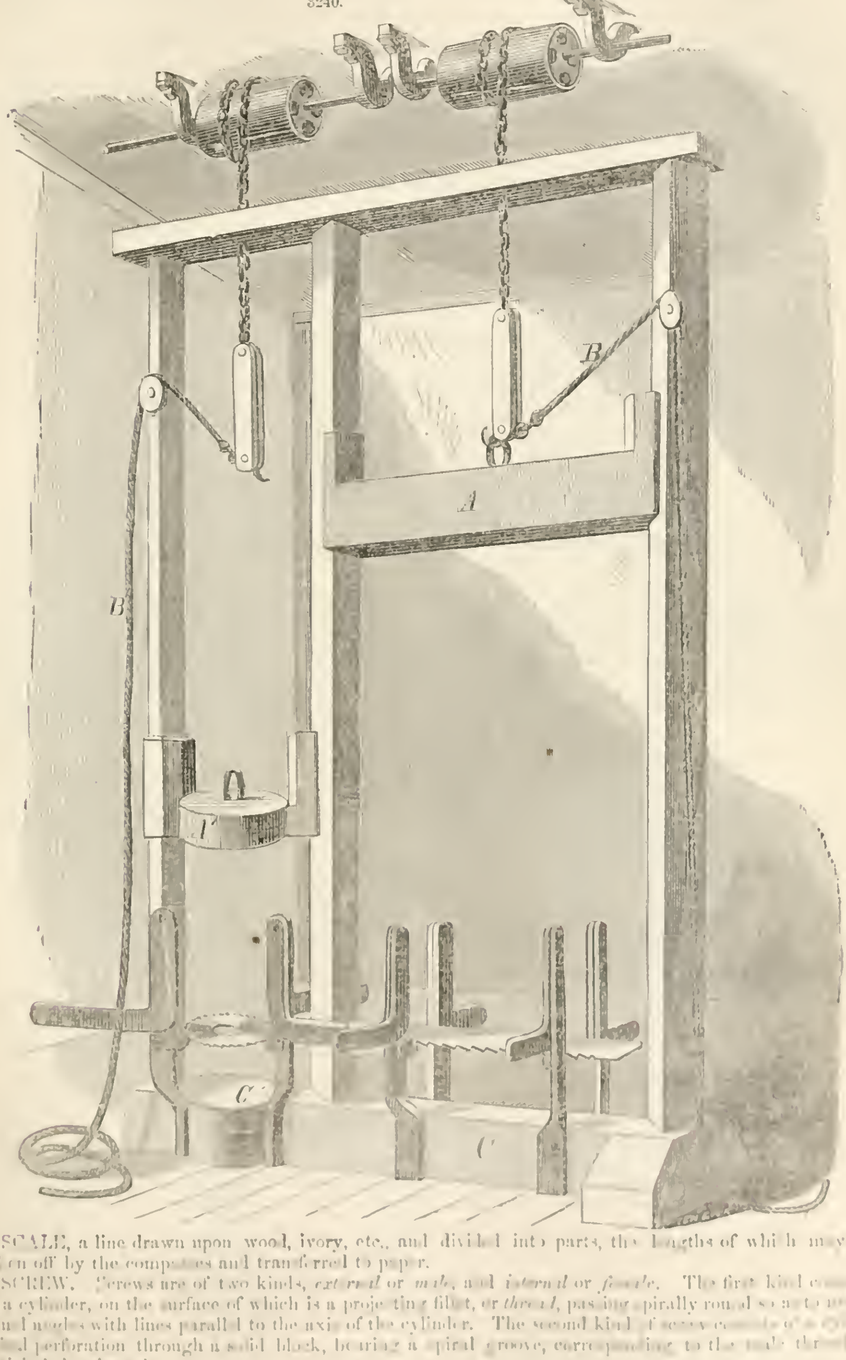
In cutting with the grain, the teeth of the saw should be coarse and inclined, and the speed moderate, so as to remove shreds rather than sawdust. In cutting across the grain, the teeth should be finer and more upright, and the velocity greater.

The usual saws used at saw-mills for the manufacture of lumber are rectilinear saws, supported in an upright frame, to which motion is given by a crank, either attached to a small water-wheel, or drum, driven by a steam engine. The feed is generally by a carriage geered and driven by a pawl on the saw frame, working into a ratchet wheel. In water mills the carriage is drawn back by a distinct wheel. In many mills the feed is continuous, the log being drawn in by feed rolls. For the manufacture of boards many saws are set in one frame, the whole log being split at once; they are called *gang* saws. Saws without frame, working in a guide at the top, and attached to the crank at the bottom are called *muley* saws. Circular saws are sometimes used for the manufacture of timber, but not to any great extent.

SAWS. *Improvement in Tempering and Straightening*, Waterman's patent. The usual method of tempering saws is to heat and then dip them in oil.—This process is slow, laborious, and costly; it is also disadvantageous, because the saws become warped, and require to be hammered up straight again by hand.

The present improvement consists in tempering and straightening the saws at one operation. This is done by heating the saws to the proper degree, and then pressing them, with a sudden and powerful stroke, between the two surfaces of cold iron. Drop presses are employed for the purpose. The engraving shows a pair of presses conjoined, one for long the other for circular saws. After being heated the saws are supported in mid air, on buttons attached to the framing at the base of the machine. The heavy drop-weights A A, are now liberated by pulling the cords B B, and the weights fall upon their respective saws, drive them down, and press them upon the solid iron base C, with tremendous force The sudden blow hardens the metal by rendering it more dense, and also straightens the saw.

3240.



SCALE, a line drawn upon wood, ivory, etc., and divided into parts, the lengths of which may be taken off by the compasses and transferred to paper.

SCREW. Screws are of two kinds, *external* or *male*, and *internal* or *female*. The first kind consists of a cylinder, on the surface of which is a projecting fillet, or *thread*, passing spirally round so as to make equal angles with lines parallel to the axis of the cylinder. The second kind of screw consists of a cylindrical perforation through a solid block, bearing a spiral groove, corresponding to the male thread to which it is adapted.

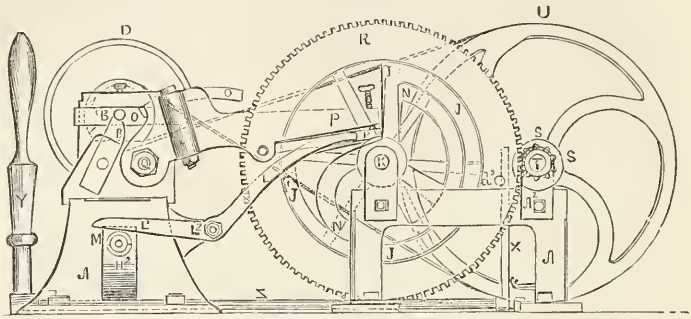
The screw is usually regarded as a continuous circular wedge. The pitch of the screw is the distance between two contiguous centers of the same thread, and the screw will be coarse or fine according to the pitch. The screw will be a *right-hand* or a *left-hand* screw, according as the wedge is wound upon the cylinder, to the right hand or to the left. *Double*, *triple*, or *quadruple* screws are those which have a double, triple, or quadruple thread, such, for example, as would be formed by placing 2, 3, or 4 strings in contact, and coiling them as a flat band round the cylinder. The screw may also vary in *section*, that is, the section of the worm or thread may be *angular*, *square*, *round*, etc.

Micrometer screws are screws of extremely fine pitch, accurately made, and used for graduation. *Wood* screws is a term applied to the common screw, as used by carpenters. *Machine* screws are a similar screw adapted to joiners in iron work.

SCREWS—SELF-OPERATING SHAVER. This is an improvement in machinery for turning or shaving the heads of the blanks which are to be formed into wood-screws, by J. Cullen Whipple, Providence, Rhode Island.

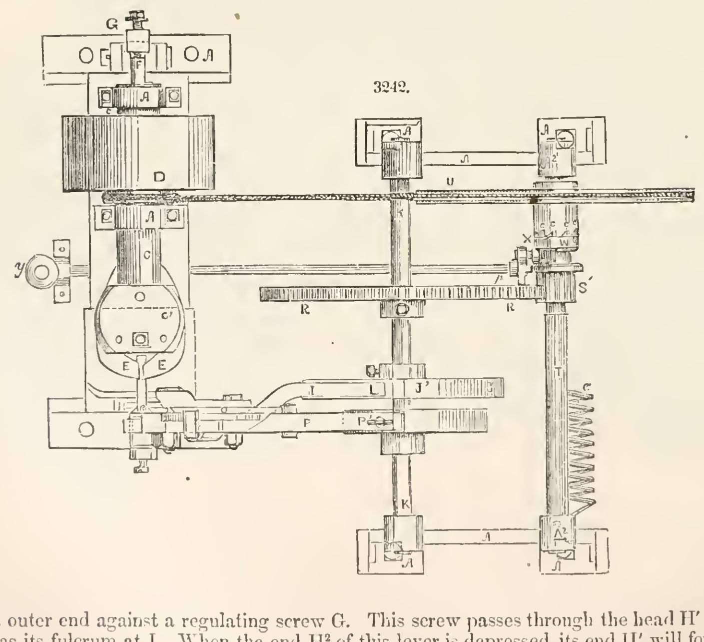
In the machines heretofore used for turning or shaving the heads of blanks, the tool or cutter by which they were finished was brought up against them by hand; but in this improved machine the parts are made self-acting by means of cams and levers, and other devices connected therewith, arranged for that purpose in the manner to be described.

3241.



In the accompanying drawings Fig. 3241 is a side, and Fig. 3242 a plan or top view. A A is the frame of the machine, which is made of cast-iron. C C is a tubular or hollow arbor or spindle, which is sustained by and runs in the heads A′ A′. The arbor or spindle C is driven by a band on a whirl or pulley D, and it is widened out at its end, C′, so as to constitute two cheeks which embrace the jaws E E. Through the tubular arbor C the sliding-bolt F F passes, and serves to close the jaws E. its wedge-formed end F′ passing in between the tails *a a* of the jaws for that purpose. The sliding-bolt F

3242.



bears at its outer end against a regulating screw G. This screw passes through the head H′ of the lever H, which has its fulcrum at I. When the end H² of this lever is depressed, its end H′ will force the bolt F forward, and cause the jaws E to close and embrace the blank which is to be turned. The lever H is depressed by means of a cam J, which is carried by a cam-shaft K K. The cam J as it revolves operates upon a lever L, having its fulcrum at L², the short arm of which L′ serves to depress the end H² of the lever H, during the time that its long arm rests upon the periphery of the cam J. The lever H has a hardened roller M, near its end H^2, upon which L′ bears. As represented in Fig. 3241, the lever L is relieved from its action on the lever H by its having fallen into the recess between the points J J′ of the cam J; the weight H^3 serves to raise the lever H. The arbor C C and the sliding-bolt F F then fall back, release the blank that has been turned, and allow a new one to be fed in. There is a second cam N N, carried by the shaft K, which cam serves to advance the tool or cutter O against the head to be turned. This tool or cutter does not differ from those used in other machines for turning the heads of screws. P is a lever upon which the cam N operates to raise the cutter and carry it regularly against the head of the blank; the fulcrum of this lever is at Q. P″ is a branch of the lever P, which by the aid of the set-screw P″ allows the action of the cutter to be accurately graduated. The periphery of the cam J is equidistant from its centre K, but that of the cam N has a gradually increasing diameter, to cause the cutter to advance gradually, as it takes a shaving off the head. The cutting part of the tool is so formed as to cut both the top and bevel of the head at the same time.

On the same shaft with the cams there is a large spur-wheel R, and motion is given to this wheel by means of a tubular pinion S, on a third shaft T, the bearings of which shaft are on the standards A^2 A^2. The shaft T also carries the large band-wheel U U, which receives a band from a small band-wheel or whirl V on the shaft C. The shaft C and the band-wheel U have their motion continuous, the band around the whirl V and the wheel U connecting these two parts. W is a sliding clutch-box, having the pinion S attached to it; and these are moved back and forth by the shipper X, which is governed by the handle Y, a rock-shaft Z on the lower end of which extends to the lower end of the shipper, by means of which the clutch-box is brought into contact with or removed from the clutch-pin, the clutching being effected by a tooth or pin *b* falling into one of the spaces *c c c*. For the purpose of arresting the wheel R at the proper time for removing a finished and feeding in a new blank, that is to say, at the period when the cams cease to act upon the levers P and L, there is a pin *p* projecting from the shipper X at its upper end, on the side opposite to that seen in Fig. 3241, which pin points towards the wheel R, and said wheel has a hole in its side, as at *d*, Fig. 3241, into which said pin will fall when the wheel comes round to the proper point. The spiral spring *e*′ draws upon the shipper X for the purpose of forcing said pin into the hole, and of arresting the wheel. There is a gage-pin *d* within the cheeks *c*′, against which a blank *e* is stopped when fed in; this pin is regulated by a set-screw *f* to suit blanks of different lengths. B is a rest which sustains a blank whilst it is being turned. Within the jaws E E there is a spring *g g* by which they are opened, and the blanks relieved as the bolt F recedes. The feeding is effected by passing the blank in between the jaws on the side shown in Fig. 3241, where B′ is the head of a blank inserted ready for the shaving or turning, by the tool O. When it has been turned and the jaws opened, it is removed and another inserted by hand; the blank being stopped by the gage-pin *d*′.

One person can readily attend two such machines, his duty being to operate the clutch at the proper time and to feed in a new blank.

SCREW BLANKS—Merrick's *patent*. Fig. 3243 denotes a plan of the blank feeder; Fig. 3244, a longitudinal, vertical, and central section.

In the said figures A represents a conical hopper, sustained in position by a suitable frame-work B. Two conic frustra C D are disposed within the said hopper, and the one over the other, and sustained upon shafts or bearings, as seen in the drawings. The said conic frustra should revolve in contrary directions, as denoted by arrows in the figures. The diameter of the base of the lower frustum is somewhat less than the diameter of the lowest part of the interior of the hopper, there being a circular space E left between them of a width to correspond with the diameter of the shank of each of the screw blanks, and permit them to move freely through it, as will be hereinafter described. The exterior surfaces of the two conic frustra should be roughened or indented in such manner as to act upon the screw or pin blanks and cause them to revolve. Generally speaking, the angles of inclination of the exterior edge of the two conic frustra and the interior edge of the hopper, with respect to a horizontal plane, are to be equal, or about equal, as denoted in Fig. 3244. Between the inner face of the hopper and the outer faces of the two frustra, I extend a partition F, which I secure to the hopper, and permit to approach as near as possible towards the frustra and not interfere with their revolving movements, and at a suitable distance from, or on the right of the said partition, and between the interior face of the hopper and the exterior faces of the frustra, I arrange a revolving beater G.

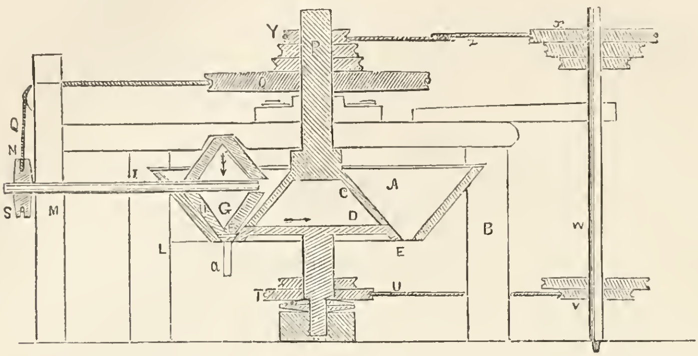
The said beater consists of one or more triangular or other suitably shaped plates H H, applied to a horizontal shaft I extending into the hopper, and sustained in bearings at L M, as represented in the figures. The said beater may be revolved by an endless band N, which may pass around a grooved pulley *o* placed upon the shaft P of the upper conic frustum, and thence over guide-pulleys Q R, and under a small pulley S fixed upon the shaft of the beater. The lower conic frustum should have a pulley T fixed upon its axis; from the said pulley an endless belt V proceeds to and around a pulley V fixed upon a vertical shaft W. The said shaft has another pulley X fixed upon its upper end, the said pulley communicating with another one (viz. Y upon the shaft of the upper conic frustum) by a cross-band L. Instead of the aforesaid modes of giving motion to the several parts, any suitable gear work may be adopted.

The screw or other blanks of the kind are to be thrown previously into the hopper on the left hand side of the partition F; as the upper conic frustum C revolves from left to right, and the lower one D from right to left, they will disturb the screw blanks which come in contact with them in such manner as to cause them to successively move downwards the circular space E before mentioned, through which the shanks will fall until arrested in vertical positions by the heads of the blanks coming into contact with the adjacent inclined surfaces of the lower conic frustum and the hopper.

As the lower frustum continues to revolve, it will advance each screw blank through the circular space E, in the direction in which it (the frustum) travels. The circular space E will thus be filled with screw blanks, whose shanks stand in vertical positions, as denoted at *a a*. The object of the beater is to prevent any one of the blanks from overriding the others or disturbing the arrangement of these which may be in that part of the space E which exists on the right of the partition F, and between it and the beater. The object of the upper conic frustum is to prevent the blanks from being carried around towards the beater in too great a body; it also facilitates the downward movements of the blanks towards the space E.

The triangular plates or arms of the beater, shaped as seen in Fig. 3244, revolve in the same direction as does the upper conic frustum. They therefore throw or keep back such blanks as might accumulate to an injurious extent in rear of them.

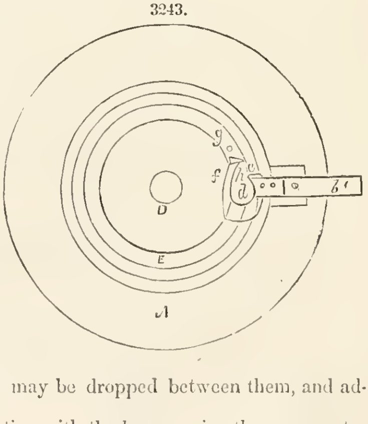
3244.



The next part of the apparatus is that by which the blanks are regularly delivered or fed from the circular space E. It consists of a horizontal slide-plate *b*, Fig. 3243, (which represents a view of the under sides of the hopper and lower conic frustum D,) affixed to the lower edge of the hopper just on the right of the partition F, the said plate being suitably sustained, so as to slide towards and from the axis of the lower conic frustum. It is forced inwards or towards the same by means of a spring *c* applied to it and the hopper. The said plate has a circular aperture *d* cut through one end of it, and a passage *e* into said aperture cut through the side of the plate, the whole being as seen in the figures. The inner end of the plate is cam-shaped, as seen at *f*, so that when a stud *g*, projecting from the under side of the lower frustum, is brought into contact with it, the stud shall press the slide outwards, or in a direction away from the frustum, and bring the passage *e* into line, or so as to correspond with the circular opening E. When this takes place, the movement of the lower frustum will carry one of the screw blanks through the passage *e* and cause it to drop out of the machine, the circular aperture *d* being made larger in its diameter than that of the head of the blank.

There is a small stud *h* fixed upon the rear side of the entrance *e* of the slide, as seen in the figure. When the slide is pressed outwards this stud enters between the screw blank which is to be discharged and the one next to it, and thereby prevents the escape of the latter. As soon as the blank is discharged, the slide-plate should be moved inwards by its spring.

3243.



The screw, or pin, or other blank thus discharged, may be received by or into any apparatus calculated to hold or dispose of it for any other operation necessary to be performed.

Instead of the conical frustra and hopper, I sometimes make use of two or more chain-belts arranged parallel to each other and at a proper distance apart, and I apply to them a hopper and beater; but I consider the said chain-belts, as mechanical equivalents to the aforesaid mechanism, by no means so useful or perfect in their operation.

The beater may be applied to two cylinders or rollers placed parallel to and apart from each other, and provided with a hopper and other contrivances by which the blanks may be dropped between them, and advanced towards the beater.

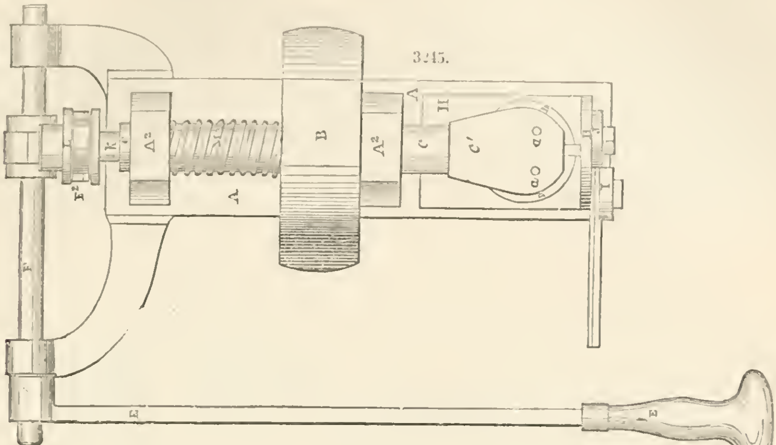
In some cases but one conic frustum may be used in connection with the hopper; in others, a greater number may be necessary, according to circumstances.

SCREWS, BURRING MACHINE FOR—By J. Cullen Whipple, of Providence, Rhode Island. Fig. 3245 is a front view of the machine, or of that part opposite to which the person stands who is using it; Fig. 3246 is a side view of it; Fig. 3247, a section through the main spindle or arbor; Fig. 3248, the under face of the machine; and Fig. 3249, the upper face of the lower end.

A A is the bed-piece or main-frame, which supports the working parts, and which is usually of cast-iron. A′ is a piece projecting therefrom, by which it may be fastened to a bench. B is a whirl or pulley on the main arbor or spindle C C. This arbor runs and slides in collars in the heads A^2 A^2. The arbor C widens out at its lower end C′, and is divided so as to form two cheeks, between which the jaws D D are to be received. These jaws work upon pins *a a*, which pass through them and through the cheeks. H H is an adjustable slide, which is fastened to the bed-piece A by a screw *b* passing through a slot.

The part H′ of the adjustable slide, which stands at right angles to the part H, has on its face a piece I fastened to it by a screw c, and this holds the tool G, by which the burs are to be removed from the under side of the heads, the proper form being given to the cutting part G′ of said tool, to adapt it

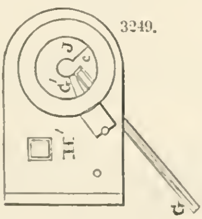
3245.



to the bevel of the head. J is a steel plate, in which there is a countersink d to admit the head of the screw to come into contact with the tool G. Where the tool is to act upon the head the steel plate J is cut away, as shown at e.

The arbor C C is tubular, and there passes through it a sliding-bolt K, having a wedge-formed head K′, by which the jaws D D are to be closed, and this closing will take place as the bolt is drawn back, and

3249.



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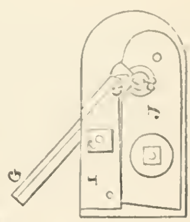

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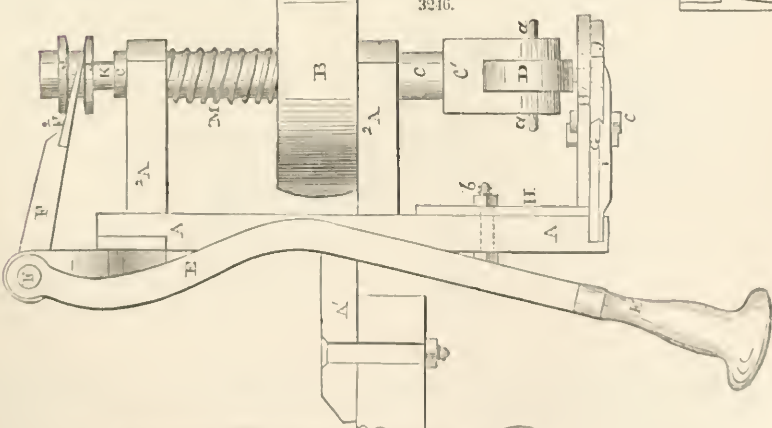

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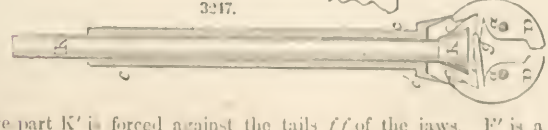


the wedge part K′ is forced against the tails f f of the jaws. F′ is a shaft, to which is attached an arm F, that is forked at its outer end F², and is received between collets L L attached to the sliding-bolt K. E E are a handle and lever, by which the sliding-bolt K and the spindle C are drawn upwards A spiral spring M surrounds the arbor C, and bearing against the uppermost of the heads A^2 and against the pulley B, causes the spindle and bolt to descend, when the handle E is allowed to recede and renders the motion in both directions regular and smooth. As the bolt K descends it is brought into contact with the pins *g g*, which are made fast to the jaws and forces them open.

In using this machine, when the handle E has been moved back, and the sliding-bolt and arbor have descended, a blank, which has been notched, is fed in through the countersunk opening in the plate J, so as to enter between the jaws. The handle E is then drawn forward, which closes said jaws and brings the head up against the cutting edge of the tool G, by which the removal of the bar is instantaneously effected, the edge of the tool projecting a little within the countersink. In removing the handle back the blank is liberated and falls out, and another is fed in.

SCREW-CUTTING MACHINE. This is an invention of PETER H. WATSON, Esq., of Rockford, Illinois, for cutting screws.

Fig. 3250 is a perspective view of the machine, as arranged for cutting a male screw upon a rod of metal.

3250.

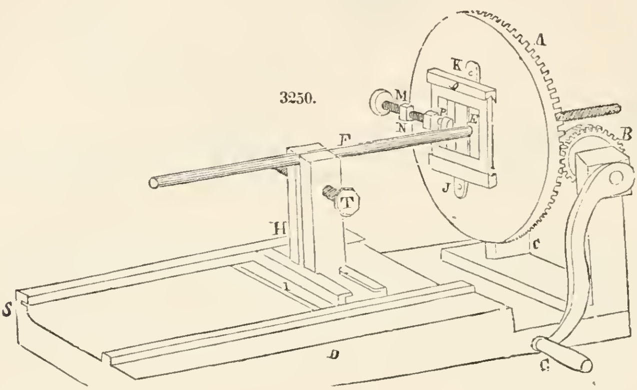


Fig. 3251 is a view of the face of the bevelled cog-wheel, carrying the dies, cutter and rest, &c.

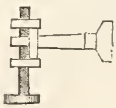
Fig. 3252 is a vertical transverse section of the carriage and jaws for holding the material to be operated on.

Fig. 3253 is a plan of the cutter.

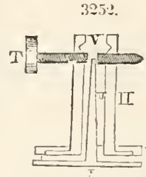
Fig. 3254 is a plan of the tap in the act of cutting the thread in a nut.

The nature of this improvement consists in combining and arranging in a suitable frame certain known mechanical principles in such a way as to form a new and useful machine, which will enable the mechanic to make screws and nuts with greater dispatch and correctness than by the modes now in use.

3254.

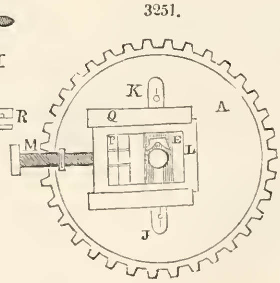


3252.



3253.

3251.



The combination consists of a cog-wheel A and pinion B working into the same, supported by suitable framework C on a permanent bed D, said cog-wheel having attached to its face two sliding-dies E E of the usual form for indenting the screw on the rod of iron F, said dies being turned with said cog-wheel, which is caused to revolve by turning a crank G on the axle of the pinion B, while the rod of iron F is held in a horizontal position between two vertical parallel jaws H, attached to sliding-carriage I, moved in parallel grooves S in the bed towards the dies, by the draft of the dies and chaser, on the rod in cutting the thread which passes through the hub of the wheel, made hollow for that purpose, the screw being perfected and finished before passing through the opening in the centre of the wheel, by means of an adjustable cutter or chaser J, of a shape corresponding to the shape of the thread to be cut, attached to the face of the wheel between the dies and the wheel directly behind the dies, and in a position to bring the cutter for chaser in contact with the thread as marked by the dies, so as to cut and perfect it as it leaves the dies, said cutter being attached to the face of the wheel by a set screw J passing through an oblong mortise in its shank.

A forked rest K is connected to the cog-wheel in the same manner so as to bear against the screw on the side opposite to that where the cutter is placed being designed to support the screw while under the operation of the chaser or cutter.

The dies are contained in and supported by a sliding-frame L, and are moved by a right and left screw M, attached by a collar to a stud N inserted into the face of the wheel turned by a milled head or other means, without changing its position longitudinally, the right thread working in a female head in the middle of the top of said sliding-frame L, and the left thread in a female thread in the middle of the sliding follower which slides in the sliding-frame, the lower die being placed against the bottom of the sliding-frame and the upper die against the under side of the follower P, so that when said screw is turned it causes the dies to approach or recede from each other simultaneously by giving the follower and bottom of the frame similar movements in opposite directions. The inner sides of the frame are made of a V-shape to enter corresponding shaped grooves in the ends of the die-plates and follower. The outsides of the sliding-frame are similarly shaped to slide in corresponding grooves made on the under sides of parallel ribs and fastened to the face of the wheel.

This arrangement is adopted for the purpose of adapting the dies to various diameters of rods upon which screws are to be made, and for centering the dies and rods.

The jaws for holding the rod of iron on which the screw is to be cut consists of two vertical parallel plates H H, notched or recessed on their inner sides where they grip or clamp the rod F, having their lower ends turned at right angles to enter and slide back and forth in parallel grooves R R on the upper side of the sides of the sliding-carriage I at right angles to the grooves S in the bed in which the carriage I moves. These jaws are opened or closed by means of a right and left horizontal screw T, turned in corresponding right and left female screws in the jaws H H, said screw being prevented from changing its position longitudinally by attaching it to the head of a post U, inserted into the carriage I by a suitable neck V, formed in the middle of the screw between the right and left threads, said neck turning in a corresponding box fixed in the head of the post U. By turning this screw the jaws will be moved simultaneously in opposite directions.

When a nut is required to be made, the piece of iron W to form the same must be held between the jaws H H instead of the rod, and a tap X with a T-head such as that represented at Fig. 3254 must be placed between the dies; then, by inserting the tapered end of the tap into the hole in the centre of the piece of iron to form the nut, and turning the crank-axle G, the thread will be cut by the said tap.

The frame C containing the cog-wheel and pinion may be made to revolve horizontally on a pivot or centre, and the cog-wheel may be made the driver and the pinion the carrier of the cutting tools and dies, especially in cutting screws of small diameter where speed is required.

SCREW FINISHER—WHIPPLE'S *patent*. (We copy from his specification.) The cutter or chaser, by means of which the threads are to be cut, is the same in all respects with that described and claimed by me in the specification of Letters Patent for a machine for cutting the threads upon wood screws, granted to me under date of the 18th of August, in the year 1842; but the combination and arrangement of the other parts of the machinery which I am now about to describe, differ essentially from that which was the subject of the patent above referred to.

Fig. 3255 is a front elevation of such a machine.

Fig. 3256 is a view of the right-hand end thereof.

Fig. 3257 is the top view, with the omission of certain parts shown fully in the next figure.

Fig. 3258 is the top view of the apparatus, into which the blanks that are to be cut are to be fed, and by which they are successively presented to the action of the tool for cutting the thread: most of the operating parts shown in this figure are omitted in each of the others.

The other figures represent parts in detail which could not be otherwise fully shown. In each of these figures, where the same parts are shown, they are designated by the same letters of reference.

A A is the frame-work of the machine, which may be of cast-iron. The part A′ is a circular horizontal table, upon which is sustained a movable zone or ring I I′, and the apparatus by which it is governed in its motion, these parts being distinctly shown in Fig. 3258. The zone or ring I I′ rests loosely upon the horizontal table A′, and is kept in place by means of a projecting circular rim N, Fig. 3258, attached to, or in one piece with the circular table A′. The outer portion I of the ring has on its periphery a series of tubes *a a* into which the blanks are to be fed; these tubes are countersunk at the upper ends so as to adapt them to the heads of the blanks, and below the countersunk part a portion of each tube is cut away, as shown at *a′ a′*, to admit the end of the cutter or chaser. The blank which is being cut is made to revolve within its tube by means of a revolving screw-driver, which takes into the nick on its head, and is operated in a manner to be presently described.

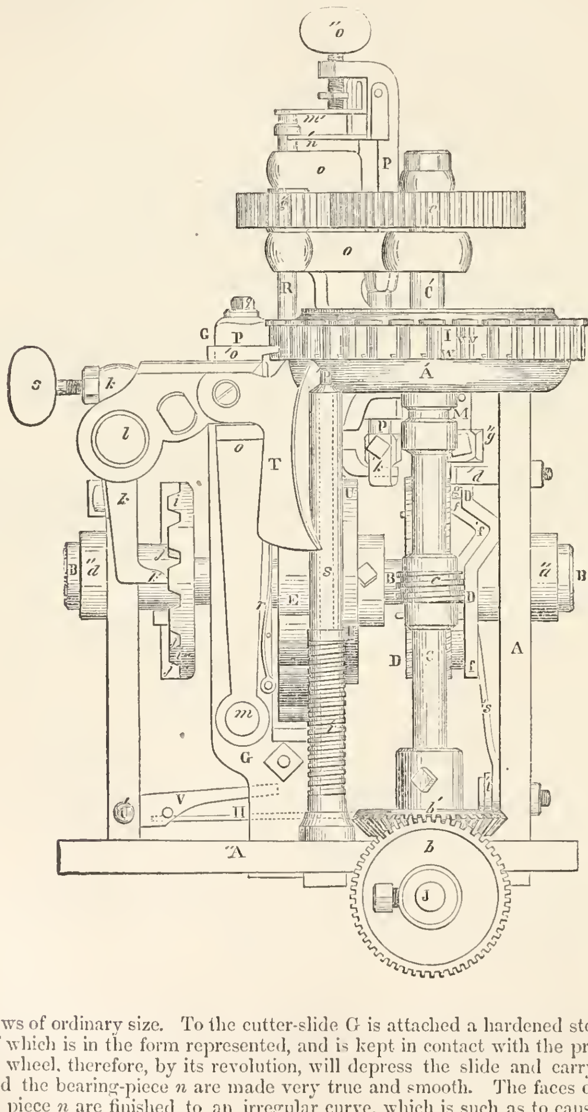
J J is the horizontal shaft, which may be connected with the first mover for the purpose of driving the machine; on this shaft there is a bevel-wheel *b* which geers into the bevel wheel *b′*, on the vertical shaft C. On this latter shaft there is an endless screw or worm *c* that mashes into a worm wheel D D on the main horizontal shaft B B_1 to which it consequently gives motion, this shaft runs into boxes *a″ a″* attached to the frame. The shaft C passes up through the table A′, in which it has its upper bearing; its continuation is seen at C″, and to its upper end is affixed the spur wheel *e′*, which, geering into the wheel *g′* on a shaft R, which is that which carries the screw-driver, gives motion thereto.

G G, shown in detail in Fig. 3261, is a bar which I will call the vertical cutter slide; this may be rectangular, and it passes through mortises in the bed A″ and in the upper part A‴, Fig. 3256, of the frame: in these it slides up and down freely as the thread is chased by the cutter. The cutter is not attached directly to the bar G, but to the upper end of a lever *o o* which works on a fulcrum pin *m*, by which it is connected to said bar; the lever *o* allows the cutter to move laterally to and from the blank to be cut; the head o′ of this lever is widened out for the purpose of sustaining the cutter, which is shown in place at *x x*, Figs. 3257 and 3264.

This is held in place by the cap P, which has a curved groove on its under side to receive it, the screw *q* pressing through said cap into the head *o′* of the lever; *r* is a steel spring that bears against the inner side of the lever *o*, serving to force it back when not pressed up by the apparatus by which the cutter is made to operate on the blanks, which I will now describe.

E, shown most distinctly in Figs. 3255 and 3256, is a cam-wheel made fast on the main horizontal shaft B. The periphery of this wheel is divided into fourteen equal parts, and is cut so as to have on it thirteen tooth-like projections *d d d′*, Fig. 3256, the part *d′* occupying two of the fourteen divisions, leaving twelve, *d d*, equal in size. Each of these projections operates as a cam in causing the cutter to operate on a blank; the number of equal projections determines the number of times that each blank shall be acted on by the cutter, and this number may be varied, but that which I have given is found

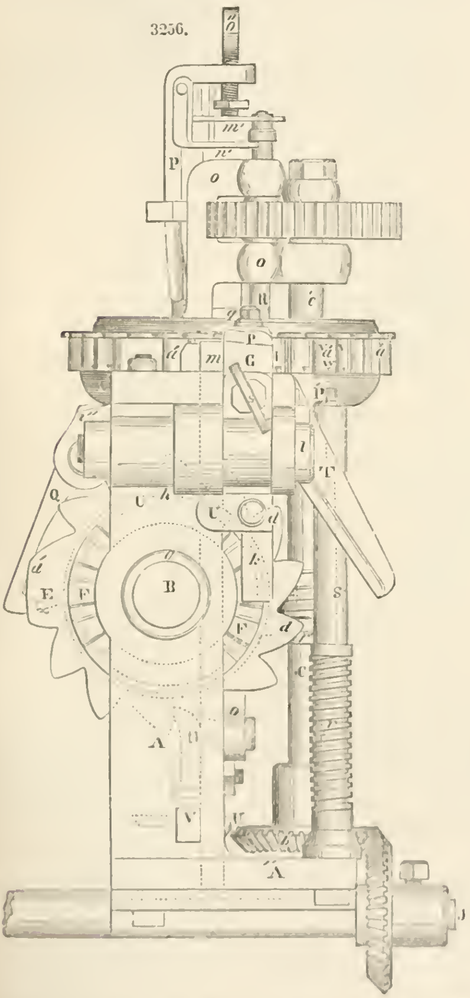
3255.



sufficient for screws of ordinary size. To the cutter-slide G is attached a hardened steel bearing-piece *n*, the upper end of which is in the form represented, and is kept in contact with the projections *d d* of the cam-wheel; this wheel, therefore, by its revolution, will depress the slide and carry the cutter down: the cam-teeth and the bearing-piece *n* are made very true and smooth. The faces of the projections *d* which act on the piece *n* are finished to an irregular curve, which is such as to cause the direct downward motion of the slide to be equal in equal periods of time, the motion of the wheel being uniform. The slide G is raised in the following manner, after each descent: H is a steel spring, shown most plainly in Fig. 3255, which presses on a lifting-piece V that works on a joint-pin U′, and bears against a pin on the back side of the slide G. At the time when this lifting is effected, the cutter is drawn off from the blank by the action of the gage-wheel F and its appendages.

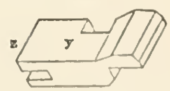
F, Figs. 3255 and 3256, is what I call the gage-wheel, which is affixed to the horizontal shaft B; this wheel has a projecting rim *i i* on its face, like a crown-wheel, which is divided into a number of parts corresponding with those of the projections on the cam-wheel, there being thirteen recesses or notches *i j*, twelve of which are of one size, whilst the other *j'* corresponds with the projection *d* on the cam-wheel. The gage-wheel F is intended to regulate the feed of the cutter in its successive actions on the blank; under the arrangement described the cutter will, as before remarked, operate twelve times in forming the thread of each screw, the operation on each being completed by one revolution of the shaft B. The cutter is forced up against the blank in the following manner: K' is a lever which works on a fulcrum-pin *l*, and the end K' of which bears upon the face of the projecting rim *i i* of the gage-wheel during the time that the cutter is operating upon the blank, when the point K is, by the revolution of the wheel F, brought opposite to one of the recesses *j*, the lever *o* with its cutter is passed back by the action of the spring *r*, and at the same instant the piece *n* falls into one of the notches on the cam-wheel, the slide G rising, consequently, to its original elevation. The lever *k* advances the cutter against a

3256.



3258.

3259.



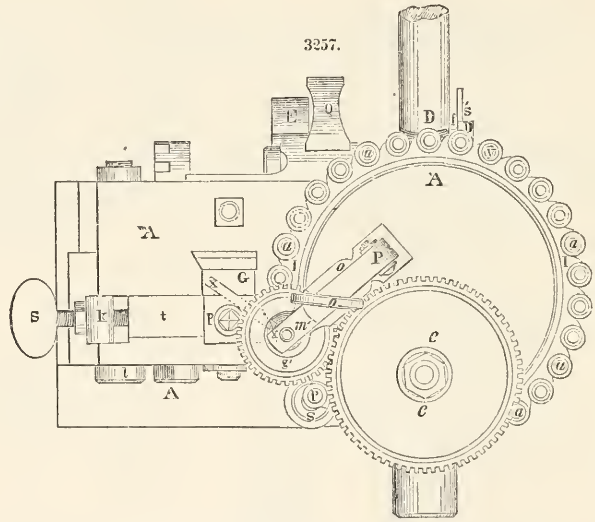
3260.

3261.

blank by bearing against a sliding piece *t*, which bearing is regulated by means of a thumb-screw *s*. Every successive cut of the tool must, of course, be to a greater depth than that which preceded it, and this is effected in the following manner: the face of the projecting rim *i i* of the wheel F is not in a vertical plane, but each projecting portion rises by a regular inclination beyond that which preceded it, which rise amounts, in machines intended for cutting ordinary ¾ inch screws, to about one tenth of an inch in its whole circumference. By this manner of forming the gage-wheel is also obtained the right taper on the screw. T is a conductor down which the chips pass from the cutter.

When the cutting of a screw is to be commenced, the screw-driver must be forced down so as to enter the nick on the blank, and when it has been completed it must be raised therefrom, and the zone or ring I I' must be moved so far round as to bring another blank into the proper situation for the action of the cutter. The apparatus for depressing and raising the screw-driver is as follows: on one side of the cam-wheel E there is attached a broad rim or hoop $v\,v$, Fig. 3255, and the situation of which is indicated also by the dotted lines V V, Fig. 3256; this hoop is continuous for about 10-11ths of a circle, about 1-11th of it being removed, as at the part h. The outer surface of it is made perfectly true and smooth, and there bears on it one end of a crooked lever Q, which is shown separately in Fig. 3263; its end Q is that which bears on the hoop U U; it has a fulcrum-pin at Q″. K″ is a pin attached to the upper end of this lever, which pins enter a notch or opening in a piece k', to which is attached the vertical sliding-rod P that makes a part of the sliding-frame P P, Fig. 3256, which frame sustains the shaft of the screw-driver: when, by the revolution of the cam-wheel, the end Q′ of the lever Q is brought opposite to the opening h in the hoop U U it falls into it, and the sliding-frame P with the screw-driver attached to it is raised; the lever Q is kept in contact with the hoop U U by the action of a spring l' that bears against it, and is attached to the circular table A′. The passing of the end of the lever Q into the recess in the hoop U occurs at the moment that a screw has been finished. R, Figs. 3255 and 3256, is the shaft of the screw-driver; this shaft passes through and revolves within in the arms O O, Fig. 3256, making a part of the stationary screw-driver frame. By means of a feather the shaft R slides freely up and down through the wheel g', which is driven by the wheel e. O, Fig. 3258, is the bottom plate or basis of the frame O O, which is fastened on to the top of the circular table A by screws, as at $f''\,f''$. The upper end of the shaft R is connected to the sliding-frame P by the springs $m'\,n'$, Fig. 3256. The lowermost of these springs serves to lift it, and the upper one, by means of the thumb-screw o'', serves to adjust it to the different thicknesses of the heads of the blanks, the shaft R is depressed, and the screw-driver kept in contact with the blank by the bearing of the lever Q on the hoop U U.

3257.



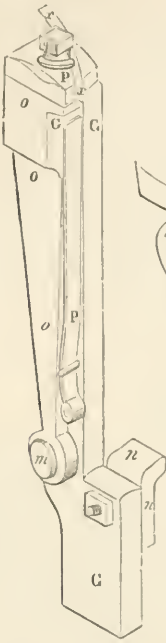
The removing of the finished screw from the tubes a is effected by the aid of the same hoop U that is concerned in the depressing and raising of the screw-driver. S, Figs. 3255 and 3256, is a stationary tubular rod placed vertically, which receives within it a small sliding-rod p'; there is a slot along the rod S, and a small arm r'' attached to the sliding-rod p' passes through this slot and bears upon the periphery of the hoop U until it arrives at the opening h; whilst it bears on the hoop the rod p' is depressed, but when it enters the opening h the spiral spring r' forces the rod p' up, which, passing into the tube containing the last but one finished screw, removes it, and it falls into a receiver.

The apparatus used for causing the zone or ring I I′ to revolve and carry a blank to the distance necessary to its being operated on by the cutter, is shown in Figs. 3255, 3258, 3259, 3260, 3261, and 3262 One side of the worm-wheel D D is widened out, so as to leave a guide-groove $f\,f\,f'$ formed upon it· this groove passes uniformly round the wheel, excepting at the point f', Fig. 3255, where it forms an angle, as represented. This groove receives the pin g which constitutes the end of a short arm g'', seen separately in Fig. 3262; from this arm a shaft M rises vertically and passes through the circular table A′, and is firmly attached to an arm or lever K which rests on the top of the table, as seen in Fig. 3258; the piece K is shown separately in Fig. 3261, and the part of it to which the shaft M is attached is represented by dotted lines in Fig. 3258. Whilst the pin g remains in the direct part of the groove $f\,f$, the piece K remains stationary, but where it enters the angular part f' the shaft M is made to revolve partially back and forth, and carries with it the piece K. The arm g'' is situated below the table A′; the shaft M to which it is attached has its step in the stud d'. To cause the pin g to pass readily back into the straight part of the groove f, a spring s', the lower end of which is seen in Fig. 3255, is made to bear against said pin, as shown in Fig. 3262. The finger V on the piece K draws back the bolt y, Fig. 3258, seen separately in Fig. 3259, so as to relieve it from one of a series of notches on the interior edge of the ring I I′. These notches $x'\,x''$, &c., correspond in number and position with the tubes for the blanks, and it will be manifest that the bolt y, when inserted in one of these notches, will keep the ring stationary. The bolt y is forced into the notches by means of a spiral spring z, acting against the plate O

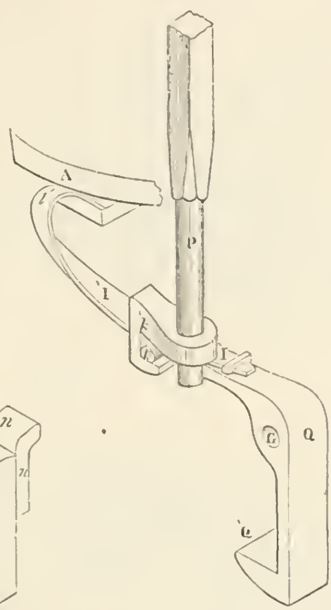
To the piece K is also connected the feed-hand L by a joint-pin a'''; this feed-hand carries the ring I I′ round to the requisite distance. The steel spring b''', which has a bearing on the pin c', serves to throw the feed-arm forward to the proper position to bear against the angle of one of the notches, as seen at x'''

In describing the various parts of this machine, I have also shown the manner in which they are intended to operate, but I will now give a general view of the action of the whole. The tubes *a a* in the horizontal ring I I′ are to be kept supplied with blanks, which are to be fed in by hand. Immediately preceding the first operation of the cutter on a blank, the lever Q will have occupied the recess *h* in the hoop U on the cam-wheel, and the lever K the recess j' in the gage-wheel; and the machine being in motion, the cutter-slide G G will be raised by the action of the spring H on the joint-piece *u*.

3264.



3263.



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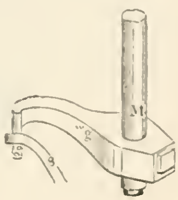


At the commencement of the ascent of the cutter-slide, the cutter will be thrown back by the action of the spring *r* on the lever *o*. During this period of time the revolving of the hoop U on the cam-wheel will bring the end of the lever Q, which had occupied the recess *h*, in contact with said hoop, on the periphery of which it will rise, thereby lowering the screw-driver, when the screw-driver will enter the nick on the blank, which it will cause to revolve rapidly; the lever K also at the proper instant will leave the recess on the gage-wheel and bear on a projecting part of its rim, bringing the cutter into contact with the blank. That one of the tooth-like projections on the cam-wheel, which is next to the double one, will at the same time be in contact with the steel bearing-piece *n*, and the cutter will be thereby caused to make its first cut, which being succeeded by the action of the remaining cam-teeth, completes the screw.

At the time of the completion of the screw last cut, the revolution of the cam-wheel will have brought the hoop U into the position in which the end of the lever Q will enter the recess *h*, and the screw-driver will be lifted.

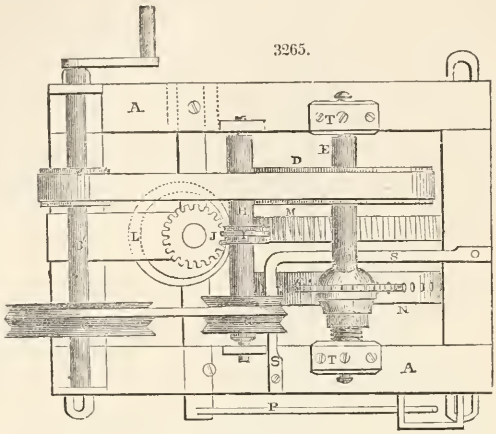
At this time the cutter will have been withdrawn from the screw, and the point *g* of the arm g'', traversing in the guide groove *f f* of the worm-wheel, will have attained its greatest variation from its direct course in the angular part of the said groove f'', in passing and returning along which it will have given the revolving motion to the shaft M necessary to the operation of the parts concerned in the shifting of the ring I I′ one notch, in the manner above described, which will bring a fresh blank into a situation to be operated on by the cutter, and will also bring the cut screw directly over the rod p'. This screw will be removed by the passing of the small arm r'' into the recess *h* by the revolution of the hoop U, which will leave the rod p' free to rise by the action of the spiral spring r'.

SCREWS—MACHINE FOR NICKING. By H. L. Pierson. In this machine the blanks or screws to be nicked are fed or placed in holes made radially in the periphery of a carrying-wheel composed of two plates, the holes being made at the junction of the two plates, and by the rotation of this wheel they are carried up to and passed under a cutter that forms the nick; they are griped and held tight during that operation, and then, by the further rotation of the wheel, are liberated and discharged. The nature of this invention consists in griping the blanks in recesses made radially in the face of a wheel by making pressure on one or both sides as the wheel rotates, so that the blanks may be dropped into the holes or recesses with their heads outwards, and griped while passing under the nicking cutter, and then, by the further rotation of the wheel, liberated that they may be discharged.

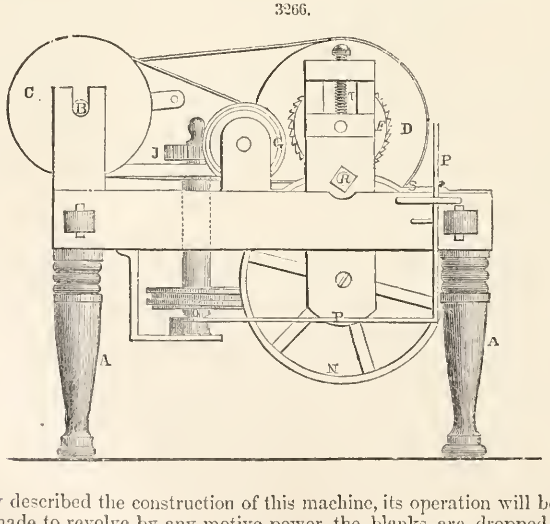
In Figs. 3265 and 3266 A A is the frame-work of the machine. B is a shaft to which the driving power is applied, upon which there are two pulleys C C, with bands for driving the different parts of the machinery. D is a whirl on the shaft E, which carries the circular cutter F, by which the screws are to be nicked. A band from the whirl C drives the whirl G on the shaft H, upon which there is an endless screw or worm I, which takes into a pinion J, upon the upper end of a vertical shaft, the lower end of which runs into a bridge-tree or shifting-bar, the end of which is shown at K, Fig. 3266. This shaft carries an endless screw or worm L, which takes into and drives the toothed wheel M, Fig. 3265, which toothed wheel is on the same shaft with that of N for holding the blanks; the lower end O of the vertical shaft being seen in Fig. 3266; the connecting-rod P acting upon the bridge-tree or shifting-bar K.

The blank-wheel N is in two parts, divided through its plane, as shown by the line along its periphery; one of these parts is fixed firmly on its axle, whilst the other part slides upon a square eye, or otherwise, upon the axle, and is capable therefore of receding from the fixed part, although it revolves with it. The periphery of this wheel is perforated with holes at the junction of its two parts, as shown in the figures, which holes are of such size as to receive and hold the blanks which are to be nicked. To cause the two portions of this wheel to grip the blank while it is being nicked, there is a friction roller which bears against the outer edge of the periphery of the movable part, immediately under the circular cutter. The dotted lines Q, Fig. 3265, mark its situation, which is opposite to the screw-nut R, Fig. 3266, which confines the friction-wheel box in its place. To react against this friction roller, a similar one is placed opposite to it, and bears upon the fixed portion of the blank-wheel; the bar S is to sustain this friction-wheel. The shaft which carries the saw is raised or lowered by means of the adjusting screws T T, and by this means the depth of the nick is perfectly regulated.

3265.



3266.

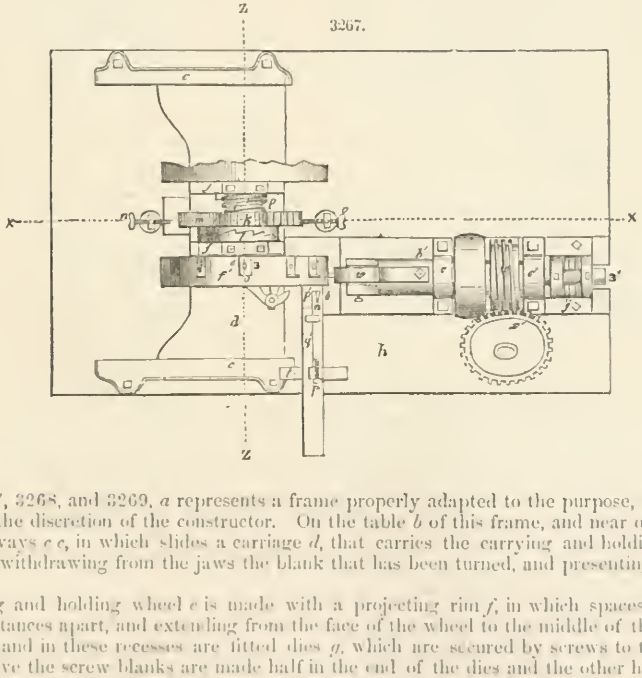


Having thus fully described the construction of this machine, its operation will be readily understood. The shaft B being made to revolve by any motive power, the blanks are dropped into the holes in the blank-wheel N as it approaches the cutter, and are held firmly whilst being cut by the pressure of the friction rollers; and being released from this pressure, they fall out by their own gravity as they are carried round to the lower part of the machine.

It will be obvious from the foregoing, that instead of having one part of the wheel firmly attached to the shaft, that both parts may be loose thereon provided they are so connected with it as to be carried around by its rotation, and admit of being pressed together to grip the blanks firmly while passing under the operation of the cutter to be nicked, whether this cutter be a rotating cutter or any other kind of instrument for this purpose, although the rotating cutter is deemed to be the best. Instead of the rollers to press together the two parts of the carrying-wheel, checks may be substituted, but with less advantage on account of the friction of the rubbing surfaces; and instead of making use of two rollers, the one that bears against the face of the permanent part of the wheel may be dispensed with by making this part of the wheel very strong, and the shaft to run in firm bearings that will afford sufficient strength to resist the pressure required to grip the blanks firmly while being nicked. It will also be obvious that the two parts of the wheel may be kept apart for the free reception and delivery of the blanks either by a boss or shoulder on the shaft, or by the introduction of something between them, or by any other equivalent means; although a projection boss, or shoulder on the shaft, is the simplest and most effective.

SCREWS, MACHINE FOR SHAVING AND TURNING. Crum & Pierson's patent. The nature of the first part of this invention or improvement in the before-mentioned machine consists in giving to the frame or carriage that carries the carrying and holding wheel (sometimes misnamed the feeding-wheel) an intermittent reciprocating motion to withdraw the turned blank and insert the points of others in the jaws, in succession, instead of giving an endwise motion to the mandrel for this purpose as heretofore; and also in giving to the carrying-wheel an intermittent rotary motion to present a new blank to the jaws preparatory to the insertion of the same into the jaws by the motion of the carriage. And the second part of this invention consists in shaving the under and upper surface of the heads, within the rim of the carrying and holding wheel, by means of a tool properly adapted to the purpose, which is attached to the end of a vibrating tool-holder, that receives its appropriate motions at right angles to the axes of the blank from a cam on the main-shaft.

3267.

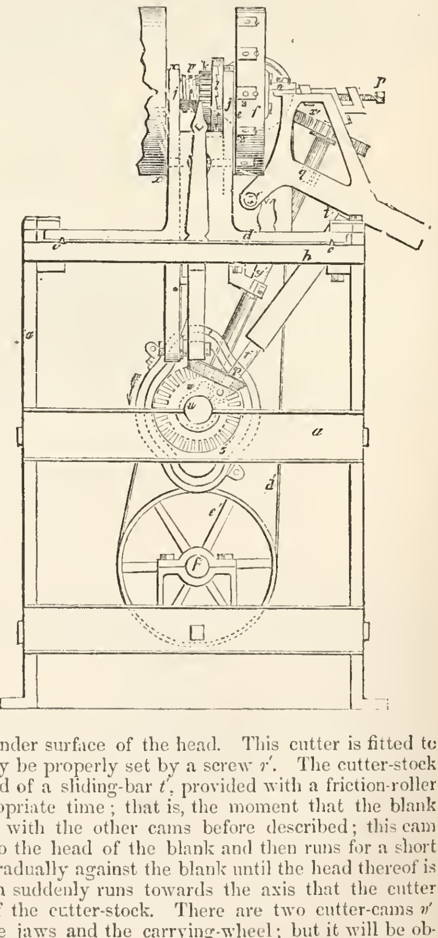


In Figs. 3267, 3268, and 3269, *a* represents a frame properly adapted to the purpose, but which may be changed at the discretion of the constructor. On the table *b* of this frame, and near one end thereof, there are two ways *c c*, in which slides a carriage *d*, that carries the carrying and holding wheel *e*, for the purpose of withdrawing from the jaws the blank that has been turned, and presenting a new one to the jaws.

The carrying and holding wheel *e* is made with a projecting rim *f*, in which spaces are cut out at equal given distances apart, and extending from the face of the wheel to the middle of the width of the projecting rim, and in these recesses are fitted dies *g*, which are secured by screws to the wheel—the holes that receive the screw blanks are made half in the end of the dies and the other half in the edge of the recesses, so that by sliding the dies the holes can be adapted to different sizes of screw blanks. The wheel thus formed is hung on the end of a shaft *i*, which turns in standards *jj* of the carriage *d*, and it is turned the distance required at each operation by a clutch wheel *l*, one half of which is attached permanently to the shaft, and the other to a cog wheel K, that turns freely on the shaft, the cogs of the wheel K engaging with a rack M, that slides freely in the standards of the carriage, so that when the carriage is moved back from the jaws during the operation of the machine, the end of the rack strikes against the end of a set screw N attached to the frame which slides the rack and turns the carrying-wheel the required distance to take the turned blank from the jaws and present another to be turned; and on the return motion of the carriage the other end of the rack strikes against another set screw *o*, which forces it back, and also the cog-wheel and that half of the clutch-wheel attached to it, the form of the clutch-cogs being such as to permit the two halves to turn in that direction independently of one another, the movable half being forced towards the other by the tension of a helical spring *p* on the shaft.

The blanks are fed into the holes of the carrying wheel *e* by hand, with the heads inwards, and the required motions are given to the wheel in the following manner. An elbow lever *q*, which turns on a fulcrum-pin *r*, has the end of one arm working in a slot *s* of the carriage *d*, while the end of the other arm is provided with a roller or wrist which runs in a cam-groove *t*, made in the face of a plate *u*, on a shaft *v*, that makes half a revolution for each complete operation; that is, for every blank that is introduced, turned and discharged; and the cam-groove is formed so that from the point 1 to 2, in the direction the reverse of the arrow, it runs out of the circle to move the carriage, and with it the carrying-wheel from the jaws *w*, to remove a blank that has had the head turned; and from the point 2 to 3, in the same direction, the groove runs towards the shaft by a curve the reverse of that from 1 to 2, for the purpose of moving the carrying-wheel towards the jaws to present a new blank, the previous motion of the carriage from the jaws having turned the carrying-wheel a distance equal to a space between two of the holes in the dies to present a new blank, and then from the point 3 to 4 the groove is concentric to hold the carrying-wheel in the same position while the head of a blank is being turned. The other half of the cam-groove is similar to the one described to repeat the operation. So soon as the carrying-wheel has completed its motion towards the jaws and while that part of the cam-groove from the point 3 to 4 is passing over the end of the lever *q*, the carrying-wheel is held firmly in that position to hold the blank firmly while it is being rotated by the jaws and acted on by the cutter; and this is done by the point of a follower *x*, that is forced by a helical spring around it to enter one of the series of holes *y* in the face of the wheel, and preparatory to turning the wheel to shift a blank, a cam *z* on the periphery of the cam-plate *u* forces up a sliding wedge-piece *a′*, that acts on a follower *x*, to force it back out of the hole in the wheel, and the moment that the cam passes the follower *x* is in a condition to be forced by the tension of the spring into the next hole when the wheel is turned round to present another blank to the jaws.

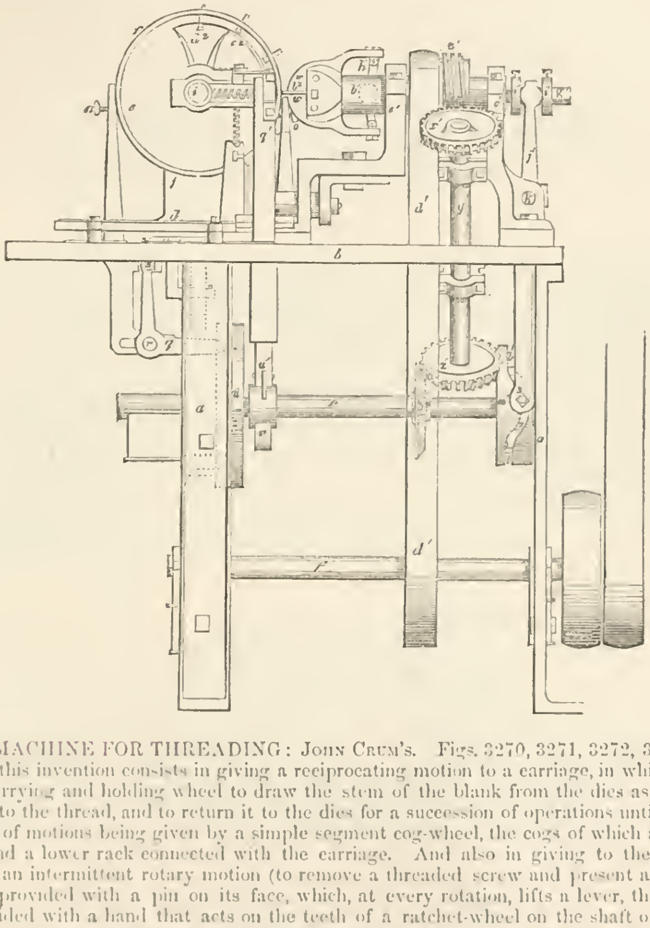
3268.



The screw-blanks thus presented are caught, gripped, and rotated by the pair of jaws *w*, that are jointed to the end of an arbor or mandrel *b′*, which runs in standards or puppets *c′ c′*, and rotated by a belt *d′* from a pulley *e′* on the driving-shaft *f′*. This mandrel is hollow, and within it there is a sliding-rod *g′*, one end of which is jointed by links *h′ h′* with the levers of the jaws, and the other end projects out beyond the back of the mandrel, and is there provided with two collars *i′ i′*, that embrace the forked end of a lever *j′* that turns on a fulcrum-pin *k′*, the other end being provided with a roller or wrist that runs in a cam-groove *l′* in the periphery of a wheel *m′* on the shaft of the cam that operates the carrying-wheel. The form of this cam-groove is such that from the point 1 to 2 it runs by a sudden curve to the left to open the jaws just as the carrying-wheel begins to move from the jaws to draw out the blank that has been turned; from 2 to 3 for a short distance it runs in the direction of the periphery to give time for the carrying-wheel to present a new blank, and then from the point 3 to 4 it runs by a curve the reverse of the one from 1 to 2, to close the jaws and grip the end of a blank, and then the groove runs in the direction of the periphery to complete half the circumference from the point 1, the groove for the other half of the circumference being a repetition of the first half to repeat the operation. It will be obvious from the foregoing and the figures that the sliding of the rod in the mandrel by its connections will open and close the jaws. So soon as the blank has been presented and gripped the cutter *n′* is moved up. The cutting edge of this cutter is somewhat in a Λ form, the edge *o′* being nearly at right angles with the axis of the screw-blank to turn the top of the head, and the other edge *v′* forming the required angle therewith to turn the under surface of the head. This cutter is fitted to a stock *q′*, and slides therein that its cutting edge may be properly set by a screw *r′*. The cutter-stock turns on a fulcrum-pin *s′* and it rests on the upper end of a sliding-bar *t′*, provided with a friction-roller *u′* at the lower end, which is acted upon at the appropriate time; that is, the moment that the blank is griped by the jaws, by a cam *v′* on the same shaft with the other cams before described; this cam suddenly runs out from the axis to carry the cutter to the head of the blank and then runs for a short distance by a slight eccentricity to force the cutter gradually against the blank until the head thereof is sufficiently reduced or turned, at which point the cam suddenly runs towards the axis that the cutter may be drawn back from the blank by the weight of the cutter-stock. There are two cutter-cams *v′* to correspond with the double cams for operating the jaws and the carrying-wheel; but it will be obvious that by doubling the motion of this cam-shaft relatively to the motions of the other parts of the machine, that the cams may be single. The cam-shaft receives its motions from the mandrel by an endless-screw *w′* on the latter, which actuates a spur-wheel *x′* on one end of a shaft *y′*, the other end of which has a bevel cog-wheel *z′*, the cogs of which take into the cogs of a similar wheel a^2 on the cam shaft, shown by dotted lines. As stated before, the screw-blanks are placed in the carrying-wheel, and carried up by its rotation, and when presented to the gripping-jaws the point is forced against a stop within the jaws by the motion of the carrying-wheel. And after being turned, the further motion of the wheel carries them up, their heads resting on to a curved rest c^2, which is so curved at d^2 as to permit them to fall out by their weight so soon as they reach the top.

By doubling the length of the carriage, and putting another carrying-wheel on the other end of the shaft, as represented in Figs. 3267 and 3268, and putting up a duplicate of the mandrel, gripping-jaws, and cutting tools, with their connections, the cam-shaft and cams will answer for two machines, with the exception of the cutter-cams, which must also be doubled to avoid complexity; but even these may be dispensed with by changing the form of the cutter-stock and the slide that communicates motion to it from the cutter-cam.

3269.

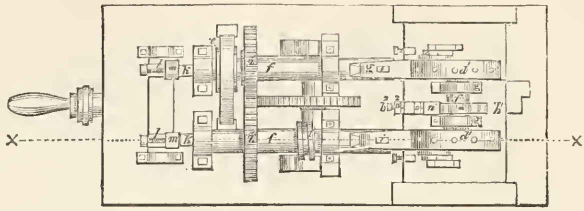


SCREWS, MACHINE FOR THREADING: John Crum's. Figs. 3270, 3271, 3272, 3273, and 3274. The nature of this invention consists in giving a reciprocating motion to a carriage, in which is hung the shaft of the carrying and holding wheel to draw the stem of the blank from the dies as they rotate to give the pitch to the thread, and to return it to the dies for a succession of operations until the thread is cut, this series of motions being given by a simple segment cog-wheel, the cogs of which act alternately on an upper and a lower rack connected with the carriage. And also in giving to the carrying and holding wheel an intermittent rotary motion (to remove a threaded screw and present a blank) from a wheel below, provided with a pin on its face, which, at every rotation, lifts a lever, the upper end of which is provided with a hand that acts on the teeth of a ratchet-wheel on the shaft of the carrying-wheel to turn it the required distance for the presentation of a blank, the wheel that carries the lifting-pin being turned a part of a revolution for each cut of the dies by an arm on the shaft of the cam that closes the dies; the number of teeth or pins on the wheel that are to be struck by the arm on the crank-shaft being such for each pin on the other face of the wheel, as to correspond with the number of cuts to be given by the dies for the completion of the thread of the screw.

The nature of this invention also consists in holding the blanks while under the operation of the dies by the pressure of a spring-roller within the rim. And the last part of this invention consists in closing the dies for the cutting of the threads by means of a cam, which makes one revolution for each cut, and acts by means of a sliding-rod on a lever that forces a rod in the hollow arbor of the jaws to close them when this is combined with a sliding wedge-piece interposed between the sliding rod and the lever to increase the depth of the cut at each operation, the said wedge-piece being made to slide for this purpose by means of another cam combined therewith.

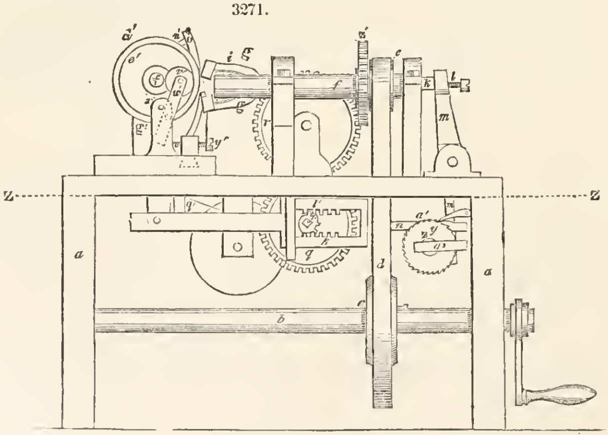
In the accompanying figures, *a* represents a frame, properly adapted to the purpose, and *b* the main driving-shaft with a pulley *c*, from which a belt *d* passes to a pulley *e* on a hollow mandrel *f* that carries the jaws *g g*, in which are secured dies or chasers *h h* made in the usual manner. The jaws are jointed to ears *i i* on the end of the mandrel with springs *j j* interposed, that tend constantly to keep the jaws open, and the rear end of the levers pass into the mandrel and are then acted on to force the dies together in threading the screw by the conical end of the rod K, that slides within the mandrel. The rear end of this rod passes out of the mandrel and is acted on when the jaws are to be closed by the point of an adjustable screw *l* on the upper end of a lever *m*, the lower arm of the said lever being acted upon by a sliding-rod *n* that bears against the face of a cam *o* on a transverse shaft *p*. The form of this cam is such that from the point 1 to 2, extending one-half of the circumference, it is concentric; at the point 2 it suddenly runs out from the centre to close the jaws, and therefore to make the dies grasp the shank of the blank, and then from this sudden swell to the point 3 it gradually runs out from the centre to increase the bight of the dies, and then by a radial line it runs back to the point of beginning, to permit the springs to force open the jaws that the screw-blank may be run back for a repetition of the operation. This cam receives its motions from the mandrel by a train of cog-wheels *q r s*, the one *q* being on the shaft of the cam and engaging with the cogs of the one *r*, which is on the shaft of the

3270.



wheel *s* that is actuated by an endless screw *t* on the mandrel. Between the lower arm of the lever *m* and the sliding-rod *n* there is interposed a wedge-formed slide *n'* placed at right angles with the sliding-rod *n*. The end *v* of this slide is forced by a spring *w* against the face of a series of cam-formed projections *x* on the face of a wheel *y* on a shaft *z*, the periphery of the said wheel being provided with teeth *a'*, which strike against a pawl or hand *b'* jointed to the main frame, the shaft of the said wheel *y* having its bearings in a frame a^3 attached to and moved by the lever *m*, so that at every back motion of the lower end of this lever to open the jaws the wheel *y* is turned a portion of a revolution, that the cam-formed projections *x* may act on the end of the wedge-formed slide and force it back, and thus cause the threading-cam at each operation to close the cutting-dies more, and in this way complete the cutting of the thread by a series of operations. The cam-formed projections *x* are as series of planes inclined to the plane of the face of the wheel from which they project, and the length of each is such, relatively to their motion, as that each shall move its whole length for the complete cutting of one screw; and of course the number of these cam-formed projections will depend on the diameter of the wheel to which they are attached and to the extent of the motion of the said wheel.

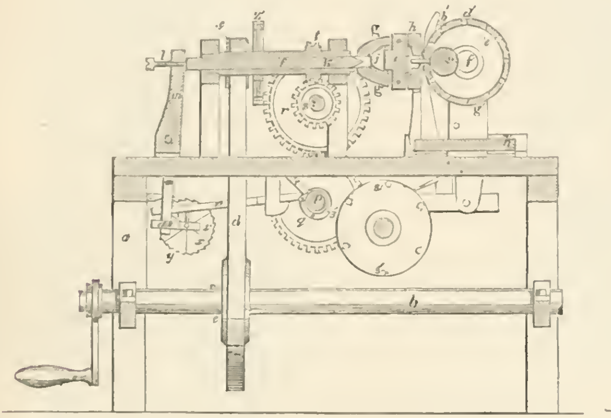
3271.



The screw-blanks *c'* are inserted in holes in the rim *d'* of what is called the carrying and holding wheel *e'*, the rim being made to project from the face of the wheel sufficiently for this purpose. The shaft *f'* of this wheel runs in standards *g'* of a carriage *h'* that runs on ways *i' i'*, and this carriage receives a reciprocating motion to move the blank towards and from the chasers or dies by a segment cog-wheel *j'* on the shaft of the threading-cam. The cogs extend over a little less than one-half of the circumference, and alternately act on the teeth of a lower rack *k'* to move the carrying-wheel towards the cutting-dies, and then on the cogs of an upper rack *l'* to run it back to form the thread, the said racks being formed in the opening of a bar attached to the carriage of the carrying-wheel. In this way the motions back and forth of the carriage are given to determine the pitch of the threads and to return the screw for the repetition of the operation.

So soon as a screw has been threaded it must be carried away and a blank presented to the dies. This is done in the following manner: On the shaft of the carrying-wheel there is a ratchet-wheel *m'*, which is turned by a hand *n'* on the end of a lever *o'* that turns on a fulcrum at *p'*; the lower arm is bent as at q', so that when lifted the hand on the upper end turns the ratchet-wheel, and with it the carrying-wheel, the required distance to carry off the threaded blank and present a new one. The lever is operated in the following manner: On the threading-cam shaft there is an arm r' which, at every rotation of the shaft, strikes one of a series of pins s' projecting from a wheel t' to turn it a distance equal to the space between the centres of any two of these pins, and on the other face of this wheel there is a pin u' which, at every entire revolution of the wheel, strikes under the bent arm of the lever o' and gives it the requisite motion to turn the carrying-wheel. Back of the lever o' there is a standard a^2 with a set-screw b^2, against which the lever strikes when thrown back by the weight of the bent part q', so that by the set of this screw the extent of motion of the lever and the carrying-wheel can be determined. The position of the arm r' on the segment cog-wheel shaft relatively to the segment of cogs should be such that the carrying-wheel will be turned for removing the threaded screw and presenting a blank when the carriage is farthest from the jaws. And the number of pins s' on the wheel t' must be equal to the number of times it is intended that the chasers or dies shall pass over the blank to complete the thread; but if desired this number may be doubled, trebled, &c., by having two, three, &c., pins u' on the other face of the wheel. It is, however, preferred to have it as described. In this way it will be seen that the carrying-wheel carries the blanks towards the jaws and inserts the blank in the open dies and moves it back to form the thread, and that these motions are repeated a given number of times until the thread is completely chased or cut, and that when completed the carrying-wheel is turned far enough around to remove the threaded screw and present a blank to the jaws to undergo the same series of operations.

3273.



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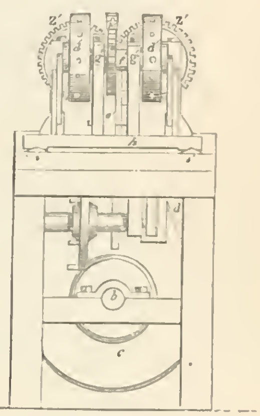
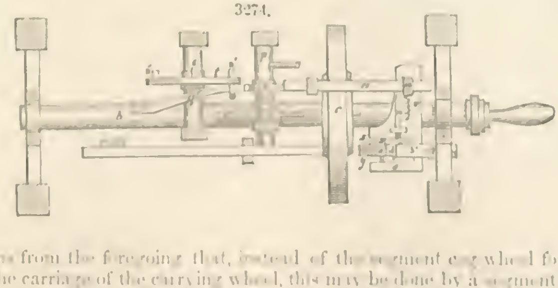


While the screw is being cut or chased it is held in its hole in the rim of the carrying-wheel by means of a roller v' within the rim of the wheel, and turning on a stud-pin at the end of a lever w', which turns on a fulcrum-pin x', the roller being held against the inner periphery of the rim of the wheel by a pressure-screw y' that bears against the lower end of the lever, so that as the blank is carried up by the wheel to be presented to the dies, the pressure of this roller against the head holds it firmly in the rim of the wheel. The machine can be made double for threading two screws at one and the same time, as shown in the figures, by having two carrying-wheels on the same shaft, and two mandrels with their jaws, dies, and sliding-rods, the two mandrels being geered together by two cog-wheels z' z'.

3274.



It will be obvious from the foregoing that, instead of the segment cog-wheel for giving the reciprocating motion to the carriage of the carrying-wheel, this may be done by a segment volute cam, the face of which shall act alternately against the front and back faces of the open space of the bar attached to the carriage, as the object is simply to give a regular reciprocating motion to the carriage, particularly during the operation of threading; for during that operation the motion of the carriage must be regular to give a regular pitch to the thread. As it is only important to give a regular motion to the carriage in the operation of threading, the segment cog or the volute cam need only act in that direction, and the motion to run back the carriage for the presentation of the blank may be given by a separate cam of a more sudden curve, or an arm of greater length to perform the return motion faster, but as these are well-known mechanical equivalents, they are simply named to indicate the various modes in which this part of the invention may be applied.

SCREWING MACHINE FOR BOLTS. Fig. 3275 is a general plan of the machine.

Fig. 3276 is an end view looking upon the frame K, the guide-rods R R and chuck L being removed

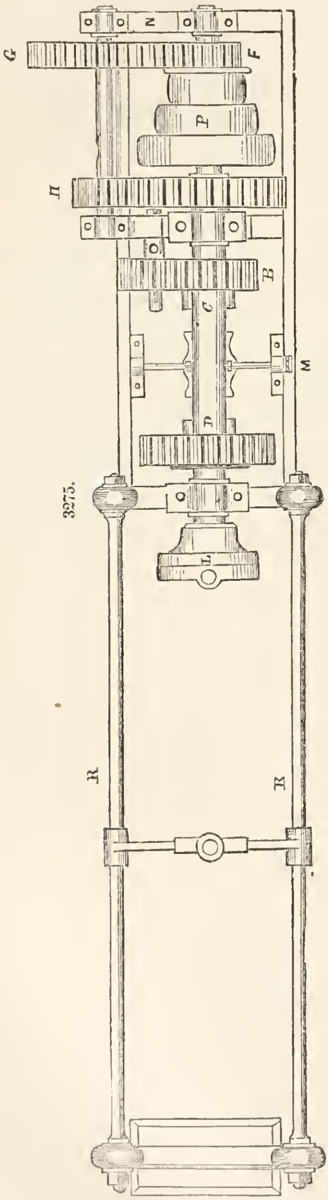
Fig. 3277 is an end view looking upon the frame N.

Fig. 3278 is a general side elevation of the machine corresponding with the plan in Fig. 3275.

Fig. 3279 is a face view of the chuck L, seen also in Figs. 3275 and 3280.

Fig. 3280 is a corresponding front view of the die-frame, which is retained upon the guide-rods R R of the machine by recesses in the projecting ends.

The same letters of reference are used in all the figures.



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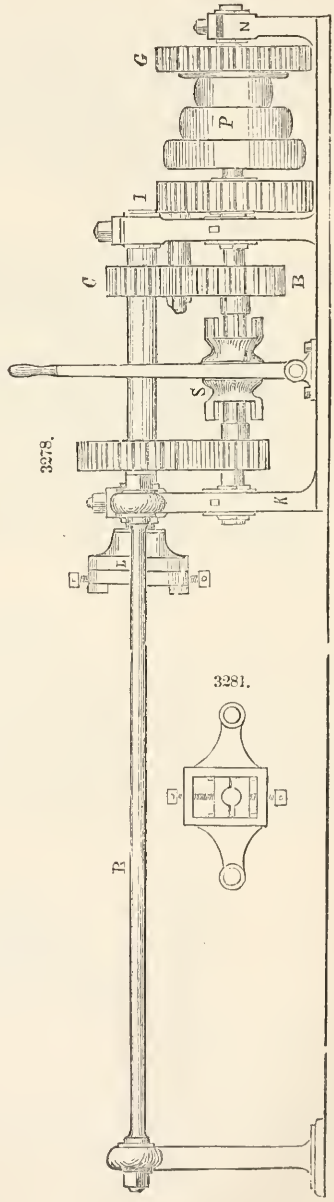


3278.

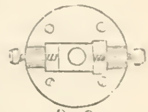
3281.

The head-frame of the machine consists of three pieces fastened to a sole in the usual manner. The forms of the frame-pieces K and N are distinctly shown in the drawings, particularly by Figs. 3276 and 3277. A separate view of the intermediate upright is not given, but it is easy to perceive from

Figs. 3275 and 3277, that it has a projecting piece corresponding to that on the bracket N to carry the spindle of the back-speed wheels G H; and that it has besides a centre-bearing corresponding to that of Fig. 3276, for the end of the main-spindle, on which are the pinion C and wheel D, and which carries the chuck L.

P, the driving-pulleys on the driving-spindle of the machine. This spindle has a bearing at each end, and a bearing also in the middle standard of the frame. The pinion F and wheel I are keyed on the spindle, and geer with the wheel and pinion G and H on a separate spindle, like the back-speed of a lathe. The clutch-wheels A and B are loose on the same spindle which carries the similar pair F and I, so that either of them may be made drivers by means of the clutch S, which slides on the shaft, and is made to turn with it by a sunk feather which connects the clutch and shaft. This clutch is worked by a lever passing to the hand of the operator in the usual manner. The pinion A geers with D on the main-spindle; B geers with a carrier-pinion E, Fig. 3276, which, in its turn, geers with C on the main-spindle.

3279.



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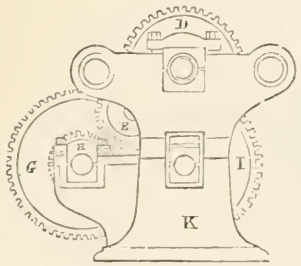

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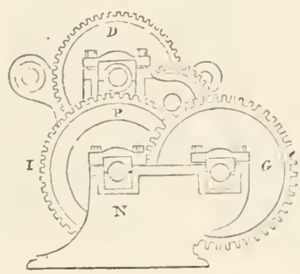

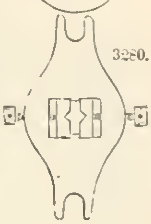

3280.

To explain the action of the machine, suppose the bolt to be centered in the chuck L, and the die-holder, shown by Fig. 3280, to be placed on the guide-rods R R, and brought up so that the end of the bolt just enters the dies; then the clutch being locked with the pinion A, and the machine set in motion, the chuck will be made to revolve, and with it the bolt to be screwed; and meanwhile the die-holder being pressed against the end of the bolt, this will enter them as into a nut and will continue to screw itself into them, and by this means the desired thread will be cut upon its circumference.

The bolt being thus screwed, the next operation is to unscrew it from the die-holder. For this purpose, the clutch is disengaged from the pinion A, and locked with B, which geering with an intermediate pinion E, reverses the motion, and it at the same time increases the speed in proportion to the increase of diameter of B to A.

This form of screwing machine has some advantages, but it is wanting in compactness and simplicity of geering, so much the aim of constructors of engineering tools.

SCREWING MACHINE, DOUBLE—By William Moore, Glasgow. This is one of the most powerful and complete machines of its class. It is capable of cutting the threads of screws of 4½ inches diameter, and, unlike most other machines of the kind. the geering is so adjusted, that both sides of the machine can be employed simultaneously upon bolts and nuts of different sizes.

A A, the two main standards of the machine, are fixed upon a strong cast-iron sole-plate B, which extends the whole length of the machine, and is securely bolted to a stone foundation. Upon these standards all the geering of the machine is mounted. The driving spindle J is placed intermediate to the screwing-spindles E and N, and carries the three-speed cone I, by which motion is communicated to the machine. The spindle J has a bearing in each of the two standards, and carries the fast pinions *a* and *b*, also the wheel U and pinion *d*, which are cast together, but run loose on the spindle. The pinion *a* geers into the two spur-wheels S and F, which are loose upon the two screwing-spindles E and N; and the pinion *b* geers with the spur-wheel K, which is loose upon a spindle L, immediately under the driving-spindle J. The wheel U geers into the wheel R, and the pinion *d* into the wheel O, fast on the screwing-spindle N. The spindle L has its bearings also in the two end standards, and carries, besides the wheel K, another wheel M, which geers with the loose wheel G on the screwing-spindle E; also a fast-pinion *c*, which geers with the fast-wheel P, upon the screwing-spindle N. The wheels K and M are loose on the shaft L, but are both fast upon a common hollow boss, so that motion being communicated to the wheel K, the other, M, will be carried round in the same direction with an equal velocity.

The arrangement of the wheels on the large screwing-spindle N is fully shown by Fig. 3286. This spindle is provided with a hollow boss Q, on which are the fast wheel R and the loose clutch wheel S; this last can be brought into action by the sliding clutch T, upon the same hollow boss Q, and which can be worked from either end of the machine, by the double handle Z Z. The wheels O and P are fast upon the spindle.

The smaller screwing-spindle carries only the two loose clutch wheels G and F, either of which can be brought into action by the sliding clutch H, which is worked by the double handle Y Y. This handle is placed upon a small rocking-shaft *l*, carried on two brackets *m m*, resting upon the sole-plate of the machine, and has the clutch-fork *n* keyed upon it, so that in moving the handle from the vertical position, the clutch will be brought into geer with one of the wheels G F, on the spindle E. The handle Z Z is in like manner fixed upon a cross-shaft *o* carried by the brackets *p p* similarly fixed upon the sole plate; but this shaft, besides the clutch fork *q* for working the clutch T on the hollow boss Q of the screwing-spindle N, has a second fork for working a clutch on the spindle L, to engage and disengage the loose boss of the wheels K and M. But these two clutches are so fixed in relation to each other, that one of them only can be in action at the same time, consequently, when the wheel S is engaged by the clutch T, the wheels K and M must necessarily be loose on the shaft L.

This arrangement of the geering being kept in view, the action of the machine will easily be comprehended. Thus supposing motion to be communicated to the speed-cone I, if the clutches T and H be in geer with the wheels S and F respectively, these wheels will be driven by the pinion *a*, with a speed proportioned to their respective diameters, and in opposite directions. Meantime, the clutch on the under shaft L, being out of action, the wheels K and M will be loose upon it, and the shaft itself will be made to revolve idly by means of the wheel P, which geers with the pinion *c* upon it. The angular velocity of the wheel F will be immediately communicated to the screwing-spindle E and its chuck V; but the angular velocity of the wheel S will be transferred to the hollow boss Q, and thence

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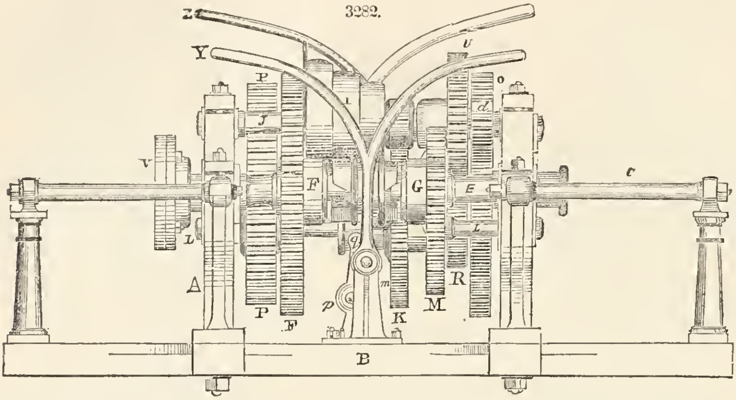

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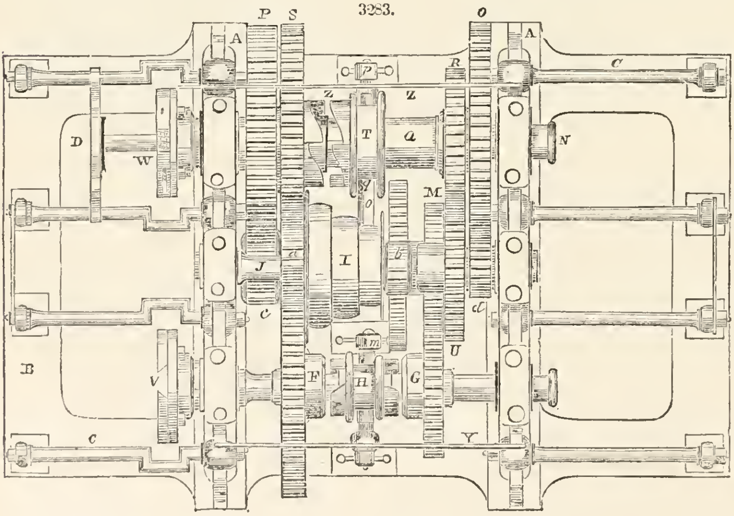

to the wheel R, which geers with the wheel U. But this last being loose upon the driving-shaft, and fast with the pinion *d*, will communicate its motion to the wheel O, which is fast upon the screwing-spindle N, and so communicate a reduced speed in the ratio of the numbers $\frac{z \times R \times d}{S \times U \times O}$. But let the clutch T be disengaged—the clutch H remaining in geer as before—then the under clutch will engage the wheels K and M to their shaft L, and in consequence this shaft will be driven by the pinion *b*, which geers with the wheel K, and will drive the wheel P, which is fast on the screwing-spindle N, with a speed, in the opposite direction to its former motion, determined by the ratio of the numbers $\frac{b \times c}{K \times P}$. Let the clutch H be brought out of geer with the wheel F, and engaged with the wheel G, then the spindle E will receive an increased speed in the opposite direction to its former motion. Thus the two screwing-spindles may be driven in either direction independently of each other, and may be employed at the same time to screw-bolts and nuts of different sizes and pitches of thread.

The screwing-spindles are of malleable iron to insure strength, and are made hollow to allow the bolts to pass into them as they are screwed. The chucks are fast upon the ends of the spindles, and to these the die-holders are bolted. The die-holder of the smaller spindle is of the common form, and fits into a dovetailed recess V, from which it can be removed and have its cutters changed at pleasure;

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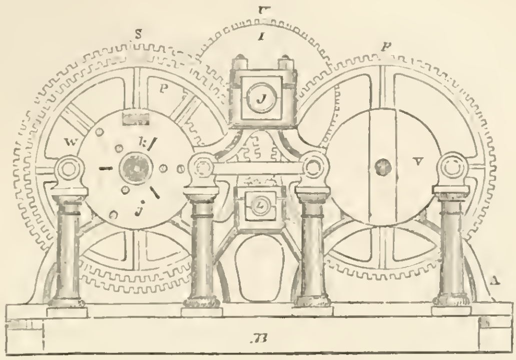

but that for the larger spindle is differently constructed, as will be observed from the face view of it given in Fig. 3287. This consists of a strong plate W, annularly recessed to receive a ring X, flush with its exterior surface. The ring X has a portion of its circumference cut into teeth to geer with a worm recessed in the plate W, and which can be worked by a handle placed upon the projecting square end of its spindle *h*. Consequently, as this worm is turned in one direction or the other, the ring X

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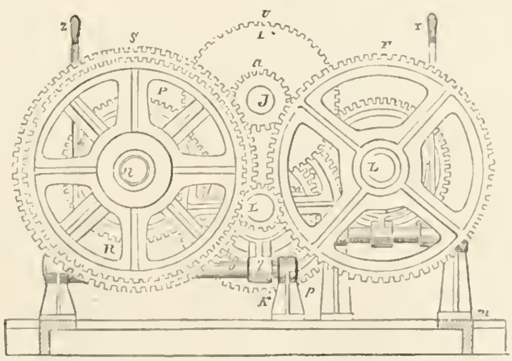

will be correspondingly affected, and will, by its motion, change the relation of the cutters *f f f*, in respect of the axis of the chuck. For this purpose, three spiral recesses *g g g* are formed on the interior circumference of the ring, into which the exterior ends of the cutters project and abut against the inner edges of the spiral recesses. It is therefore clear that if the ring be made to pass through a

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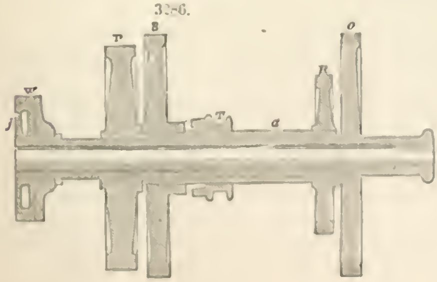

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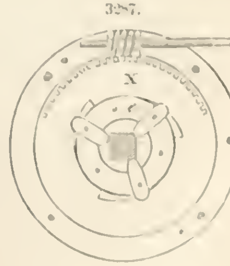

small arc from right to left, the cutters will be forced to approach the centre; and conversely, if the motion be from left to right, the cutters will be allowed to expand and receive a larger diameter of bolt. The cutters are accurately fitted into recesses prepared for their reception in the ring *e*, which is of a piece with the plate W, and the whole is covered by the thin plate *j*. In this plate are three ra dial slots $k\,k\,k$, through which pass three small round pins projecting from the cutters, for the purpose of guiding them in a rectilinear motion.

In the operation of screwing, the head of the bolt is caught in the gland-frame D, Fig. 3288, which fits between the guide-rods C C, along which it slides towards the chuck, as the thread is being cut, and the screw thereby formed passes into the hollow interior of the screwing-spindle. When nuts are to be tapped, they are inserted into glands which fit the guide-rods C C, at the opposite end of the machine, and the taps are fitted into the square holes in the ends of the spindles.

SEA-LIGHTS, or Light-Houses. Powerful lights exhibited from lofty towers or headlands, to warn navigators of their proximity to the land. These are divided into coast-lights, which occupy the most salient points; bay-lights, located within the recessed lines of coast; channel-lights, arranged to designate some particular course for vessels to steer over a bar or past some danger, and hence are often called "leading-lights;" tide-lights, to indicate the height of tide at the port; and lastly, floating-lights, which are vessels from which are exhibited lights to indicate the vicinity of some shoal lying off from the shore, in a position where no permanent structure can be erected.

Light-houses, properly speaking, are of modern origin, and date their efficiency from about the year 1780, when Citizen Argand, of Geneva, in Switzerland, invented the admirable lamp that yet bears his name, and which combines in a degree not yet equalled by any other the best principles of combustion, and consequently the evolution of a brilliant light. Previous to the invention of Argand, navigators were compelled to trust to the dim and murky light of wood and coal fires, burned on the tops of towers or lofty promontories, which, when the wind was off shore, must have been nearly or quite concealed by their own smoke. Coal lights have been continued in the Baltic till within ten years past. Smeaton, who erected the celebrated Eddystone Light-house, (justly considered the work of a man of genius, and as displaying a high degree of mechanical skill,) had not the talent sufficient to devise any improvement in the lights, but was obliged to illuminate that superb Pharos with tallow candles! How great would be his delight, could he now see the beautiful combination of science and practice that are united in the admirable dioptric apparatus of Fresnel, which is installed in the Eddystone Light-house, and makes it one of the most efficient lights in the English Channel!

The great increase of commerce and navigation in the last century, and the repetition of frightful disasters by frequent shipwrecks, naturally directed the minds of men to suggest means for ameliorating the danger to which shipping of all classes was then exposed, and an effort to improve the light-houses was one step towards the accomplishment of this desirable object. The clumsy means of producing light from wood and coal fires, prevented the use of a glazed lantern to protect the flame from the furious winds of the Atlantic, and consequently the application of optical instruments to magnify the light. These fires were made in large iron braziers, and about 225 lbs. of coal were used in one night. The first attempt to economize the light from coal or other fires, and to direct the rays to the horizon, was made in 1727, at the Cordouan Light-house, by M. Bitri, an engineer employed to repair that structure. He placed over the flame an inverted cone of tin plates, which reflected all the light incident upon its surface, and must have added materially to its effect as long as the tin was kept polished; but it is evident that with an open fire beneath the cone, the smoke and gas must speedily have destroyed the polish, and with it the reflecting power.

The effects of a light in giving out rays without any controlling apparatus, will be to fill a sphere whose radius is equal to the distance at which the light is visible. In the light shown from a light-house, those rays which are thrown upwards or downwards beyond the reach of vision, would be totally lost for practical utility, and it therefore becomes necessary to economize the light, to deflect these rays and cause them to assume that direction only in which they are required: in short, our apparatus must be so ordered as to produce a *horizontal band or zone of light.* To do this we have two methods, both of which have been successfully applied: the first being to collect the rays in a concave mirror, and by its reflective power project them to the horizon; a circle of these mirrors would thus be visible from every point of the horizon: this is termed the catoptric method. Secondly, to place lenses of a proper form *around* the light, when all the rays falling upon these will be refracted in a horizontal plane: this is called the dioptric method, and is the more modern and by far most perfect of the two systems.

As the catoptric or reflector system is the only one used in the United States, we shall briefly describe the form and construction of the reflectors, which ought to be paraboloidal to produce the proper result, though, we regret to say, there are few such reflectors in this country.

It is proper to premise that a parabola is a curve of the second order, obtained by cutting a cone in a plane parallel to one side, and possessing this remarkable property, that a line drawn from the focus to any point in the curve makes, with a tangent at that point, an angle equal to that which a line parallel to the axis of the curve makes with that tangent. An inspection of the diagram will render this apparent, and it is easy to see that a revolution of this curve upon its axis will generate a parabolic conoid, which is the form of concave mirror we require for light-houses.

The line P V G, Fig. 3289, is a parabolic curve, and within it is the *focal point* F, which is the situation of the lamp-flame in the reflector, of which this may be supposed to represent a section. Now, a ray from the lamp at F falling on the concave surface at d, will be reflected in the direction $a\,f$, which is parallel to the axis of the curve V Z, and the angle of reflection $b\,a\,c$ is equal to the angle of incidence $d\,a\,c$; in other words, it makes with the normal $a\,z$ the angle $g\,a\,h$ equal to the adjacent angle $h\,a\,i$, and this property belongs to every portion of the surface of the parabola, and consequently the rays from the focal point will be represented by the lines F $x\,x'$, F $w\,w$.

With respect to the invention of parabolic mirrors, we find them mentioned at a very early period, though not in connection with the subject of illumination, but in reference to their powers of focalizing the rays of the sun to form burning instruments, an inverse principle of that of lamp reflectors.

In a work entitled "Pantometria," by Leonhard Digges, published in London in 1571, the author states that, "with a glasse, framed by a revolution of a section parabolicall, I have set fire to powder half a mile and more distant." In the prosecution of this subject the celebrated Napier and Sir Isaac Newton experimented with parabolic reflectors before 1673, and Buffon, the great naturalist, with the same object proposed the polyzonal lens, now adapted to light-house purposes, as will be described further on. The first parabolic reflectors for light-houses of which any authentic record remains, were used at the port of Liverpool, England, previous to 1777, for in that year Wm. Hutchinson, dock-master of the port, published his "Practical Seamanship," and in that work he fully describes the apparatus used in the four light-houses built at Liverpool in 1763. These reflectors were formed to a parabolic curve by a somewhat rude process, which he describes.

Figs. 3290 and 3291 represent the parabolic reflectors used in the Liverpool light-houses, copied from a plate in Hutchinson's "Practical Seamanship," formed of wood, and lined with pieces of looking-glass, or of plates of tin. The oil is kept on a level with the flame by a dripping pot, supplying the reservoir at the back.*

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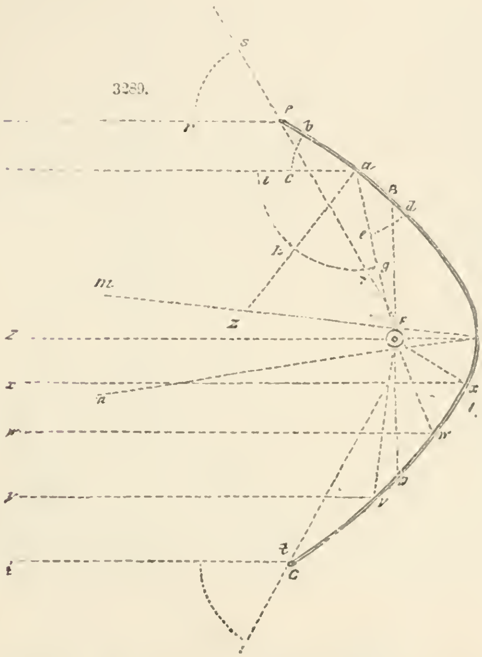

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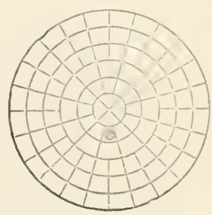

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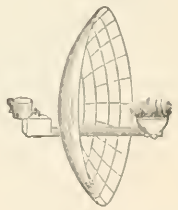


He evidently had a perfect knowledge of the properties of the parabolic reflector, and had also a just idea of its correct application as an illuminating instrument, and he also proposed other and more complete reflectors, similar to those now in use; but like Smeaton, who proposed the use of lenses, neither seems to have attempted the production of a more perfect method of obtaining the artificial light, one thinking candles best, the other preferring a rude oil lamp. The invention of Argand's lamp, in 1780, led the celebrated Chevalier de Borda to propose its union with parabolic reflectors of silver plate, for the illuminating apparatus of light houses. A suite of Argand lamps and silver-plate parabolic reflectors were accordingly made by Lenoir, the eminent optician, and set up in the Cordouan Light house in 1783 by M. Teulere, *Ingenieur en chef Ponts et Chaussées*, who had just completed the alteration of that structure, and raised it to its present height of 206 feet. This apparatus was arranged, moreover, as a *revolving light*, being the first one of that kind ever exhibited, the reason for which will be explained further on.

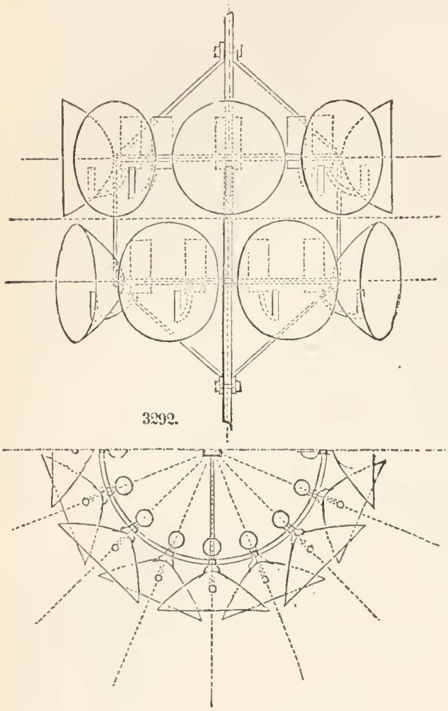
The Trinity House, London, adopted De Borda's plan of the Argand lamp and silver plate parabolic reflector in 1788, and the Scottish Light house Board did the same in 1803, at Inchkeith. The invention was imported into this country in 1810, and, strange to say, a patent was granted for this importation, and our government bought out the patentee in 1812, although the Argand lamp was a French

* "We have had," says Mr. Hutchinson, "and used here in Liverpool, reflectors of 1, 2, and 3 feet focus, and 3, 5½, 7½, and 12 feet diameter. The smallest made of tin plates soldered together, and the largest of wood covered with plates of looking-glass, and a copper lamp; the cistern part for the oil and wick stands behind the reflector, so that nothing stands before the reflector to interrupt the blaze of the lamp acting upon it, but the tube that goes through with a spreading burner mouth-piece, to spread the blaze parallel thereto, and with the middle of it just in the focus or burning point of the reflector. The lamps are, like the reflectors, proportioned to make a greater or less blaze as required; their spreading burning parts are from 3 to 12 and 14 inches broad, and are trimmed every four hours. Thus are these light-houses constructed, kept, and situated, and have stood the test of a fair trial, and the preference and advantages given to them even by their opponents, as there always will be to new things, commonly calling them new whims, till time and trial confirm them as useful improvements."

patent, and, combined with the reflector of De Borda, had then been in public use in the French and English light-houses for thirty years.

The manner in which these instruments are applied to produce the effect of fixed and revolving lights will be understood by inspecting the diagrams.

Fig. 3292 is a half-plan and elevation of a fixed light of 16 lamps. The reflectors are arranged in two series, one above the other, on circular frames of iron; at the back of each reflector an Argand lamp is attached, the supply-tube from which passes through a hole cut in the reflector and leading to the burner, which is accurately set in the focus of the instrument. Each reflector must thus illuminate that portion of the horizon towards which it faces, and consequently the distant observer sees the light of but *one* lamp.



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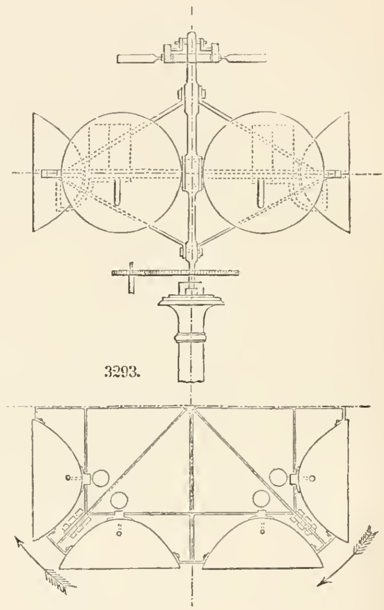

3293.

Fig. 3293 is a half-plan and elevation of a revolving light of four faces. In the diagram there are but two lamps on each of the four sides of a square, though as many as ten lamps are often so placed in lights of the first class. It is obvious in this arrangement that the light from this apparatus must be visible in four directions only, and these 90° apart, or at right angles to each other, while the intervening spaces must be dark or eclipsed. By causing this apparatus to rotate slowly on its vertical axis, the bright and dark portions of the square will be presented alternately to the eye of a distant observer; in other words, the light will appear and disappear at intervals of time corresponding to the speed of rotation. Two objects are gained by this arrangement: 1st. A distinctive appearance, by which a light that is eclipsed at regular intervals can never be mistaken for a light steadily visible, or, as they are termed, a fixed light. 2d. The power and brilliancy of the light is greater than in a fixed light, just in proportion to the number of lamps on each face of the frame; for while in the fixed light we cannot receive the light of but *one* reflector at a time, owing to the circular form of arrangement, in the revolving light we have the combined power of from two up to ten reflectors at one view, simply by placing so many reflectors on each face of the frame. The difference, then, between the illuminating power of the two methods of fixed and rotary lights, is in the ratio of 2 to 1, 3 to 1, or 10 to 1, as the case may be. Consequently, the relative economy of the two plans is in a like ratio. In a fixed light of 24 lamps, the seaman can only have the aid of *one* reflector, no matter from what direction he views the light; while in a revolving light of 24 lamps, arranged in groups of eight reflectors on the three sides of a triangular frame, the seaman has eight times as powerful a light presented to his view at short intervals—yet the cost of maintaining these two lights is exactly similar. Notwithstanding the simplicity of this fact, and the cogent reasons that exist for availing ourselves of the superior economy and brilliancy of the revolving light, it is rarely adopted in the United States light-houses. With more than 300 lights on our coast, there are yet but 38 revolving lights, against 287 fixed.

In Fig. 3289 the theoretical properties of the parabola are stated, and it is obvious that if these should remain true in practice, the beam of light from such a reflector would be a simple cylinder of a diameter equal to the double ordinate of the mirror. Such, however, is fortunately not the case

The size of the flame of the lamp causes a divergence of the reflected light, which divergence increases and decreases with the length of the focal axis of the mirror and the size of the flame. In practice, the effective divergence of the beam of light from a 21-inch reflector of 4 inches focal axis is found to be about 14 degrees in azimuth. Hence we require 26 reflectors in a fixed light, in order to produce a tolerably equal distribution of light around the horizon. If a less number is used, the intervals between each pair of reflectors is poorly lighted, and not visible at any great distance.

3294.

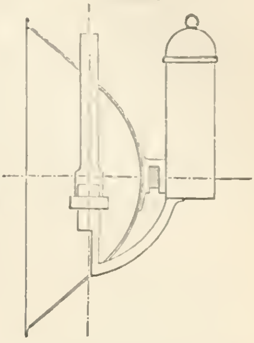

Fig. 3294 is a vertical section of a parabolic reflector, with its lamp in the proper place, and the burner in the focal point.

Dioptric system of lights.—One of the earliest notices of the application of lenses to light-houses is in Smeaton's Narrative of the Eddystone Light-house, where it is mentioned that a London optician, in 1759, proposed grinding the glass of the lantern to a radius of seven feet six inches. About the middle of the last century, however, lenses were actually tried in several light-houses in the south of England, and in particular at the South Foreland in the year 1752; but their imperfect figure and the quantity of light absorbed by the glass, which was of impure quality and of considerable thickness, rendered their effect so much inferior to that of the paraboloidal reflectors then in use, that after trying some strange combinations of lenses and reflectors, the former were finally abandoned.

The celebrated Buffon, in order to prevent the great absorption of light by the thickness of the material, which would necessarily result from giving to a lens of great dimensions a figure continuously spherical, proposed to grind, out of a solid piece of glass, a lens in steps, or concentric zones. This suggestion of Buffon about the construction of large burning glasses was first executed, with tolerable success, about the year 1780, by the Abbé Rochon.

The merit of having first suggested the building of lenses in separate pieces seems to be due to Condorcet, who, in his *Eloge de Buffon*, published so far back as 1773, enumerates the advantages to be derived from this method. Sir David Brewster also described this mode of building lenses in 1811, and in 1822 the late eminent Fresnel, unacquainted with the suggestions of Condorcet or the description by Sir David Brewster, explained, with many ingenious and interesting details, the same mode of constructing those instruments which he had discovered for himself in 1819.

Spherical lenses, like spherical mirrors, collect truly into the focus those rays only which are incident near the axis; and it is, therefore, of the greatest importance to employ only a small segment of any sphere as a lens. The experience of this fact, among other considerations, led Condorcet, as already noticed, to suggest the building of lenses in separate pieces. Fresnel, however, was the first who actually constructed a lens on that principle, and fully availed himself of the advantages which it affords; and he has subdivided, with such judgment, the whole surface of the lens into a centre lens and concentric annular bands, and has so carefully determined the elements of curvature for each, that it does not seem likely that any improvement will soon be made in their construction.

Fig. 3295 represents a plan of the great lens; Fig. 3296 a section through the line A B.

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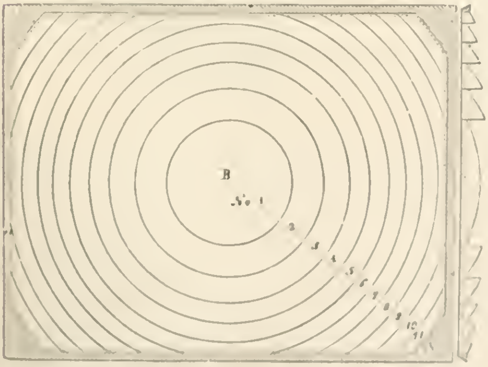

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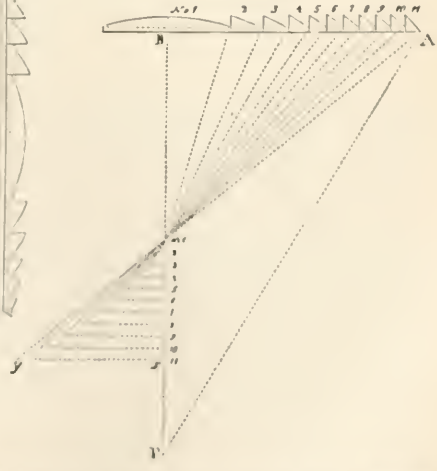

The central disk of the lens, which is employed in lights of the first order, and whose focal distance is 920 millimetres, or 36·22 inches, is about 11 inches in diameter; and the annular rings which surround it gradually decrease in breadth, as they recede from the axis, from $2\frac{3}{4}$ to $1\frac{1}{4}$ inches. The breadth of any zone or ring is, within certain limits, a matter of choice, it being desirable, however, that no part of the lens should be much thicker than the rest, as well for the purpose of avoiding inconvenient projections on its surface, as to permit the rays to pass through every part of it with nearly equal loss by absorption. The objects to be attained in the polyzonal or compound lens are chiefly, as above noticed, to correct the excessive aberration produced by refraction through a hemisphere or great segment, whose edge would make the parallel rays falling on its curve surface converge to a point much nearer the lens than the principal focus, as determined for rays near the optical axis, and to avoid the increase of material, which would not only add to the weight of the instrument and the expense of its construction, but would greatly diminish by absorption the amount of transmitted light.

In applying lenses to the flame of a light-house lamp, similar considerations must guide us in making the necessary arrangements as in the case of reflectors. The size of the flame and its distance from the surface of a mirror have an important practical bearing on the utility of the instrument, and the divergence of the resultant beam materially affects its fitness for the purpose of a light-house. So also in the case of the lens; unless the diameter of the flame of the lamp has to the focal distance of the instrument a relation such as may cause an appreciable divergence of the rays refracted through it, it could not be usefully applied to a light-house; for, without this, the light would be in sight during so short a time that the seaman would have much difficulty in observing it. To determine the amount of this divergence of the refracted beam, therefore, is a matter of great practical importance, and we shall briefly point out the conditions which regulate its amount, as they are nearly identical with those which determine the divergence of a paraboloidal mirror illuminated by a lamp in its focus. The divergence, in the case of lenses, may be described as *the angle which the flame subtends at the principal focus of the lens*, the maximum of which, produced at the vertex of Fresnel's great lens by the lamp of four concentric wicks, is about 5° 9′.

This will be easily seen by examining Fig. 3297, in which $Q\,q$ represents the lens, A its centre, F the principal focus, b F and b' F the radius of the flame; then is the angle $b\,A\,b'$ equal to the maximum divergence of the lens. $\sin b\,A\,F = \frac{b\,F}{A\,F} = \sin b'\,A\,F = \frac{\text{rad. of flame}}{\text{focal distance}}$; and twice b A F = the whole divergence at A. Then for the divergence at the margin of the lens, or at any other point, we have $F\,Q = \sqrt{(A\,Q^2 + A\,F^2)}$ and $Q\,x = \sqrt{(Q\,F^2 + F\,x^2)}$; and for any angle at Q, we have $\sin F\,Q\,x = \frac{F\,x}{F\,Q}$.

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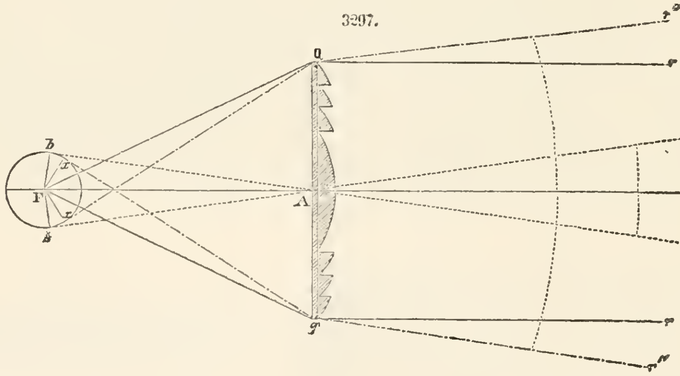
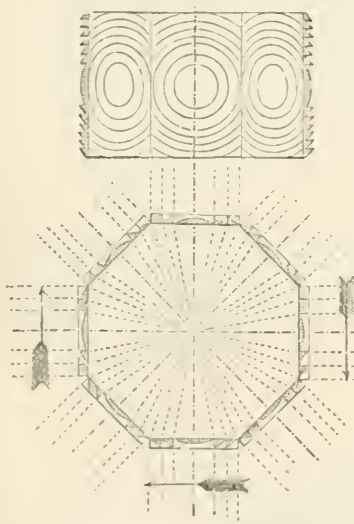


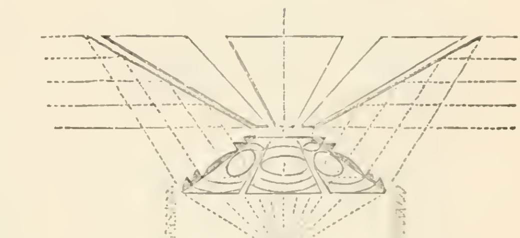
On the subject of the illuminating power of the lenses, it seems enough to say that the same general principle regulates the estimate as in reflectors. Owing to the square form of the lens, however, there is a greater difficulty in finding a *mean focal distance* whereby to correct our estimate of the angle subtended by the light, so as to equate the varying distance of the several parts of the surface; but, practically, we shall not greatly err if we consider *the quotient of the surface of the lens divided by the surface of the flame* as the increased power of illumination by the use of the lens. The illuminating effect of the great lens, as measured at moderate distances, has generally been taken at 3000 Argand flames, the value of the great flame in its focus being about 16, thus giving its increasing power as nearly equal to 180. The more perfect lenses have produced a considerably greater effect.

The application of lenses to light-houses is so obvious as to require little explanation. They are arranged round a lamp placed in their centre, and on the level of their focal plane in the manner shown in Fig. 3298, which is a vertical section and plan of a revolving light of eight lenses, that form, by their union, a right octagonal hollow prism, circulating round the flame which is fixed in the centre, and showing to a distant observer successive flashes or blazes of light, whenever one of its faces crosses a line joining his eye and the lamp, in a manner similar to that already noticed in describing the action of the mirrors. The chief difference in the effect consists in the greater intensity and shorter duration of the blaze produced by the lens; which latter quantity is, of course, proportional to the divergence of the resultant beam. Each lens subtends a central horizontal pyramid of light of about 46° of inclination, beyond which limits the lenticular action could not be advantageously pushed, owing to the extreme obliquity of the incidence of light; but Fresnel at once conceived the idea of pressing into the service of the mariner, by means of two very simple expedients, the light which would otherwise have uselessly escaped above and below the lenses.

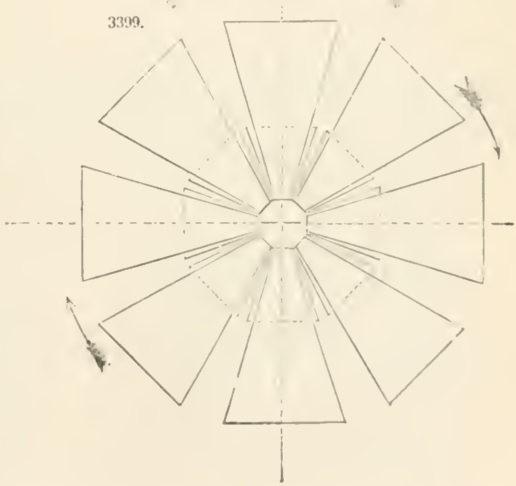
For intercepting the upper portion of the light, he employed eight smaller lenses of 500 mm. focal distance (19·68 inches) inclined inwards towards the lamp, which is also their common focus, and thus forming, by their union, a frustum of a hollow octagonal pyramid of 50° of inclination. The light falling on those lenses is formed into eight beams rising upwards at an angle of 50° inclination. Above them are ranged eight plane mirrors, as in Fig. 3299, so inclined as to project the beams transmitted by the small lenses into the horizontal direction, and thus finally to increase the effect of the light. In placing those upper lenses, it is generally thought advisable to give their axes a horizontal deviation of 7° or 8° from that of the great lenses, and in the direction contrary to that of the revolution of the frame which carries the lenticular apparatus. By this arrangement the flashes of the smaller lenses precede those of the large ones, and thus tend to correct the chief practical defect of revolving lenticular lights, by prolonging the bright periods. The elements of the subsidiary lenses depend upon the very same principles, and are calculated by the same formulæ as those given for the great lenses. In fixing the focal distance and inclination of those subsidiary lenses, Fresnel was guided by a consideration of the necessity for keeping them sufficiently high to prevent interference with the free access to the lamp. He also restricted their dimensions within very moderate limits, so as to avoid too great weight. Their focal distance is the same as that for lenses of the third order of lights.



3298.



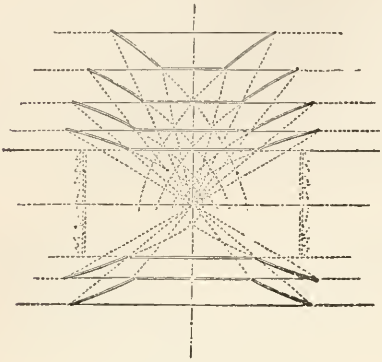
3299.

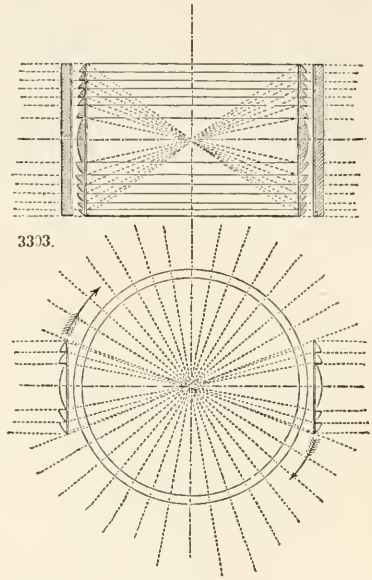


Owing to certain arrangements of the apparatus which are necessary for the efficiency of the lamp, but a small portion of those rays which escape from below the lenses can be rendered available for the purposes of a light-house; and any attempt to subject them to lenticular action, so as to add them to the periodic flashes, would have led to a most inconvenient complication of the apparatus. Fresnel adopted the more natural and simple course of transmitting them to the horizon in the form of flat rings of light, or rather of divergent pencils, directed to various points of the horizon. This he effected by means of small curved mirrors, disposed in tiers, one above another, like the leaves of a Venetian blind—an arrangement which he also adopted (see Fig. 3300) for intercepting the light which escapes above as well as below the dioptric belt in fixed lights. These curved mirrors are, strictly speaking, generated (see Fig. 3301) by portions such as ab of parabolas having their foci coincident with F, the common flame of the system. In practice, however, they are formed as portions of a curved surface, ground by the radius of a circle, which osculates the given parabolic segment. The mirrors are plates of glass, silvered on the back and set in flat cases of sheet brass. They are suspended on a circular frame by means of screws which, being attached to the backs of the brass cases, afford the means of adjusting them to their true inclination, so that they may reflect objects on the horizon of the light-house to an observer's eye placed in the common focus of the system.

Having once contemplated the possibility of illuminating light-houses by dioptric means, Fresnel quickly perceived the advantage of employing for fixed lights a lamp placed in the centre of a polygonal hoop, consisting of a series of refractors, *infinitely small* in their length and having their axes in planes parallel to the horizon. Such a continuation of vertical sections, by refracting the rays proceeding from the focus, only in the vertical direction, must distribute a zone of light *equally brilliant* in

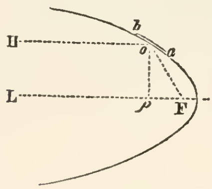
3300.



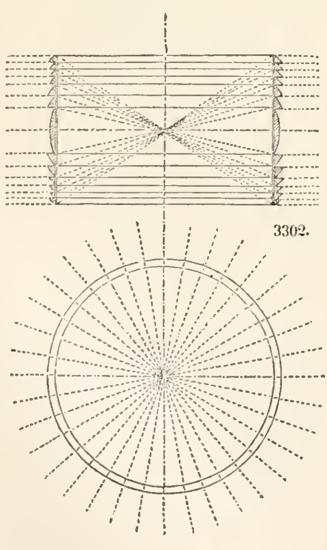


3303.

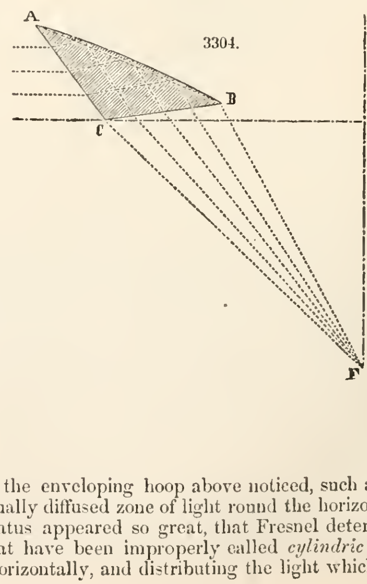
3301.



every point of the horizon. This effect will be easily understood, by considering the middle vertical section of one of the great annular lenses, already described, abstractly from its relation to the rest of the instrument. It will readily be perceived that this section possesses the property of simply refracting the rays *in one plane coincident with the line of the section*, and in a direction parallel to the horizon, and cannot collect the rays from either side of the vertical line; and if this section, by its revolution



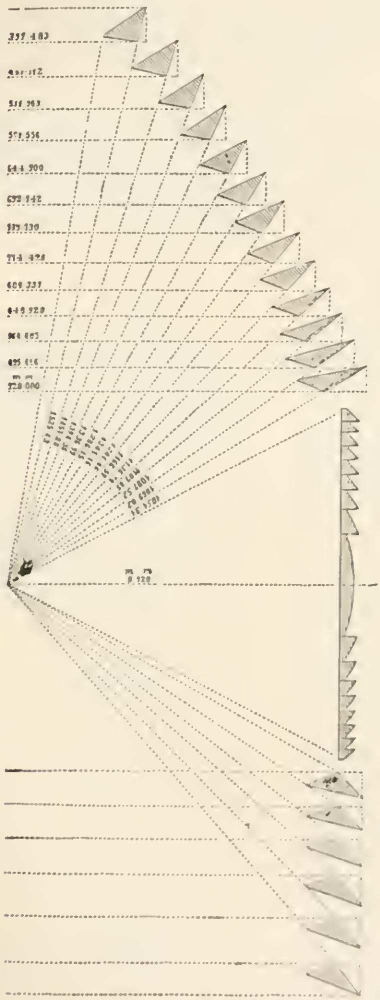
3302.



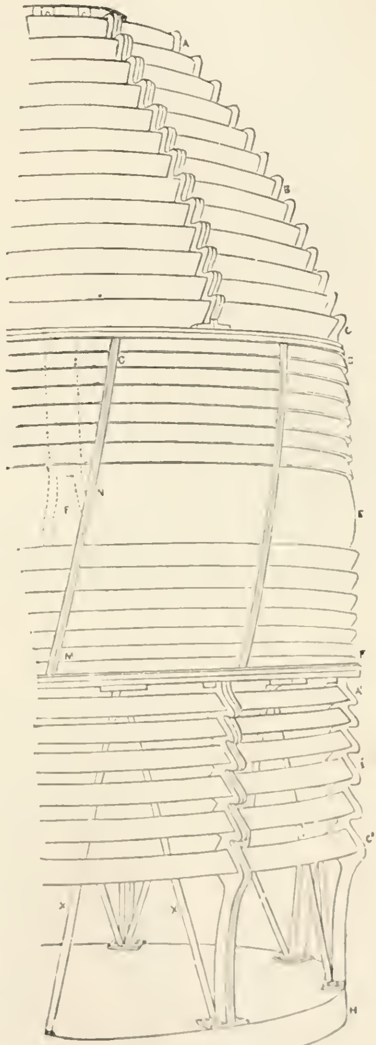
3304.

about a vertical axis, becomes the generating line of the enveloping hoop above noticed, such a hoop will of course possess the property of refracting an equally diffused zone of light round the horizon, Fig 3302. The difficulty, however, of forming this apparatus appeared so great, that Fresnel determined to substitute for it a vertical polygon, composed of what have been improperly called *cylindric lenses* but which in reality are mixtilinear prisms placed horizontally, and distributing the light which they receive from the focus nearly equally over the horizontal sector which they subtend. This polygon has a sufficient number of sides to enable it to give, at the angle formed by the junction of two of them, a light not very much inferior to what is produced in the centre of one of the sides; and the upper and lower courses of curved mirrors are always so placed as partly to make up for the deficiency of the light at the angles. The effect sought for in a fixed light is thus obtained in a much more perfect manner than by any conceivable combination of the paraboloidal mirrors.

3305.



3306.



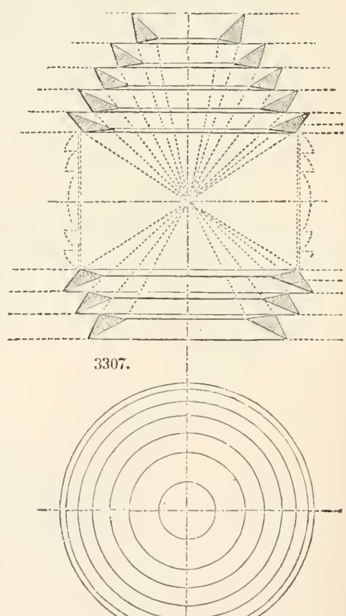
An ingenious modification of the fixed apparatus is also due to the inventive mind of Fresnel, who conceived the idea of placing one apparatus of this kind in front of another, with the axes of the cylindric pieces crossing each other at right angles. As those cylindric pieces have the property of refracting all the rays which they receive from the focus, in a direction perpendicular to the mixtilinear section which generates them, it is obvious that if two refracting media of this sort be arranged as above described, their joint action will unite the rays which come from their common focus into a beam, whose sectional area is equal to the overlapped surface of the two instruments, and that they will thus produce, although in a disadvantageous manner, the effect of a lens. It was by availing himself of this property of crossed prisms, that Fresnel invented the distinction for lights which he calls *a fixed light varied by flashes;* in which the flashes are caused by the revolution of cylindric refractors with vertical axes ranged round the outside of the fixed light apparatus already described. See Fig 3303.

The loss of light by reflection at the surface of the most perfect mirrors, and the perishable nature of the material composing their polish, led to the introduction of *totally reflecting prisms* as a substitute for the silvered glass mirrors placed above and below the great refracting belt. These prismatic zones or catadioptric rings, involve some very difficult calculations in order to determine the proper section of each. In a dioptric light of the first order there are 13 zones above the refractor and 6 below it. In each one the triangular section differs according to its position with respect to the focal centre of the system of lenses.

The problem is, therefore, the determination of the elements and position of a triangle A B C, Fig. 3304, which, by its revolution about a vertical axis, passing through the focus of a system of annular lenses or refractors in F, would generate a ring or zone capable of transmitting in a horizontal direction, by means of *total reflection*, the light incident upon its inner side B C from a lamp placed in the point F. The conditions of the question are based upon the well-known laws of *total reflection*, and require that all the rays coming from the focus F shall be so refracted at entering the surface B C, as to meet the side B A at such an angle, that instead of passing out they shall be *totally reflected* from it, and passing onwards to the side C A shall, after a second refraction at that surface, finally emerge from the zone in a horizontal direction. For the solution of this problem, we have given the positions of F the focus, of the apex C of the generating triangle of the zone, the length of the side B C, or C A, and the refractive index of the glass.

The position of the several prismatic zones is shown in the annexed section, Fig. 3305, or generatrix of the complete system drawn in perspective elevation, Fig. 3306, which is a fixed light of the first order. A B C, catadioptric zones. D E F, compound dioptric belt with diagonal joints C N M. A′ B′ C′, lower catadioptric zones, one division being left out for free access to lamp. F, focus with flame or lamp. X X X, diagonal supports for the upper catadioptric zones. H H, service table, on which the lamp rests and where the keeper stands to trim the burner, and which is supported by a pillar resting on the light-room floor.

The original conception of this magnificent apparatus is seen in the annexed diagram, Fig. 3307, which represents a plan and vertical section of Fresnel's fourth order, combining a central annular refractor, with totally reflecting zones above and below. Mr. Stevenson has very unjustly attempted to appropriate this invention as his own; but the only claim he can properly advance is that of proposing the adoption of this plan of Fresnel's on a larger scale.

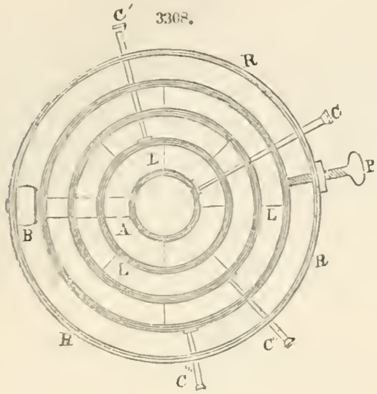


3307.

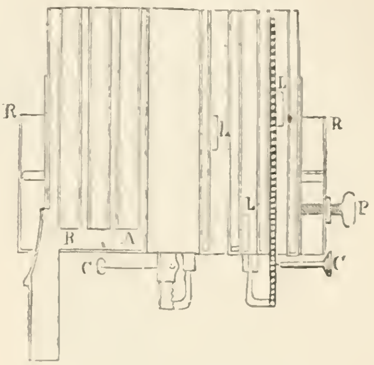
We have next to consider the great lamp, to the proper distribution of whose light the whole of the apparatus above described is applied. Fresnel immediately perceived the necessity of combining with the dioptric instruments which he had invented a burner capable of producing a large volume of flame; and the rapidity with which he matured his notions on this subject and at once produced an instrument admirably adapted for the end he had in view, affords one of the many proofs of that happy union of practical with theoretical talent, for which he was so distinguished. Fresnel himself has modestly attributed much of the merit of the invention of this lamp to M. Arago; but that gentleman, with great candor, gives the whole credit to his deceased friend, in a notice regarding light-houses, which appeared in the *Annuaire du Bureau des Longitudes* of 1831. The lamp has four concentric burners, which are defended from the action of the excessive heat produced by their united flames, by means of a superabundant supply of oil, which is thrown up from a cistern below by a clockwork movement and constantly overflows the wicks, as in the mechanical lamp of Carcel. A very tall chimney is found to be necessary, in order to supply fresh currents of air to each wick with sufficient rapidity to support the combustion. The carbonization of the wicks, however, is by no means so rapid as might be expected; and it is even found that after they have suffered a good deal the flame is not sensibly diminished, as the great heat evolved from the mass of flame promotes the rising of the oil in the cotton. The large lamp at the Tour de Corduan burns for seven hours without being snuffed or even having the wicks raised; and, in the Scotch light-houses, it often, with Colza oil, maintains, untouched, a full flame for no less a period than seventeen hours.

The annexed diagrams will give a perfect idea of the nature of the concentric burner. The first, Fig. 3308, shows a plan of a burner of four concentric wicks. The intervals which separate the wicks from each other and allow the currents of air to pass, diminish a little in width as they recede from the centre. The next, Fig 3309, shows a section of this burner. C C′ C″ C‴ are the rack-handles for raising or depressing each wick; A B is the horizontal duct which leads the oil to the four wicks; L L L are small plates of tin by which the burners are soldered to each other, and which are so placed as not to hinder the free passage of the air; P is a clamping-screw, which keeps at its proper level the gallery R R, which carries the chimney. The next, Fig. 3310, shows the burner with the glass chimney and damper. E is the glass chimney; F is a sheet-iron cylinder, which serves to give it a greater length, and has a small damper D, capable of being turned by a handle for regulating the currents of air; and B is the pipe which supplies the oil to the wicks. To prevent the occurrence of such accidents as stoppage of the machinery of these lamps, and to render their consequences less serious, various precau tions have been resorted to. Amongst others, an alarum is attached to the lamp, consisting of a small cup pierced in the bottom, which receives part of the overflowing oil from the wicks, and is capable, when full, of balancing a weight placed at the opposite end of a lever. The moment the machinery stops the cup ceases to receive the supply of oil, and, the remainder running out at the bottom, the equilibrium of the lever is destroyed, so that it falls and disengages a spring which rings a bell sufficiently loud to waken the keeper should he chance to be asleep.

3308.



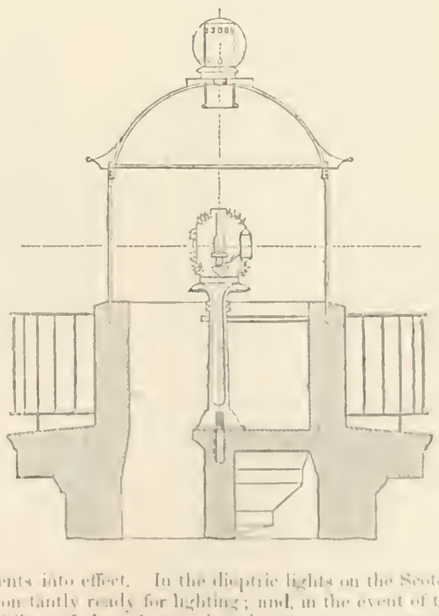
3309.



There is another precaution of more importance, which consists of having always at hand in the light-room a spare lamp, trimmed and adjusted to the height for the focus, which may be substituted for the other in case of accident. It ought to be noticed, however, that it takes about twenty minutes from the time of applying the light to the wicks to bring the flame to its full strength, which, in order to produce its best effect, should stand at the height of nearly four inches ($10^{cm.}$) The inconveniences attending the great lamp have led to several attempts to improve it; and, among others, M. Delaveleye has proposed to substitute a pump having a metallic piston, in place of the leathern valves, which require constant care, and must be frequently renewed. A lamp was constructed in this manner by M. Lepaute, and tried at Corduan; but was afterwards discontinued until some of its defects could be remedied. It has lately been much improved by M. Wagner, an ingenious artist, whom M. Fresnel had

3310.

3311.



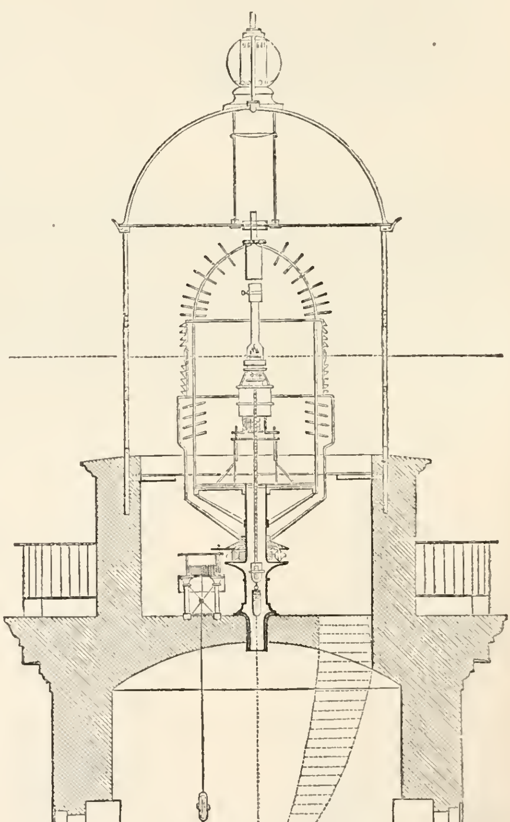
employed to carry some of his improvements into effect. In the dioptric lights on the Scotch coast, a common lamp, with a large wick, is kept constantly ready for lighting; and, in the event of the sudden extinction of the mechanical lamp by the failure of the valves, it is only necessary to unscrew and remove its burner, and put the reserve lamp in its place. The height of this lamp is so arranged that its flame is in the focus of the lenses, when the lamp is placed on the ring which supports the burner of the mechanical lamp; and as its flame, though not very brilliant, has a considerable volume, it answers the purpose of maintaining the light in a tolerably efficient state for a short time, until the light-keepers have time to repair the valves of the mechanical lamp. *Only three occasions* for the use of this reserve-lamp have yet occurred.

The most advantageous heights for the flames in dioptric lights are as follows:

			Inches.
1st Order	10 to 11	centimetres	= 3·94 to 4·33
2d Order	8 to 9	"	= 3·15 to 3·54
3d Order	7 to 8	"	= 2·76 to 3·15

The dioptric system of Fresnel has another capital advantage over the old system of reflectors, by which a great economy is secured, and what is more important, the amount of light at each station can be graduated to the wants of navigation and the peculiar features of the location. The dioptric system is divided into four orders of magnitude, represented by Figs. 3311, 3312, and 3313, drawn to a uniform scale. Each order may be either a fixed light, a revolving light, or a fixed light varied by flashes, or a flashing light. Here are four different appearances or characteristics, in addition to which, the times of the flashes and eclipses can be so essentially varied as to produce new distinctive appearances perfectly intelligible to the practical seaman.

3312.



1. Lights of the 1st order, Fig. 3212, have an interior radius or focal distance of 92 centimetres, or 36·22 in., and lighted by a lamp of four concentric wicks, consume annually 570 gallons of oil. The revolving lights of this order, having eight large polyzonal lenses, with the catadioptric zones above and below, produce a beam of light whose power is equal to 5000 Argand flames of one inch diameter and one and a half inch height. The fixed lights of the same order with catadioptric cupole and zones, produce a beam whose power in all azimuths is equal to 800 Argand burners, as above.

2. Lights of the 2d order, Fig. 3313, having an interior radius of 70 centimetres, or 27·55 in., lighted by a lamp of 3 concentric wicks, consume annually 384 gallons of oil. The best revolving lights of this order have a brilliancy equal to 3000 Argand burners as above, and the fixed lights of same order, have a power in all azimuths equal to 450 such burners.

3. Lights of the 3d order, having an interior radius of 50 centimetres, or 19·68 inches, and lighted by a lamp with two concentric wicks, consume annually 183 gallons of oil. The revolving lights of this order produce a flash equal to 800 Argand burners, and the fixed lights of same order have a power in all azimuths of 100 such burners.

4. Lights of the 4th order, Fig. 3311, have an interior radius of 15 centimeters, or 5·9 in., and are lighted with a simple Argand burner, consuming annually 48 gallons of oil. The flash of this light is equal to 150 burners, and as a fixed light its power in all azimuths is 25 burners.

There is no combination of reflectors that can be made to produce such powers of light as the first order described above. A revolving reflecting light, such as the one on Beachy Head, has three faces of ten reflectors each, whose combined power of $10 \times 280 = 2800$ burners. We have thus three portions of the horizon illuminated at the same time with a power equal to 2800 burners.

The consumption of oil per lamp at Beachy Head is 44 gallons per annum, which, for 30 lamps, gives an aggregate combustion of 1320 gallons of oil each year. The aggregate power of light produced is $2800 \times 3 = 8400$ burners. A 1st order dioptric illuminates eight portions of the horizon at one time, with a power of 5000 burners, or an aggregate effect of 40,000 burners, consuming in one year 570 gallons of oil.

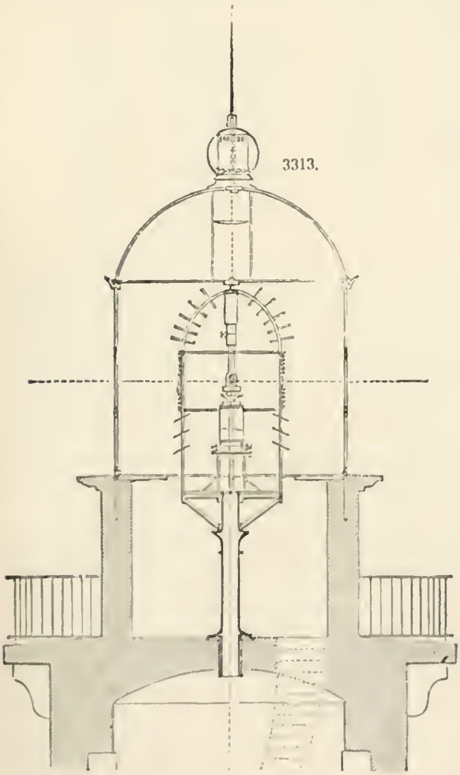
We have thus the following comparison:

1st order dioptric	570 galls. oil	...... 5000×8 points	$= 40,000$
1st " catoptric	1320 " "	...... 2800×3 "	$= 8,000$

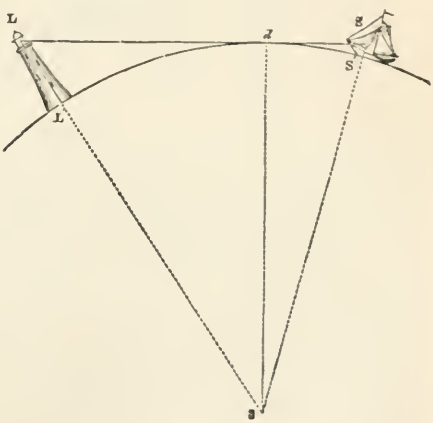
Saving in oil $=$ 750 gallons per annum.
Gain of light $= 31,600$ burners in eight points.
Gain of light $=$ 3,200 " at any one point.

The greater the amount of sea horizon there is to be illuminated, the more economical and useful becomes the dioptric light; while the catoptric system increases in first cost, and maintenance afterwards, by the same law. In the first no increased consumption of oil is caused by extending the area of illumination, while in the latter system the number of lamps and consequent cost and consumption must be increased in proportion to the number of degrees of horizon to be lighted.

The spheroidal form of the earth requires that the height of a light-house tower should increase proportionally to the difference between the earth's radius and the secant of the angle intercepted between the normal to the spheroid at the light-house and the normal at the point of the light's occultation from the view of a distant observer. The effect of atmospheric refraction, however, is too considerable to be neglected in estimating the *range* of a light, or in computing the height of a tower which is required to give to any light a given range; and we must, therefore, in accordance with the influence of this element on the one hand *increase* the range due to any given height, and, *vice versa*, *reduce* the height required for any given range, which a simple consideration of the form of the globe would assign. In ascertaining this height, we may proceed as follows:



3313.



3314.

Referring to the accompanying figure, 3314, in which $S' d L'$ is a segment of the ocean's surface, O the centre of the earth, $L' L$ a light-house, and S the position of the mariner's eye, we obtain the value of $L L' = H'$, the height of the tower in feet by the formula,

$$H' = \frac{2\,l^2}{3} \quad \text{......} \quad (1.)$$

in which $l =$ the distance in English miles $L' d$ at which the light would strike the ocean's surface. We then reduce this value of H' by the correction for mean refraction, which permits the light to be seen at a greater distance, and which $= \frac{2\,l^2}{21}$, ... (2.)

So as to get,
$$H = \frac{2\,l^2}{3} - \frac{2\,l^2}{21} = \frac{4\,l^2}{7} \quad \text{......} \quad (3.)$$

an expression which at once gives the height of the tower required, if the eye of the mariner were just on the surface of the water at *d*, where the tangent between his eye at S and the light at L would touch the sea. We must, therefore, in the first instance, find the distance $dS = l'$, which is the radius of the visible horizon due to the height $SS' = h$ of his eye above the water, and is, of course, at once obtained conversely by the expression,

$$l' = \frac{\sqrt{7h}}{2} \text{ .... (4.)}$$

Deducting this distance from S L, the whole effective range of the light, we have $Ld = l$, and operating with this value in the former equation,

$$H = \frac{4l^2}{7}$$

we find the height of the tower which answers the conditions of the case. From the above data the following table has been computed:

H Heights in feet.	λ Lengths in English miles.	λ' Lengths in nautical miles.	H Heights in feet.	λ Lengths in English miles.	λ' Lengths in nautical miles.	H Heights in feet.	λ Lengths in English miles.	λ' Lengths in nautical miles.
5	2·958	2·565	70	11·067	9·598	250	20·916	18·14
10	4·184	3·628	75	11·456	9·935	300	22·912	19·87
15	5·123	4·443	80	11·832	10·26	350	24·748	21·46
20	5·916	5·130	85	12·196	10·57	400	26·457	22·94
25	6·614	5·736	90	12·549	10·88	450	28·062	24·33
30	7·245	6·283	95	12·893	11·18	500	29·580	25·65
35	7·826	6·787	100	13·228	11·47	550	31·024	26·90
40	8·366	7·255	110	13·874	12·03	600	32·403	28·10
45	8·874	7·696	120	14·490	12·56	650	33·726	29·25
50	9·354	8·112	130	15·083	13·08	700	35·000	30·28
55	9·811	8·509	140	15·652	13·57	800	37·416	32·45
60	10·246	8·886	150	17·201	14·91	900	39·836	34·54
65	10·665	9·249	200	18·708	16·22	1000	41·833	36·28

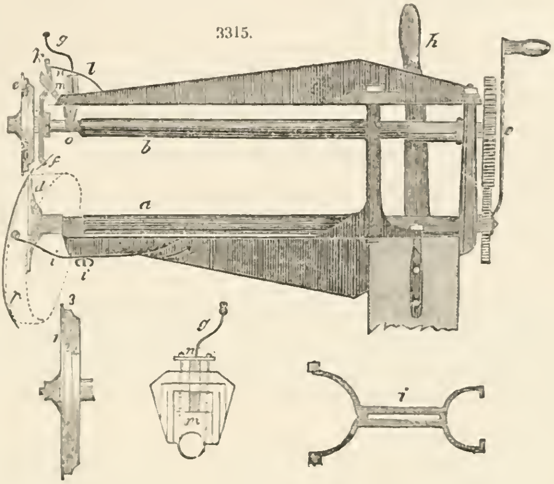
If the distance at which a light of given height can be seen by a person on a given level be required, it is only needful to add together the two numbers in the column of lengths λ or λ', (according as nautical or English miles may be sought,) corresponding to those in the column of heights H, which represent respectively the height of the observer's eye and the height of the lantern above the sea. When the height required to render a light visible at a given distance is required, we must seek first for the number in λ or λ' corresponding to the height of the observer's eye, and deduct this from the whole proposed range of the light, and opposite the remainder in λ or λ' seek for the corresponding number in H.

SEAMING MACHINE, DOUBLE. George R. Moore, Philadelphia, Penn. Fig. 3315 represents a general view of this machine. All the parts that are not lettered compose the frame simply, the construction of which is obvious from the drawing, as it is similar to other tin machines, and made of the same materials; it may, however, be varied.

We proceed to describe the working machinery, noticing first the two arbors *a* and *b*, which are connected by cog-wheels, and turned by the crank *c*. Two heads, *d* and *e*, are affixed to the ends of these arbors, and between these heads the double seaming is performed. A pan *p* is represented in dotted lines, as placed over the head *d*, on the lower arbor, so as to bring the edge which is to be seamed down between the head *e*, and a small roller *f*, hereinafter described. The shape of the head *e* should be carefully noticed. This head consists of a flanch 1, projecting from a cylindrical surface 2, similar to some other machines now in use; this cylindrical surface is terminated by a shoulder 3, that connects with a conical moulding 4. The bevel surface of the head *e* bears first upon the edge of the pan, which is sustained by the head *d*, the shoulder 3, above named, coming against the bottom, and the edge is forced to yield to the bevel of the head *e*, as this is screwed down upon it by means of the screw *g*; and should any part of the edge be inclined to slip out towards the top of the pan, (as this edge is always composed of three thicknesses,) it is prevented from so doing by the little roller *f*, attached to the collar *k*, that surrounds the arbor *b* near the head.

At this stage of the operation the crank *c* is turned, the pan revolves in the machine, and the edge is turned down as far as the bevel part 4, of *e*, will turn it, while the shoulder 3 prevents the edge of the pan from bending too far down towards the centre; after this the head *e* must be raised up a little by turning the screw *g*, attached to the box, (in which the arbor *b* runs,) and then the lever *h* is brought into use to move the arbor *b* inwards, by which the cylindrical part 2 of the head *e*, which is parallel with the outer surface of the head *d*, is brought over the same and then screwed down towards it, by the screw *g*, when, by again turning the crank, the work is completed. The outside shoulder 1 of the head *e* keeps the bottom of the pan close against the head *d*. The lever *h* passes through an aperture in the frame, where it has room to be moved back and forth, and places are fitted to receive it when so moved, into which it is thrown by a spring, or by its own elasticity. It also passes between two shoulders on the arbor *b*, and its lower end is connected to the frame by a pivot. Its use has already been explained. *i* is a sliding gage for the purpose of holding in proper position flaring articles, such as the pan represented in the drawing, where the bottom needs to be thrown out from a perpendicular with the arbors, in order to bring the body parallel with them. This gage consists of a shank that is attached by the screw *j* to the frame, and is terminated by heads branching out for the bottom of the pan to rest against, upon the inside. This is found to be indispensable when the work is much flaring. The heads of this gage are provided with soft or smooth surfaces, to prevent them rubbing the tin so as to mar or injure it. When it is not desirable to use the gage, the work will rest against the head *d*, which is faced nearly to the edge with leather, although other materials may be used, to prevent its rubbing the tin.

3315.



The piece *k* is a collar with a lever attached thereto; the collar part of it is fitted upon the arbor *b*, allowing the arbor to turn freely in it, while the upper end passes through a loop *m* in the frame, to keep it in an upright position; and below the collar, this lever passes through the little roller *f*. The only use of the loop *m* is to bring the roller *f* to bear properly upon the work; and to secure this the better, the lever *k* is made crooked at the top, so that, by pressing it down, this part of it is brought towards the frame, and consequently the roller *f* is moved up closer towards *e*, and *vice versa*.

A spring *l* is applied to throw *k* back as it rises up, to make it easy to get the work properly into the machine.

SEWERS. Subterranean passages formed for the drainage of a town. The inclination and depth of sewers must be regulated according to circumstances. The Holborn and Finsbury regulations require that "the inclination be not less than $\frac{1}{4}$ inch to every 10 feet in length, and as much more as circumstances will admit in those portions that are in a straight line, and double that fall in portions that are curved." It is stated in the regulations of the Westminster Commission, (1836) that the current required for sewers in all cases is $1\frac{1}{4}$ inch to every length of 10 feet; but later regulations order "that the current of all sewers to be built, be regulated by the commissioners according to surface required to be drained," without stating any particular inclination. It is, as already observed, frequently a matter of difficulty to obtain sufficient inclination in a sewer, and yet to make it deep enough to drain the basement story of the neighboring houses.

To remedy the evils of insufficient declivity, the process of *flushing* has been adopted in the sewers; that is, the water is allowed to accumulate for a time by means of gates or dams, and is then suddenly let loose so as to act like a powerful current in sweeping all the loose matter before it. Sewers receive the drainage of houses by means of small channels or *drains*, usually of circular form.

The Westminster commissioners require that the bottoms of private drains shall be 12 inches above the bottom of the sewer; and they recommend that such drains have a fall of at least $\frac{1}{4}$ inch in a foot. Glazed stoneware pipes are excellent substitutes for brickwork in the smaller drains. They are more quickly laid than the others can be built, and they present a much better surface for the rapid flow of the sewage. They are constructed in various forms of bends and junction pieces, and from the comparative thinness of these pipes a much larger capacity is obtained with a given quantity of excavation for laying them, than brickwork sewers, which even for the smallest diameter cannot be less than half a brick, or $4\frac{1}{2}$ inches in thickness. Each pipe has a socket at one end for receiving the plain end of the adjoining pipe.

The entrances to private drains are usually secured by a *stink trap*. These traps are constructed in a variety of forms, but they depend for their action upon the formation of what the chemist calls a *water-lute*.

The form of sewer most generally adopted is the egg section, with the smallest end down so that under a diminished flow the velocity of the current may not be impaired. The size of the sewer must depend on the area to be drained, the requirements of the rain shed, and the house sewage. Knowing the descent, the discharge may be calculated from the usual formulæ for the flow of water through pipes, very liberal allowance being made for accidental obstructions, and for excessive falls of rain. Mr. Phillips, before the Metropolitan Sanitary Commission of England, classed the sewers by 7 sizes, the first being 3.9 × 2.3, with an area of 6.6 square feet, and the 7th class 15 inches × 9 inches, area, .736 square feet.

SEWING MACHINES. The application of machinery to the purposes of sewing, is of very recent date. It was only since the invention of Mr. Howe in 1846, that it assumed any practical value, and still more recently by other improvements, has it become a household utensil. The germ of the sewing machine is the tambouring machine, a description of which may be found in the Edinburgh Encyclopedia, under the head of "Chainwork." This machine contained 54 needles, placed one inch asunder and was designed to tambour muslin $\frac{5}{4}$ wide, one whole row being wrought at the same time. In the details of its construction may be found many principles which are still employed.

3316.

The tambour or chain stitch is that in general use in the cheaper single thread sewing machines. The form of stitch is represented in fig. 3316; a loop of thread *e*, is thrust through the fabric *c*, and held open till the next movement of the needle forces a second loop through the cloth and through the first loop; the first loop is now drawn tightly, and the second loop held open for the third stitch, and so on. At the completion the upper surface of the work shows a single line of thread, the lower a succession of loops: about four and a half yards of thread are a fair average for one yard of this work. The great objection to this stitch is the facility with which it may be ravelled, and on this account it is often used in cloth bleacheries and printeries, where pieces of cloth are stitched together for the purposes of undergoing temporary operations. The low price of these machines has led to a large sale of them, and for many purposes they may be considered of practical value, but the purchase and use of them tend to develop the necessity of sewing machines, and the purchase of the more costly, and by far the most useful double-threaded machines.

Besides the tambour machine, there are two other single-threaded machines essentially different in principle.

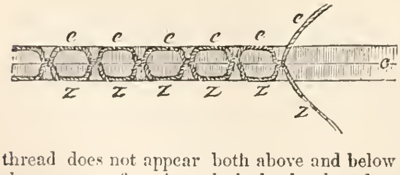
The first is the invention of Benjamin W. Bean of New York City, patented March 4, 1843, reissued March 10, 1849. The following is the claim: "What I claim as my invention is the combination of a straight or curved needle and two or more paired wheels for forming the doubles or corrugations of the cloth, the whole being made to operate together essentially as above specified, and in combination therewith. I claim one or more cogged wheels, applied substantially as above specified, and for the purpose of advancing the doubles of the cloth along the needles as above explained."—This machine formed a running or basting stitch.

Second, the Robinson & Roper machine; this is essentially a hand-sewing machine, single-threaded, forming the same kind of stitches that are made by hand, to wit: back stitches, half and quarter back, side, sail, quilting, hemming, running, etc. Two needles are employed, one above, the other below the cloth, traversing large arcs in a circular slide. The needles are somewhat like those used in the first tambouring machines. The eye opens at the side for the slipping in of the thread, which is retained in its place by a piston sliding down through the upper part of the needle. The principle of the action of the machine is as follows: a needleful of thread, say about 18 inches, is drawn off the spool in its proper position beneath the upper needle, as the upper needle passes down through the cloth it forces down a loop, which is caught in the eye of the lower needle, and by the down movement of this needle, the whole needleful is drawn through the cloth, and by the return motion of the under needle, a loop is presented at the upper surface for a similar operation on the part of the upper needle. When the needleful of thread is exhausted, another is supplied by the operator. The variety of form of stitch is effected by changes in the relative position of the upper and lower needles.

A similar machine with a rotary feed, has been constructed for the working of eyelet holes; for this improvement a patent was granted to S. H. Roper, November 4, 1856.

To Elias Howe, Jr., of Spencer, Mass., now of New York City, is due the credit of inventing the first practical sewing machine. This he patented in 1846, and under licenses from him, are manufactured all the most valuable and practical sewing machines, as I. M. Singer's, Grover & Baker's, and Wheeler & Wilson's.

3317.



The stitch invented by Mr. Howe may be properly termed a lock-stitch; it is formed with two threads, one above and the other below the fabric sewed; interlocked with each other in the centre of the fabric, as in fig. 3317, *c* being the section of fabric sewed, *e* the thread above the fabric, and *z* the thread below the fabric; a single line of thread extending upon each surface of the fabric from stitch to stitch. The same thread does not appear both above and below the fabric at each alternate stitch, but that shown upon the upper surface is exclusively the thread *e*, and that shown upon the lower surface exclusively the thread *z*. It may be formed by hand with two ordinary needles as follows:

Take two needles threaded in the ordinary manner, and a piece of soft cloth; tie the long ends of the thread together, and thrust the needle *h*, containing the thread *e*, through the cloth head first, as in fig. 3318, say three-fourths of an inch; withdraw it slightly, and a small loop of the upper thread *e* will be formed below the fabric. Through this loop pass the needle with the lower thread *z*, and withdraw the needle *h*, entirely from the fabric. The upper thread *e*, thus surrounds the lower thread *z*, and interlocks with it; the point of interlocking being drawn into the fabric as in fig. 3318, and the process repeated, a seam will be formed with a single line of thread visible upon each surface, and having the same appearance as that given by stitching. About two and one-half yards of thread are an average for a yard of seam with this stitch, one yard being expended upon the upper surface of the fabric, one upon the lower, and one-half of a yard in passing through the fabric. A firm knot might be tied at each stitch, but as this would involve a waste of thread and form an uneven seam, it has not been practised.

In the machine invented by Mr. Howe, this stitch was formed in the following manner: one of the

threads was carried through the cloth by means of a needle, the pointed end of which passed through the cloth. The needle had the eye to receive the thread near the point, the other end was held by a bar or arm vibrating upon a pivot. When the needle was forced through the cloth about three-fourths of an inch, a small shuttle carrying a bobbin, filled with silk or thread, was made to pass between the needle and the thread which it carried, and when the needle was drawn up, it forced the thread received from the shuttle into the body of the cloth and formed a stitch; this being repeated, a seam was formed.

The cloth to be sewed was suspended perpendicularly upon pins projecting from a baster plate, between which and a pad-plate in front of it, which pressed the fabric upon the baster-plate, it passed, while the stitch was formed, the needle having a horizontal action. This baster-plate with the fabric was moved forward by a mechanical contrivance, by which also the length of stitch was regulated. The invention of the endless rotary feed, and the change of the needle from a horizontal to a vertical action, were the first improvements upon it. The baster-plate was abandoned, the fabric was laid horizontally upon a cloth-plate beneath the vertical acting needle, pressed upon the plate by a cloth presser, and moved forward by a wheel with pins or other projections upon its periphery, penetrating the fabric from beneath, by the action of which also the length of stitch was graduated. The pins penetrating the cloth were objectionable, in not allowing that free movement to the fabric which is essential in forming curved seams. A feed was desired that should not only advance the fabric, but should intermit its action, so that the fabric might be readily turned in any direction. The rough surface feed, with the yielding spring pressure invented by A. B. Wilson, admirably answers these requirements, and the patent has become the joint property of the three manufacturers above named.

Many expedients are devised to increase the speed of shuttle machines—a machine was invented in which the shuttle had a rotary motion, and was made to travel an entire circuit at each stitch; but the shuttle was kept in its place with difficulty; the thread was liable to become entangled, and was untwisted at each stitch. Another machine was invented for using a shuttle pointed at both ends, to take a stitch at each movement backwards and forwards.

The sewing machines of I. M. Singer are identical in their stitch with Howe's machine. Many improvements in construction and in the details have been the subjects of patents of either Mr. Singer himself, or have been acquired by purchase. In general arrangement the machines are strong and well made, and the seam secure. They are applied to the sewing of leather as well as that of cloth.

The Grover & Baker Machine. Although making use of two threads to form the stitch, the seam is widely different in its appearance from that of the lock stitch; it may be called the double-threaded tambour stitch, Fig. 3319 represents the stitch in process of formation, fig. 3320 when completed.

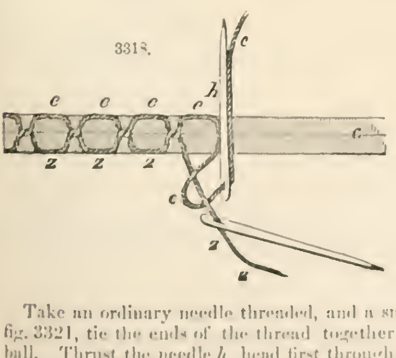
3319.

3320.

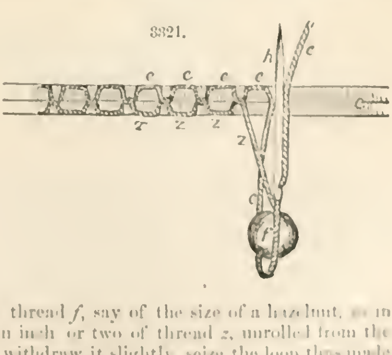
On the upper surface a single thread is shown, on the lower side three. The upper needle forms a loop as in all machines, and the seam is made by a chain stitch passing through this loop. The stitch is strong and somewhat elastic, and the machine simple, but it is the least economical of thread of all the machines; the stitch requiring about six and a half yards of thread for each yard of seam. Like all the other sewing machines, the machine embodies several patents.

The Wheeler & Wilson Machine. In 1851, Mr. A. B. Wilson patented his celebrated lock-stitch machine, which, with the co-operation of Mr. N. Wheeler, was soon introduced into successful operation. The merit of Mr Wilson's invention consists in the rough surface feed above mentioned, and in the improved mode and mechanism by which sewing is effected. The main feature of the invention consists in a "rotating hook," by which the needle or upper thread upon being passed through the fabric, is enlarged and carried around a stationary bobbin containing the lower thread, interlocked with it, and the point of interlocking drawn into the fabric. It may be made by hand in an analogous manner.

3318.



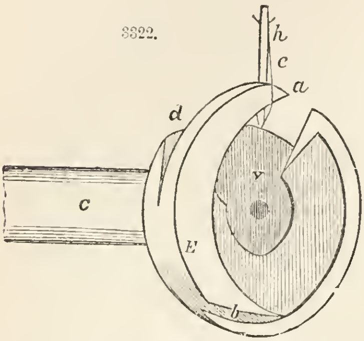
3321.



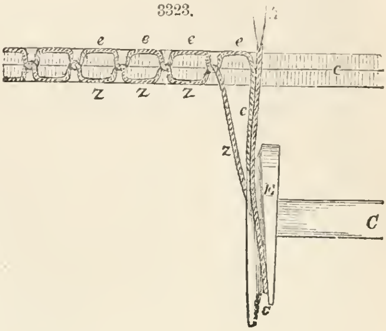
Take an ordinary needle threaded, and a small ball of thread f, say of the size of a hazelnut, as in fig. 3321, tie the ends of the thread together, leaving an inch or two of thread z, unrolled from the ball. Thrust the needle h, head first through the fabric, withdraw it slightly, seize the loop thus made by the upper thread, enlarge it, and instead of passing the ball with the lower thread through this loop, hold the ball stationary and pass the loop around it as in fig 3321; then withdraw the needle entirely from the fabric, and draw up the loop, so that the point of the threads c and z interlocked will be in the centre of the fabric. The manner of making this stitch with the Wheeler & Wilson machine is represented by the following diagrams.

E in *fig.* 3322 is the rotating hook referred to; it is formed by cutting away a portion of the periphery of the circular concave disk, upon the end of the arbor C. Y, is the concavity of the disk; *a*, the point of the hook cut clear to the point *d;* and *d* is a small groove diagonal across the periphery of the hook to the point *b*, where the edge is beveled off; *h* is the needle with the eye near the point, that has been thrust through the fabric, with the thread *e*, the loop of which has just been entered by the point of the hook *a*. The lower thread is contained in a double convex metallic bobbin, to lie in the concavity Y of the hook E, and held in its position by a concave ring (not represented) between which

3322.

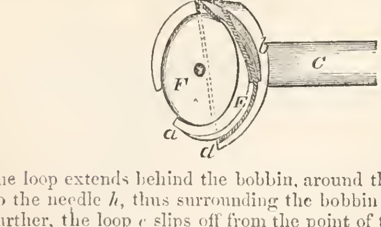


3323.

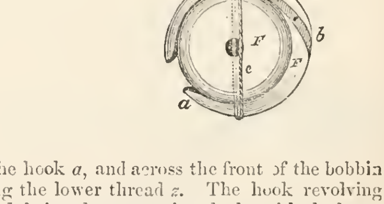


and the concave surface of the disk it lies. No axis passes through it, so that a loop of thread can pass around it as around the small ball of thread in the last diagram. By the revolution of the hook after entering the loop of the upper thread, this loop is enlarged and carried forward. Fig. 3323 represents the hook as having made about one-third of a revolution, and the lower thread *z* extending from the lower surface of the fabric to the bobbin in the concavity of the hook containing it. The upper thread *e*, extends through the fabric from a previous stitch, down into the concavity of the disk, behind the bobbin, around the hook at the point *d*, thence diagonally along the groove and to the eye of the needle *h*. Fig. 3324 represents the hook as having made about half a revolution, with the bobbin F in its proper position. The upper thread *e* has been drawn further behind the bobbin, thence around the hook at *d*, and diagonally across the periphery of the hook in the groove by *b* to *h* the needle. As the hook further revolves to the position in fig. 3325, both lines of the loop *e* are upon the same side of the hook. The line of thread that extended in fig. 3324 along the groove of the hook from *d* to *b*, has slipped off at the termination of this groove, and fallen in front of the bobbin F, so that

3324.



3325.



the loop extends behind the bobbin, around the point of the hook *a*, and across the front of the bobbin to the needle *h*, thus surrounding the bobbin and inclosing the lower thread *z*. The hook revolving further, the loop *e* slips off from the point of the hook, and being drawn up, interlocks with the lower thread *z* in the fabric, and forms a stitch similar to those represented in the several figures above.

The following is a description of the accompanying plates.

To illustrate more clearly the method of making the Howe stitch by the Wheeler & Wilson Machine, we have exhibited the rotating hook E and the bobbin F, carrying the lower thread detached from the machine. In the subsequent figures the same parts are represented in their proper places combined with the other parts of the machine, and which are respectively numbered as follows: 1, 1, the Bed Plate supporting 2, 2, the front standards, and 3, 3, the back standards. 4 is the Arbor with its bearings in the front standards, and upon which are, 5 the Rotating Hook, 6 the Feed Cam, 7 the Band Pulley, 8 the Eccentric Ring, and 9 the Spooling Spindle. Moving in grooves in the front standards is 10 the Feed Bar; 11, 11, Ears of the feed bar, 12 the Spiral Feed Spring, working between the left front standard and the left ear of the feed bar. 13 the Feed Tongue, slotted in the feed bar, and furnished with 14

Feed Points. 15 is the double convex metallic Bobbin, containing the lower thread, and held in the concavity of the rotating hook by 16, the Bobbin Ring, mounted upon 17, the Ring Bar, sliding in a groove in the bed plate, and held by 18 the Thumb Screw. 19 is the Fixed Arm, projecting from the back standard, and supporting 20, the Cloth Presser, attached to the Piston in 21, the Piston Cylinder. 22 is the Thumb Screw of the cloth presser, 23 the Lever of the cloth presser. 24 is the Needle Rocker, pivoted upon 25, 25, the Centre Screws, 26 the Short Arm of the rocker hinged by 27 to 28 the Connecting Rod. Upon the rocker is 29 the Needle Arm, bearing 30 the Thread Spool, 31 the Spool Brake, 32 the Brake Screw, 33, 33 the Thread Eyelets, 34 the Needle Yoke, 35 the Needle. 36 is the Loop Check, 37 the Spool Pin, 38 a spool of Thread, 39 a Thread Guide, 40 a Tension Pulley, 41 volute Tension Spring, 42 large Seam Gauge, 43 Gauge Screw, 44 Screw for Small Gauge, 45 the fabric sewed, 46 the Cloth Plate, 47 Table Screws. 52 Feed Slots, 53 Set Screw, 54 Feed Stop, 55 Stop Pivot, 56 Thread Guard, 57 Thread Hold, 58 small Gauge, 59 Spiral Spring of the cloth presser, 60 Needle Hole.

In constructing the machine, the lower surface of the bed-plate 1 1 is planed with perfect exactness, and made the plane to which all the planes and lines of the machine are adjusted. The standards 2 2 are levelled to a plane parallel with the plane of the bed-plane, at a fixed height above it, and pierced in another parallel plane for the arbor 4, and grooved in a parallel line for the feed-bar 10. The bed-plate is grooved in the same line for the slide bar 17; the standards 3 3, are pierced parallel to the line of piercing in 2 2, for the centre screws 25 25; and the arbor 4, and the rocker 24, are adjusted parallel to each other and to the plane of the bed-plate 1 1. The connecting-rod 28, the short arm 26, the needle arm 29, the fixed arm 19, are adjusted at right angles to the lines of 4 and 24. The rotating hook 5, the bobbin 15 and the needle 35, move in planes vertical to the plane of the bed-plate 1 1. The rotating hook is a portion of the thread of a screw, formed upon the periphery of this circular concave disc. To the left of the notch *d*, is a portion of another parallel thread of the screw: the disc is cut away below the point *d* into its concavity, so that the thread of the screw forms the clear point of the hook *a*. The groove between the two threads of the screw extends diagonally across the periphery of the hook disc to the point *b*, where the hook thread of the screw is entirely chamfered off and the groove disappears. The concave surfaces of the disc, and the slide ring 16, contain the bobbin 15; the needle 35 is curved to the arc in which the end of the needle arm vibrates. A perfectly rectangular figure is formed: the arbor 4 forms one side; the connecting-rod 28, the second; the rocker 24, the third; and the needle arm 29, with the needle 35, and the rotating hook 5, the fourth. The opening is made for sewing between the needle and the hook.

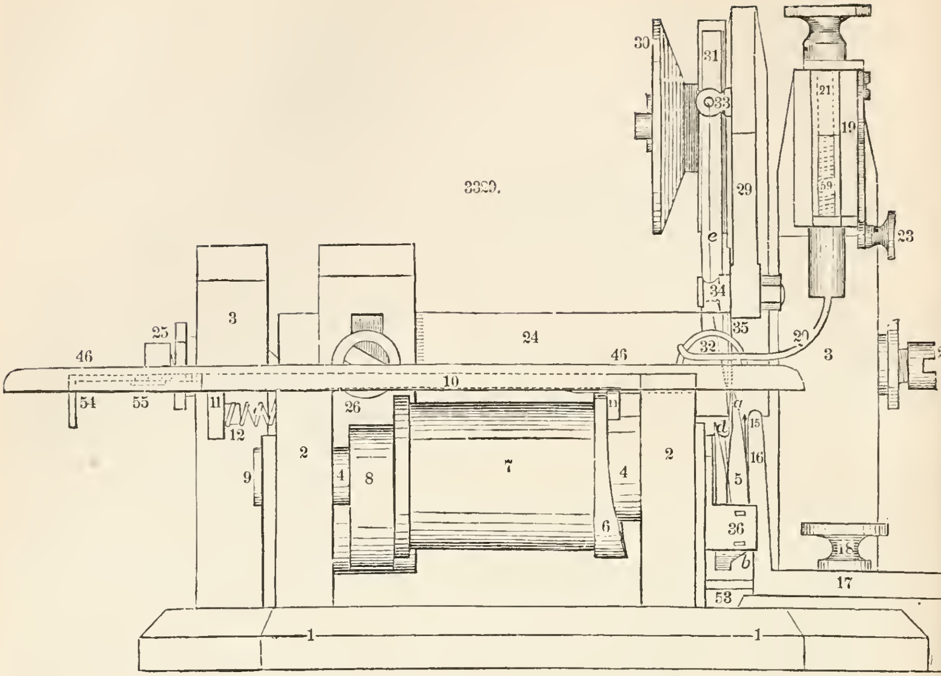
The working parts are secured to a frame constituted by the bed-plate 1 1, and the standards thereon, 2 2 and 3 3. The slide ring 16, is adjusted by the set screw 53, to retain the bobbin 15, and allow it to turn freely in the concavity of the hook disc. The needle 35 is adjusted with its head in the needle yoke 34, to vibrate through a small hole 60, in the cloth plate 46, and so that in its rise the eye will be brought just below the point of the hook *a*, which revolves so close by the right side of the needle 35, that nothing can lie between them as they come opposite each other. The eccentric ring 8, through the connecting-rod 28 and the rocker 24, vibrates the needle arm so that it begins to rise just before the point of the hook *a* reaches the needle. The pressure of the fabric upon the thread about the needle as it begins to rise, loops the thread slightly upon the right of the needle; this loop is caught, enlarged and carried around the bobbin as before illustrated. When the loop of thread is about to slip from the hook, as is represented on fig. 3325, it is checked for an instant until the hook has completed its full revolution and enters the next loop, in the process of enlarging which, it draws up the loop already formed. 36, the loop check employed, is a small piece of leather or an equivalent, held in contact with the periphery of the hook, so that the loop cannot pass until the chamfered part *b* of the hook reaches and frees it, as it does, just as the hook enters the next loop.

This rotating hook is of singularly ingenious, simple, and novel construction, and is equivalent to several pieces of elaborate machinery. It performs the three operations of enlarging the loop of the upper thread, passing it around the bobbin carrying the lower thread, and tightening the preceding loop.

The bobbin 15 is placed in its proper position, with the thread flowing from the top towards the front of the machine, in which direction it revolves slowly. The thread is wound upon this bobbin with great facility, at the rate of one hundred yards per minute. For this purpose it is placed upon the spooling spindle 9, and the spool of thread upon the spool pin 37; the thread is then rewound upon the bobbin by working the treadles as in sewing.

The upper thread may be used from the original spool 38, or from another spool 30 on which it has been rewound. The tension of the two threads used is a point of importance. To form the stitch perfectly, the point of interlocking the two threads should be drawn to the centre of the fabric sewed, so that each thread may be held firmly, and the seam present the same appearance upon each side—a single line of thread extending from stitch to stitch. In this machine the tension of the lower thread is rendered sufficiently great by the friction between the surface of the bobbin 15, and the rotating hook in the cavity of which it is placed, the two revolving in opposite directions. The tension of the upper thread must be so adjusted, as to draw the lower thread into the fabric in the formation of a stitch.

Were the spools of thread always uniform, and the thread uniformly wound, there would be no difficulty in using the thread from the original spool. But this is not the case. In fig. 3331 it is shown as fed from the original spool 38, through the thread guide 39, to the tension pulley 40, and thence through the eyelets 33, 33, to the needle 35. The tension is attained by the volute spring 41, pressing upon the wheel 40, which may be regulated at pleasure by the thumb screw at the end. In fig. 3331 the tension is attained by the break 31, upon the spool 30, and which is regulated by the thumb screw 32. The next point of importance is the Feed. This is that part of the mechanism by which the fabric to be sewed is moved forward, and the length of stitch regulated. The length of stitch does not depend at all upon the speed of the machine, but upon the feed alone.



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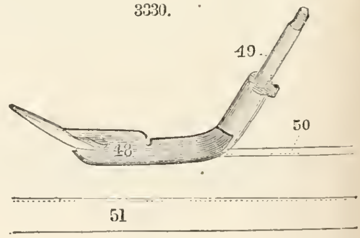

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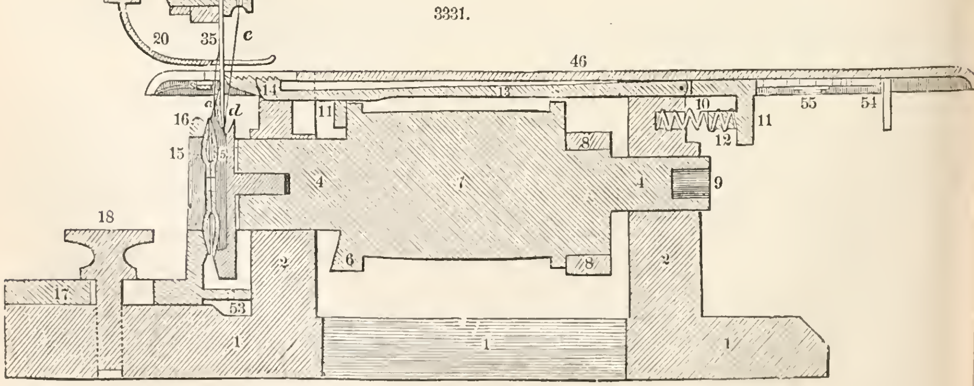
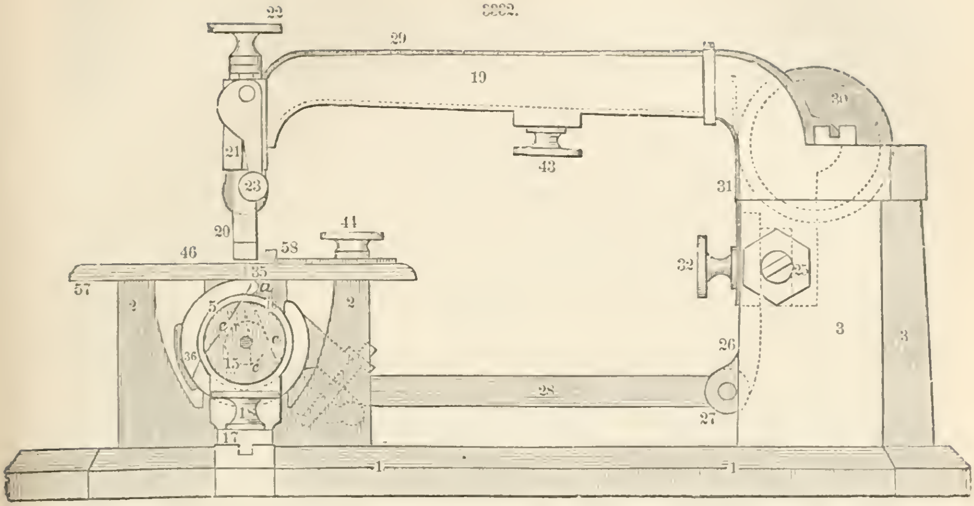


3331.

3332.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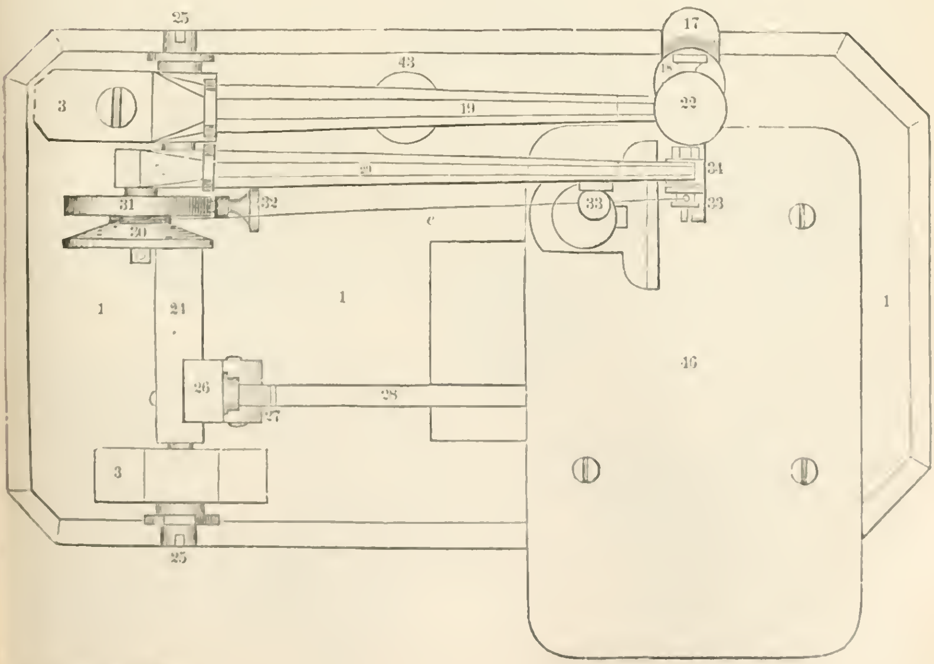
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The feed consists of a bar 10, lying in grooves in the front standards, and directly beneath the cloth plate 46. It has a slot nearly its entire length, in which is pivoted, near the left end, a tongue 13, with its right end resting upon the right front standard, armed with two rows of small points 14. The relative position of the feed bar and its appendages to the cloth plate is best seen in fig. 3327. The cloth plate is furnished with a slot 52, through which the feed points when raised project, and enter the fabric held upon the cloth plate by the cloth presser 20. The feed is worked by the cam 6, which rotates with the arbor 4. As this cam revolves, the swell of its periphery strikes the under surface of the feed tongue 15, and raises the feed points 14, through the slot 52, while the swell on the right side of the cam 6, presses upon the right ear 11 of the feed bar, and throws it forward. The cam further revolving, brings a point of depression both on its periphery and its side next to the feed bar ear, when the points drop below the surface of the cloth plate, and the feed spring 12, throws the bar back to the left against the feed slot 54, and the next revolution of the cam throws it forward again. It will be observed that while the needle penetrates the cloth, the feed points are below the surface of the cloth plate, and intermit their action upon the cloth; hence the needle constitutes a pivot upon which the fabric may be turned to sew a curved seam of any radius.

The feed points rising and penetrating the cloth at each stitch, their movement forward determines the length of the stitch, which is graduated by regulating the play of the feed bar. The play of this bar is limited to the difference between the narrowest and the widest parts of the feed cam, which is about one-fourth of an inch, and may be graduated to any length within these limits by the eccentric feed slot 54, against which the heel of the feed bar is thrown by the feed spring 12. As the narrowest or widest parts respectively of this slot are turned towards the feed bar, greater or less play of it is permitted, and longer or shorter stitches are made. This slot is turned with great facility while the machine is in motion, by pressing upon the lever with which it is furnished. The machine when used is mounted upon a neat work-table, and driven by sandal treadles and band 7. The fabric to be sewed 45, is laid upon the cloth plate 46, beneath the needle, and held by the cloth presser 20. The operator seats herself before the table, on which the machine is placed, with her feet upon the sandal treadles by which the machine is driven. The threads being adjusted, the machine is touched into motion by a gentle pressure of the feet upon the sandals. The cloth moves forward from left to right, and the sewing is accomplished in the manner above described. Two and one-half yards of thread is the average required for a yard of sewing. There is no limit to the number of stitches that may be made in any given time. The driving wheel is graduated ordinarily so as to make five stitches at each tread, so that from six hundred to one thousand stitches per minute are readily made.

The bearings and friction surfaces are so slight, that the propelling power required is merely nominal. The rotary hook, feed, bobbin, and other parts at all subject to wear, are made of finely tempered steel; the other parts of the machine are tastefully ornamented, or heavily silver plated.

Various appliances are furnished for regulating the widths of hems, etc., as 42 and 58. The seam guide 42 is attached to the fixed arm 19, by the thumb screw 43, and extends down over the cloth plate with various projections for guiding the work. It is slotted and jointed so as to be adjusted in various positions. A smaller gauge 58 is commonly used, but not in conjunction with 42. It is fastened to the cloth plate by the thumb screw 42.

Another appendage is the hemmer 48; it is used in place of the cloth presser 20, and is in fact a cloth presser, so convoluted, that as the edge of the cloth passes through it is turned down as in ordinary hemming and beautifully stitched. All numbers of thread are used, and needles of various sizes are furnished suited to the several threads.

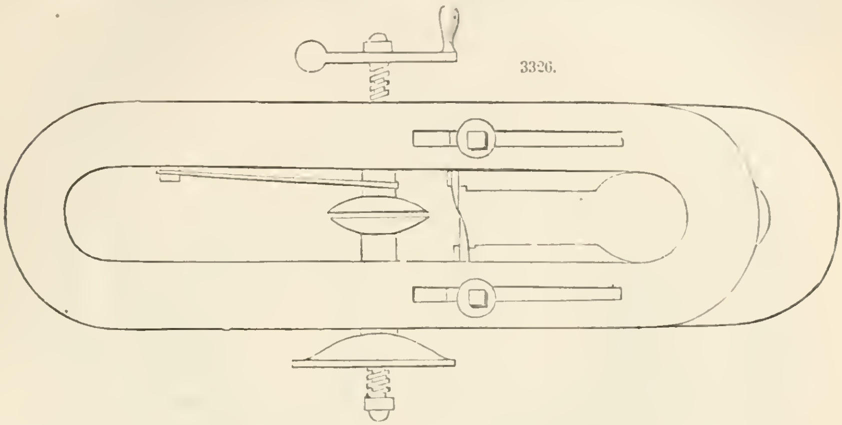
Thousands are used by seamstresses, dressmakers, tailors, manufacturers of skirts, cloaks, mantillas, clothing, hats, caps, corsets, ladies' gaiters, umbrellas, parasols, silk and linen goods with complete success; sometimes from one hundred to two hundred are used in a single manufactory. The amout of sewing that an operator may accomplish depends much upon the kind of sewing and her experience; one thousand stitches per minute are readily made, which would form more than a yard of seam with stitches of medium length. Fifty dozens of shirt collars, or six dozens of shirt bosoms are a day's work. Upon straight seams an operator with one machine will perform the work of twenty by hand; on an average one probably performs the work of ten seamstresses.

The Wheeler & Wilson machine is applicable to every variety of sewing for family wear; from the lightest muslins to the heaviest cloths. It works equally well upon silk, linen, woolen and cotton goods, seaming, quilting, hemming, gathering and felling, performing every species of sewing except making button-holes, stitching on buttons, and the like. Its mechanism is the fruit of the highest inventive genius, combined with practical talent of the first order. Its principles have been elaborated with great care, and it involves all the essentials required in a family sewing machine. It is simple and thorough in construction, elegant in model and finish, facile in management, easy, rapid, and quiet in operation, and reflects additional credit upon American mechanical skill.

SHEARS ROTARY, Ruggles' Patent. This machine is made of sizes adapted to cut sheet metal of all numbers. One straight and one circular cutter are employed, the latter being revolved and moved slowly along the edge of the former. The cutting edges do not lap by each other except in cases of very thin metal, but are at a vertical distance of about half the thickness of the metal to be cut.

SHEARS ROTARY. Fig. 3326 is a representation of Bulkley & Norton's patent improved rotary shears. The shears, when used, stand in the position of the figure, and revolve upon the perpendicular axis or standard. The material to be cut is placed between the clamps, put up to the cutters and the gauge, and held there by the screw, and is cut by one revolution of the machine.

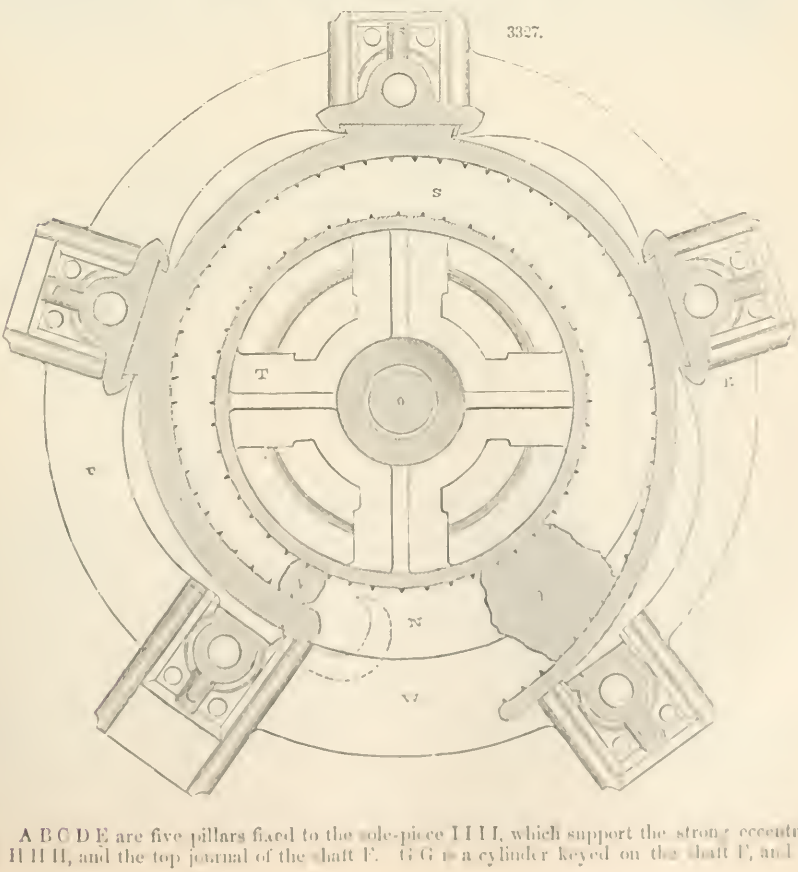
The cutters revolve and are placed upon a movable half bows, which is easily set to any required size. A boy can use them, and his work will be cut perfect, while there is great saving of labor and stock, as it leaves the work and pieces perfectly smooth. They will cut any wire varying but a hair's breadth from 2½ to 22 inches in diameter. The above shears have been in constant use in various heavy manufacturing establishments more than five years, and the many high testimonials of their value which we have seen are fully corroborative of their excellence. When tin is required to be cut in a circular form these shears must be exceedingly useful; indeed it is said that an entire box of tin can be cut perfectly uniform in twenty or thirty minutes by this improvement. Orders for these shears are addressed to the patentees and proprietors, Messrs. Bulkley & Norton, Berlin, Conn.



3326.

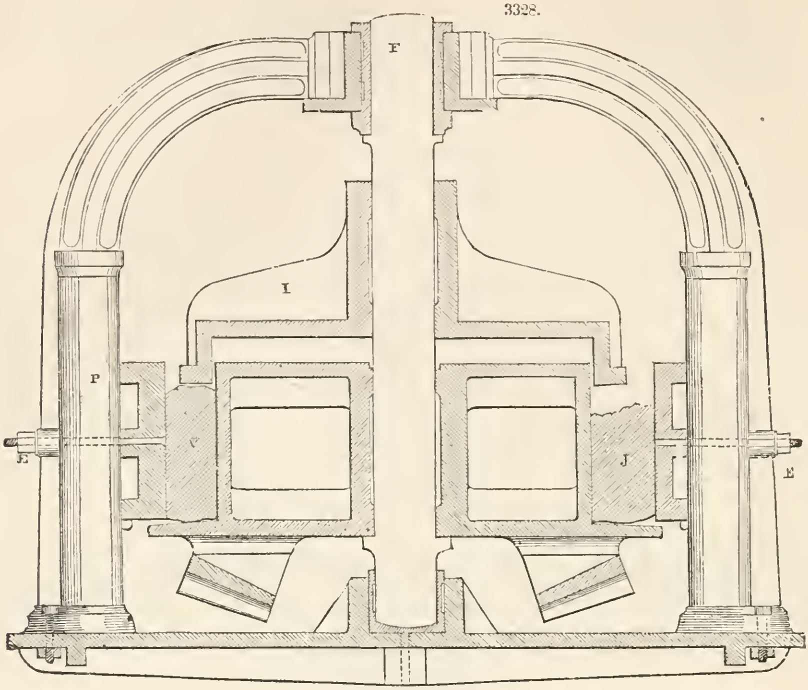
SHINGLER, BURDEN'S PATENT. This machine, which is represented in Figs. 3327, 3328, and 3329, is the invention of HENRY BURDEN, Esq., of the Troy Iron Works, New York. Fig. 3327 is a cross-section through B F E. Fig. 3328 is a vertical section through B F E. Fig. 3329 is a perspective

3327.



view. A B C D E are five pillars fixed to the sole-piece I I I I, which support the strong eccentric casing H H H H, and the top journal of the shaft F. G G is a cylinder keyed on the shaft F, and driven

3328.



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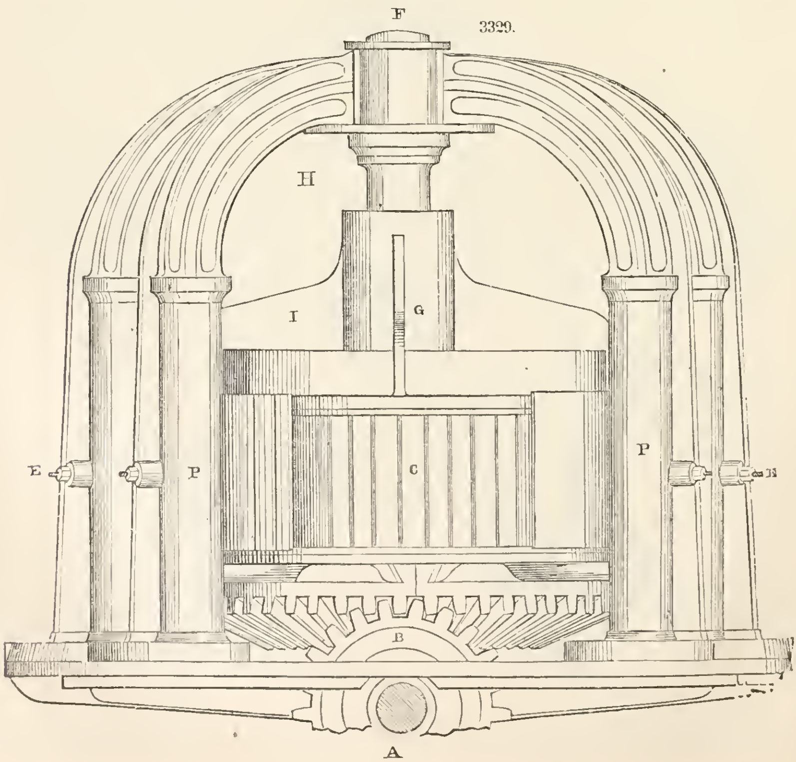


in the direction of the arrow by the pinion I. K K is a heavy ring or thimble which is allowed to rise and fall up and down the shaft F; its weight upsets the upper end of the bloom. The dotted line at L represents a large hook, to deliver the bloom when finished. The dotted line at M represents a scraper to clean away any slag that may remain on the flange of the cylinder. D is the rough bloom entering, and E is it just leaving in its finished state. F F F F are flanges to strengthen the eccentric casing. The bloom being thrown in at the wide end is laid hold of by the cylinder, and by its action pressed against the outside casing, and revolving on its own axis, is taken through the machine, being thus gradually brought to its finished state, and at the same time deprived of its scoria. The under end of the bloom is upset by the action of the flange of the cylinder, and the upper end by that of the lifting-ring K K, in the most perfect manner.

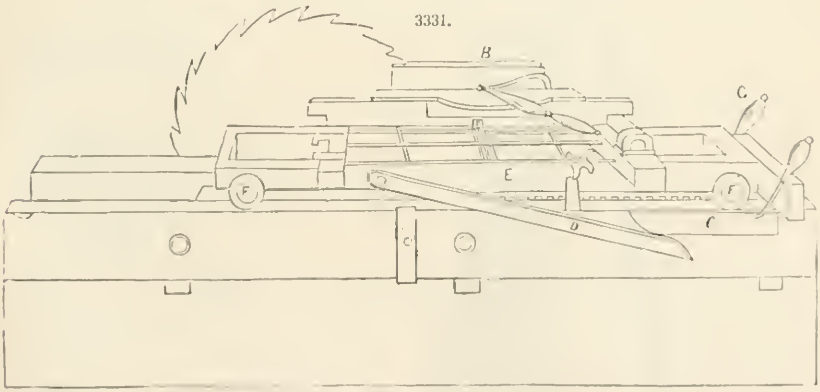
The advantages are:—1. The entire saving of shingler's wages, no attendance being necessary. 2. Very considerable saving in first cost. 3. Great, or rather, almost entire saving of repairs. 4. Considerable saving in power. 5. The immense saving, in time, from the quantity of work done, one machine being capable of working to sixty puddling furnaces. 6. Saving of waste, nothing but the slag being thrown off. 7. The staffs are also saved. 8. It will be readily seen, from the shortness of the time required to finish a bloom, (six or seven seconds,) that the scoria can have no time to set, and is thus got rid of much better than when allowed to congeal. 9. The blooms from this machine being discharged so perfectly hot, they roll much better, and thus, besides being much easier on the rollers, the bars produced are much sounder and better finished.

By the use of this machine, common iron, of an excellent quality, can be finished off at the first heat, viz., that of the puddling furnace.

SHINGLE MACHINE—JOHNSON'S. Fig. 3331 represents a machine invented by Mr. J. G. Johnson, of Augusta, Maine.

The machinery is adjusted to a frame of 10 feet in length by 3 feet 10 inches in width. On this is placed a movable carriage E E, which runs on trucks attached to the carriage F F. B is the block or bolt of wood to be sawed, and is held in its place by dogs. C is a piece of wood fastened on the end of the frame, the object of which is to cause the lever D to turn the set-shaft one quarter round every time the carriage returns back; this lever is raised by a piece of wood fastened to the main frame. To this lever is also fastened a hook, which hooks on to the set-shaft. G G are handles attached to a rod which has a cam on it. By turning the handles up, the rack is raised out of geer and stops the carriage while the operator supplies another bolt or block of wood. The set-shaft has a dog on each end, placed at right angles so as not to set but one of the blocks at a time. Those dogs move two gages that are secured to the headstock which holds the block or bolt of wood. The carriage is fed by a decreased motion received from the saw-shaft.

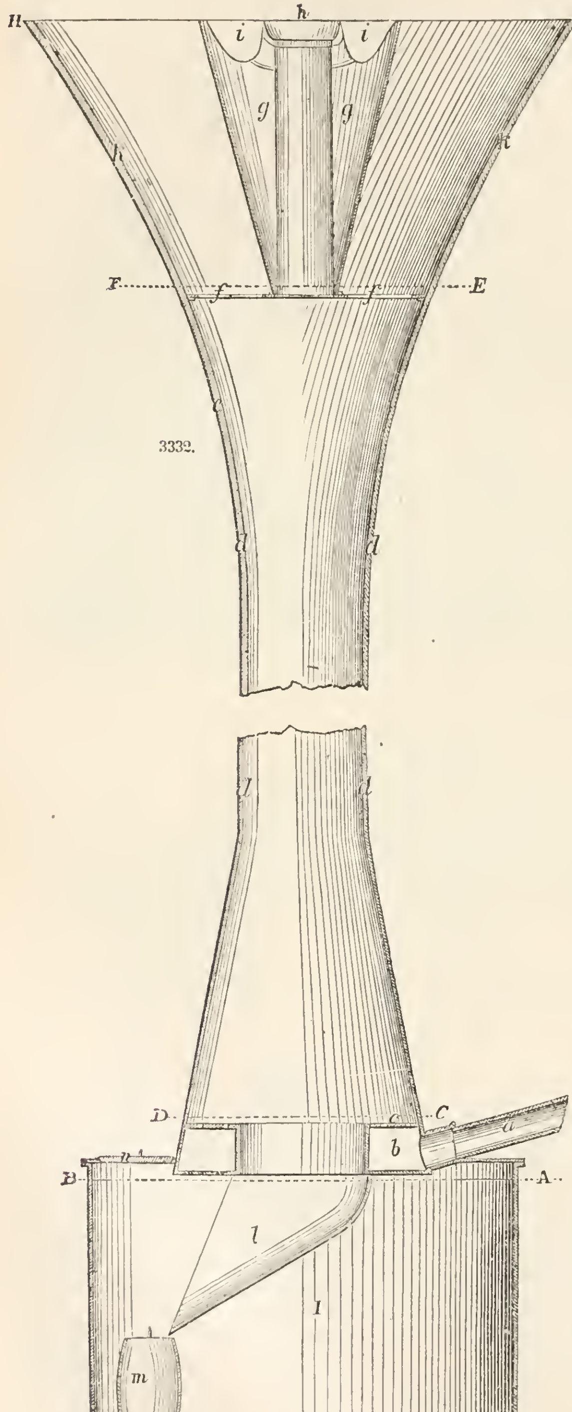
3331.



SHOT. The usual method of making lead shot, is by letting melted lead, with a small alloy of arsenic, fall through the air from a considerable elevation, and thus the leaden rain becomes cold, and solidified into leaden hail or shot. To carry out this process, high shot towers are erected; at the top the lead is melted and poured into colanders with different sized holes according to the size of the shot required. That the shot may not be bruised in falling upon one another, they are received into a vessel of water at the bottom. To separate the imperfect shot, a slab of polished iron is tilted at a certain angle, and the shot are strewed along the upper part of the inclined plane thus formed. The perfect shot proceed rapidly in straight lines and fall into a bin placed to receive them, about a foot distant from the bottom of the slab, whilst the misshapen shot on the contrary, travel with a slower zig-zag motion and fall without any bound into a bin immediately at the foot of the incline.

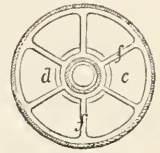
To obviate the necessity and expense of high towers, an expedient is in use for causing the fused metal to fall through an ascending current of air. This method, of which the following is a description, has been secured to David Smith by patent.

Fig. 3332 is a vertical sectional elevation of a sheet metal cylinder, set up as a tower within a building, and may be of about twenty inches internal diameter to each fifty feet of height, or nearly in such proportions for other heights. Fig. 3333 is a plan at the line A B of Fig. 3332; Fig. 3334 is a plan at the line C D of Fig. 3332; Fig. 3335 is a plan at the line E F of Fig. 3332; and Fig. 3336 is a plan at

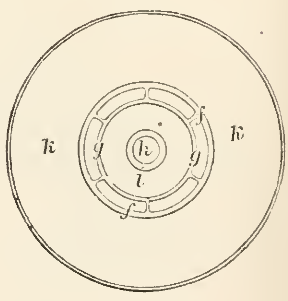


3332.

3335.

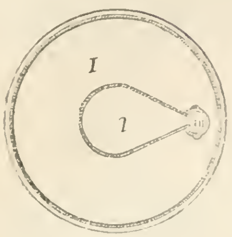


3336.

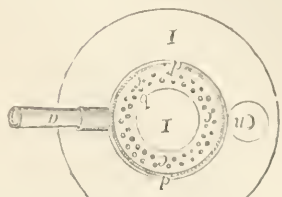


the line G H of Fig. 3332. The similar letters used as marks of reference apply to the like parts in all the figures.

3333.



3334.



In these, I is a water-cistern beneath the tower. A is a pipe from any competent blowing apparatus, leading into a hollow annular ring-chamber *b*, the bottom of which is to be supported in any proper manner above the cistern I; the inner face forms a portion of the passage for the descending shot; the upper face *c* is fitted with holes, as shown in plan Fig. 3334, to pass and dispense the entering and ascending air; and the outer side of the ring *b* forms the base of a truncated cone that sustains a metal cylindrical tower *d d*, which at *e e* spreads to pass the ascending blast through a frame *f f*; this is shown in plan Fig. 3335, and in Fig. 3332 is shown as sustaining a cylindrical standard *g*, the upper central portion of which receives the pouring-pan *h*: this is made changeable for each separate size of shot, to be made by larger or smaller holes through the bottoms of the successive pans, as usual; and round the pouring-pan *h* is a circular waste-trough *i*; round these parts the tower *d d* finishes also a trumpet-mould K K. The intent and effect of this arrangement is, that the fluid metal running through the pouring-pan *h* into the ascending current of air, in a tower fifty feet high, when the air is passing up with twice the velocity of the descending metal, will be operated on to the same, or to a greater extent, by the air, as when it falls through the stagnant air in a costly tower of one hundred and fifty feet or more high; and in the like proportions with the greater or less velocities of the ascending current of air. The particles of metal fall through the open centre of the ring *b* into the water in the cistern I, where, for convenience, a shoot *l* carries the particles of metal into a tub *m*, which may be placed empty, and removed when full through a scuttle *n* in the cover of the cistern.

The patentee does not intend to confine himself to the proportions of the parts as here described, nor does he intend confining himself to the parallel cylindrical form of the tower *d d*, *k k*, as this may be made more or less conical; and the other parts may be varied in any way that is substantially the same, in the means employed to produce the like and intended effects.

SHUTTLES. See LOOM.

SILEX. The earth of flints. The characteristic ingredient of a great variety of minerals, as quartz, chalcedony, flint, etc.; the predominating material in granite, many varieties of sand stone and quartz rock. Its chief importance in practical arts is in the manufacture of GLASS.

SILVER. See METALLURGY.

SINKING. In mining, digging downwards. In *rising* and *sinking* a shaft one set of men sink from an upper level while another set *rises* from a lower level and meet them.

SLATE. An argillaceous stone, readily split, and employed to cover the roofs of buildings. Most of the slate at present used in this country is Welsh, but within a few years it has been extensively quarried in Vermont.

Slate has heretofore been all cut out in quarries by hand labor. The workmen with picks cut grooves in the rock to the depth required, and then the slate comes off in thin layers the size of the space between the cut grooves, forming rectangular slabs. To supersede this slow method of quarrying slate, H. J. Bremner, of Nazareth, Pa., has invented a machine, in which cutters are operated so as to feed forward and cut out a groove in one direction, the desired length, and then it (the machine) is turned, and the cutters made to cut a transverse groove, and thus proceed until the rock is so grooved that the space between the side and two end grooves or cut channels, forms a slab of the size desired for the slate; the slate is then forced out, and splits easily into as many separate slabs as there have been horizontal layers from the surface to the depth the cutters have penetrated.

Machine for Cutting and Trimming Slate. A machine for cutting and trimming slate has been invented and patented by Asa Keyes, of Brattleboro', Vermont. The nature of the invention consists in applying a rapid succession of stone hammer blows, each of which beats off a minute piece of the slate, while it (the slate) is carried along by a carriage on ways. The wheel which carries the hammers or cutters is heavy, and this weight of the wheel not only furnishes the momentum of the individual blows of each hammer, but supplies the purpose of a fly-wheel to the machine. The hammers are held into mortises cast in the wheel, by bolts and nuts.

SLEEPERS. Pieces of timber laid on the ground, taking a bearing their whole length; the term is applied to the cross ties on a railroad.

SLIDE-REST. See TOOLS.

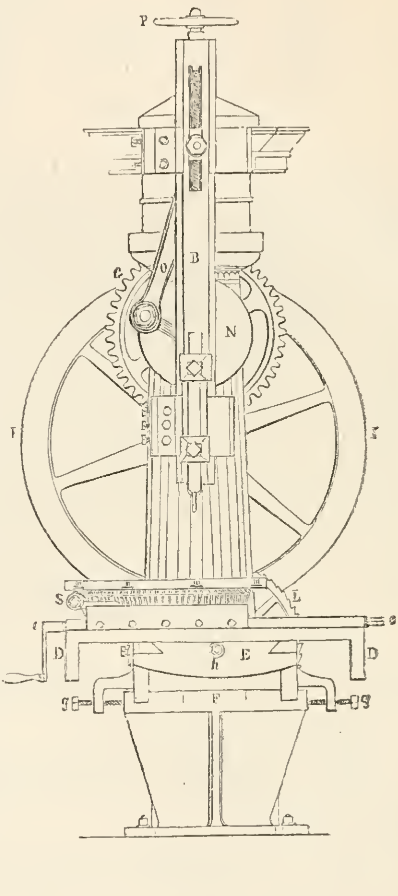
SLIDE VALVE. See ENGINES, AND LAP AND LEAD OF SLIDE VALVES.

SLIDING RULE. A rule constructed with logarithmic lines, formed upon a slip of wood, ivory or brass, inserted in a groove in another rule, so that by means of another scale upon the rule itself the contents of a surface or solid may be known.

SLOTTING MACHINE, *Self-acting*, by CAIRD & Co., Greenock. The following figures represent a machine adapted for slotting or paring work of moderate size, and for cutting the key-grooves or seats of wheels not exceeding five feet in diameter. It is at once elegant in design, simple in construction, and capable of adaptation to a great variety of circumstances.

Fig. 3337 is a front, and Fig. 3339 a side elevation of the machine, showing the general arrangement of the working parts. Fig. 3338 is a general plan, and Fig. 3340 a transverse section of the work-table and part of the framing on which it rests.

3337.

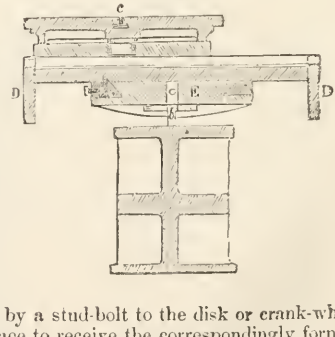


The framing consists of a strong fluted column A, with two brackets of proportionate strength for carrying the working geer and slotting-bar, and a sole-frame for supporting the work-table and its appendages, and having a strong bottom plate by which the machine can be bolted to a stone foundation. The whole of this framing consists of a single casting, and therefore may be presumed to possess all the strength and rigidity which can possibly be obtained with the form adopted and the weight of metal employed; two conditions of the utmost importance in machines of this kind, in which the strain varies suddenly from the mere weight of the slotting-bar to the maximum pressure necessary to effect the cut.

The projecting palms of the brackets are faced and formed with dovetail edges, between which the slotting-bar B slides in its up and down motion. Two of these dovetail pieces are attached by screws, and can be adjusted by set-pins, as they are worn by the sliding action of the bar. On the lower extremity of this bar the slotting-tool is attached by two glands and set-screws, in the usual way; and, at some distance from its upper end, it has an adjustable stud fitted into it, to which the upper end of the connecting-rod O is jointed. The mode of fixing and adjusting the stud is clearly shown in the front elevation of the machine. From this view it will be observed that the bar has a long slot, occupying about a third of its length at the upper end, between the parallel cheeks of which the rectangular body-part of the stud is accurately fitted. This part of the stud is formed with shoulders which bear against the inside of the bar, and has a strong screwed pin projecting from its exterior surface, on which a large pinching-nut is passed. This nut being screwed tight against the face of the bar, the stud is effectually secured from shifting its position in the slot, by the friction induced between the bar and the shoulders of the stud on the inside, and the nut on the outside.

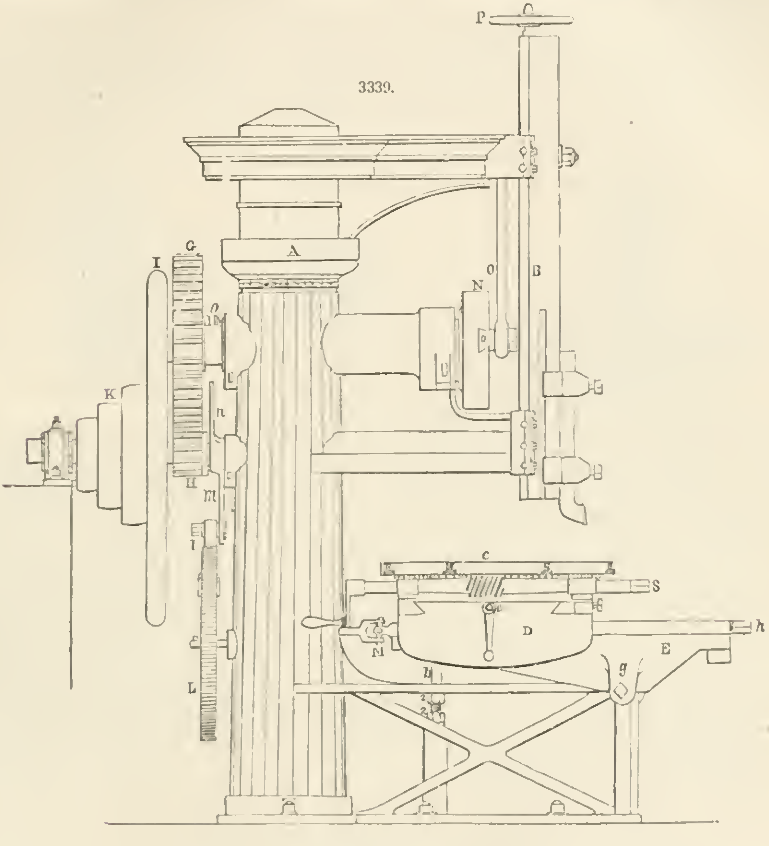
The rectangular body of the stud is traversed by a long square-threaded screw, which occupies the whole length of the slot in the bar, and which can be worked by the small hand-wheel P, fixed on its upper end. This screw is so fitted into the machine as to have no end-long motion independent of the bar; but when turned by means of the wheel P, on its upper extremity, it will cause the stud to assume any required position in the slot. But it is easy to perceive that by changing the position of the stud in the slot, the height of the slotting-bar will be correspondingly changed in relation to the work-table of the machine. In effect the stud may be considered as a fixed point by which the bar is suspended, and consequently by turning the hand-wheel of the screw in one direction or other, the bar will be correspondingly elevated or depressed, and the tool thereby set at any height above the table that may be necessary for the kind of work under operation. And when it is so adjusted, the stud is made fast in its place by tightening the pinching-nut on the screwed tail projecting in front of the bar, as above described.

3340.



The lower end of the connecting-rod O is flexibly attached by a stud-bolt to the disk or crank-wheel N, which has a radial dovetail groove *a* formed in its plane face to receive the correspondingly formed head of the bolt. This bolt or stud is embraced by a strong ferule of slightly greater length than the eye of the connecting-rod, which fits upon it freely; and being in its place, a large nut is passed upon the projecting end of the bolt, which fixes the ferule between it and the edges of the groove in the face of the wheel, and thereby effectually secures the stud in the required position, while the connecting-rod is left free to revolve on the ferule, in consequence of the latter being slightly greater in length than the eye of the rod. The position of the stud in relation to the centre of the crank-wheel obviously determines the length of the stroke of the slotting-bar. Thus, the wheel admits of the stud being fixed at seven and a half inches from the centre as a maximum, and therefore the utmost throw will be fifteen inches.

3339.



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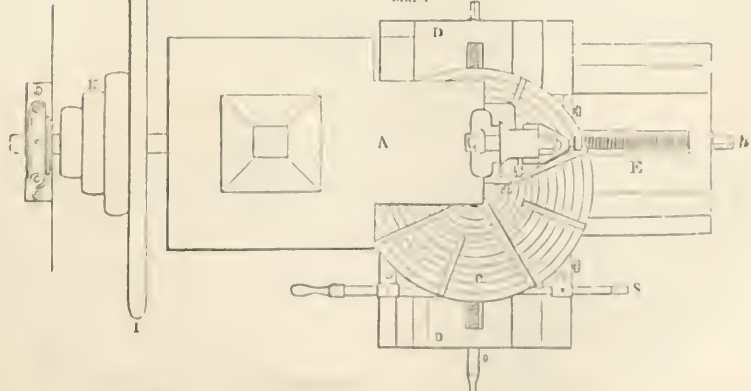


The crank-wheel N is fast upon the end of a strong shaft which passes through a long socket cast in the middle bracket of the frame, and which is bushed at the two extremities. These bushes are formed in halves, to admit of their being adjusted, as they wear, by cotters acting against the under brasses, as shown in the side elevation of the machine. On the opposite end of the crank-wheel shaft is keyed the spur-wheel G, which geers with the pinion H on the driving-shaft. The cone-pulley K receives motion by a strap from the main shaft, and is susceptible of three modifications of speed, to suit the kind of work under operation, the fly-wheel I rendering the motion uniform, and obviating the jerks and variations to which it would otherwise be liable. This shaft has one of its bearings in the columnar frame of the machine, while the other is independently supported by a pillow resting on the sole of a wall recess.

The sliding-table D is movable on the upper surface of the bed-plate E, in a direction parallel to the sole-frame of the machine; and the circular table C is capable of sliding horizontally on this last, in a direction at right angles to the direction of motion of the table D. From the sectional view, Fig. 3340, it will be observed that the table C is provided with a rectangular sole-plate, to which it is attached by a central stud and socket, in such a manner as to be capable of working freely on the stud as on an axis. By this arrangement two motions of the upper table are obtained, one rectilineal and the other circular. The rectilineal motion is obtained from the sole-plate, on which are bevelled ledges, adjusted to slide in corresponding faces formed on the table D, as shown in Fig. 3338; and the circular motion is obtained by causing the upper plate to revolve on its centre. The first of these motions is communicated by means of a screw *e*, which passes through a longitudinal recess, formed for its reception in the table D, and works into a nut attached to the sole-plate of the upper table. To obtain the circular motion, the table C is formed with a worm-wheel on its circumference, into which the worm on the spindle S geers; and as this spindle is attached by its bearings to the rectangular sole-plate, which cannot revolve in consequence of its attachment to the table D, it is obvious that by turning the crank-handle on the worm-spindle, the plate C will be made to revolve on its central stud.

The table D can also be worked by hand, by placing a crank-handle on the square end of the screw *h*, the self-acting mechanism to be described presently being out of geer. This screw has its bearings in the bed-plate E, and works in a nut attached to the under side of the table. It may also be observed that one of the dovetail or bevelled ledges of each of the sliding-tables is adjustable by set-screws when reduced by wearing, as shown in the section of the table D.

A self-acting motion may be given to the under table by means of an arrangement of parts shown in the side elevation of the machine. These consist of the ratchet-wheel L, which is keyed upon the end of a spindle connected by a universal joint at M, with the screw *h*; and a pawl *l*, attached to the end of the lever *m*, on the same axis and formed of a piece with the lever *n*. In one arm of the wheel G is fixed a stud *o*, carrying a small friction pulley, and adjustable, like the stud in the crank-wheel, to any required distance from the centre. This stud, as the wheel revolves, comes in contact with the lever *n*, which, being loose on its axis, yields to the pressure, and through the lower arm *m*, and pawl *l*, transmits its motion to the ratchet-wheel, and through this again to the screw *h*. The pawl *l* can be applied to either side of the ratchet-wheel, so that the table may be made to travel upon the bed E, in either direction, and as the throw of the lever *n* can be regulated by the position of the stud *o*, the amount of the feed motion may thus be adjusted to the kind of work. The object of the universal joint at M is to permit the table to be set at a small angle with the horizontal plane, when necessary, as in cutting the key-seats of wheels. This is effected by raising the inner end of the table by means of the screwed link *b*, jointed to the bed-plate E, as shown in Fig. 3340, and acted upon by the set-nuts marked 2, 2, shown in the side elevation of the machine. The bed-plate of the table, when in this position, is supported by two palms fitted to a cylindrical piece formed on the front of the main sole; and is prevented from moving laterally by the set-screws *g g*.

The circular motion of the table C may be communicated by the handle on the end of the worm-spindle S; but, to render it self-acting, a double ratchet-wheel is substituted for the handle, and is worked by pawls attached to a rocking-lever, which communicates by a series of small rods with the lever *m*. The transverse motion of the upper table can also be given by the handle on the end of the screw *e*; but a ratchet may also be substituted for this handle, and worked by a pawl connected with the levers employed to transmit the circular motion of the table. Thus each and all of the three motions of the table may be rendered self-acting, and the work thereby carried on independently of that constant attention which would otherwise be requisite on the part of the workman. It is seldom, however, that more than one of the self-acting motions is required to be in action at a time, the other motions being adjusted by hand.

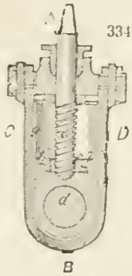
Literal References.

A, the frame of the machine.
B, the slotting-bar.
a, dovetail groove in the crank-wheel N.
C, the circular table upon which the work is fixed.
D, the under slide of the table.
E, the bed-plate of this slide.
b, a link with adjusting nuts for setting the work-table at an angle.
e, guide-screw of the upper table.
g g, set-screws for preventing lateral motion of the table.
h, guide screws of the lower table.
G, spur-wheel on the crank-wheel shaft, geering with
H, a pinion on the driving-shaft.
I, fly-wheel on the driving-shaft.
K, cone-pulley for driving the machine.
L, a ratchet-wheel by which motion is transmitted to the slide-screw *h*.
l, a pawl for working the wheel L.
m, lower arm of the lever to which the pawl is attached.
n, upper arm of the same lever receiving motion from the stud *o*.
M, a universal joint by which the spindle of the ratchet-wheel L is connected to the screw *h*.
N, the crank-wheel on the main shaft.
O, the connecting-rod to the slotting-bar.
P, hand-wheel on the screw for adjusting the stroke of the machine.
S, the spindle of the worm geering with the worm-wheel on the table C

SLUICE-COCKS, WALLER'S *Patent.* This invention consists in applying movable bushes or facings to sluice-cocks, and in constructing the bushes in such a manner that they shall be harder, and fit more truly, and may be more readily applied and replaced when worn; it further consists in a mode of rendering the working surfaces of sluice-cocks, which are made without movable bushes, more hard and durable

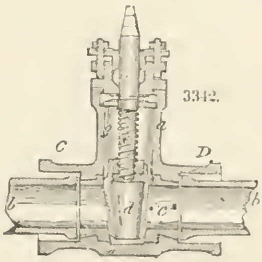
Fig. 3341 is a vertical section of the improved sluice-cock; Fig. 3342 also represents a vertical section, taken on the line A B of Fig. 3341; and Fig. 3343 is a horizontal section taken on the line C D of Figs. 3341 and 3342. *a* is the body of the cock, and *b b* are portions of two pipes which enter the sockets of the cock, and are retained therein water-tight by the application of melted lead, in the usual manner. The body of the cock is bored out, and the backs of the bushes *c c* are turned in a lathe, so as to fit the recesses thus formed. The bushes are made, by preference, of cast-iron, (although other metal may be used;) the working surfaces are chilled in the act of casting, and are ground or "faced up" with emery in a lathe. The bushes are coated on their backs with marine glue

3341.



3343.

3342.



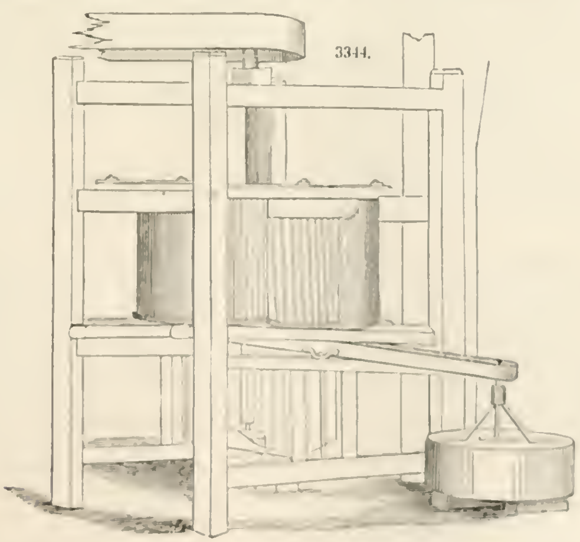
or similar material, previous to introducing them into the cock; and after the bushes have been introduced into the cock, they are moved back in the recesses before mentioned, into a proper working position by forcing down the plug *d* into its place. The patentee does not confine himself to the shape of the recesses formed in the body of the cock, as that may be varied. *e* is a screw for raising and lowering the plug; *f* is a screw-nut, fitted into a recess at the top of the plug; *g g* are ribs, formed on the interior of the upper part of the cock; and *h h* are corresponding ribs on the outer surface of the upper part of the plug; the use of the ribs being to guide the plug correctly in its movement up and down. The surfaces of the plug are chilled in the act of casting, and are then ground with emery.

When making sluice-cocks without movable bushes, the patentee causes the surface against which the plug works to be chilled in the act of casting the body of the cock, so as to make it more durable, and this surface is afterwards rendered true by means of a revolving tool and emery.

The patentee claims, Firstly, the mode of preparing the bodies of sluice-cocks with recesses for receiving bushes; the planes of the surfaces being inclined to the central line of the barrel of the cock as above described. Secondly—the mode of applying movable bushes to cocks. Thirdly—making the movable bushes, and also the plugs of sluice-cocks, with chilled working surfaces as described. Fourthly—the making of sluice-cocks with chilled surfaces, which form the bed of the plug.

SMUT MACHINE. F. HARRIS & SONS' Patent Smut and Scouring Machine, for cleaning all kinds

3344.



of grain, was, we understand, originally invented for hulling and pearling rice and coffee, as also for smutting and polishing wheat and other grain. It has been in successful operation for several years past, giving entire satisfaction to all who have used it, and acknowledged to be superior for cleaning and scouring grain—being capable (when set the right distance apart) of pearling barley and wheat with ease.

This machine is constructed of three concave and convex stones, of a very porous and gritty nature, dressed similar to a mill-stone, are equally as durable, with a perforated iron case around the running or concavo-convex stone, (which makes 400 revolutions per minute,) all set into a frame, as represented in Fig. 3344, with a perpendicular blower or fan attached to the spindle, capable of blowing every thing from the grain without a particle of waste.

This machine is capable of cleaning from 70 to 80,000 bushels of grain previous to being dressed or picked, which makes it do the work as well as when first put in operation. The stones can be set as necessity requires, closer or further apart, so as to suit all kinds of grain, and are well adapted for custom mills.

SOLDERING. Soldering is the process of uniting the edges or surfaces of similar or dissimilar metals and alloys by partial fusion. In general, alloys or solders of various and greater degrees of fusibility than the metals to be joined, are placed between them, and the solder when fused unites the three parts into a solid mass; less frequently the surfaces or edges are simply melted together with an additional portion of the same metal.

The circumstances to be considered in respect to soldering, are, for the most part, that the solders must be necessarily somewhat more fusible than the metals to be united; and that it is of primary importance that the metallic oxides and any foreign matters be carefully removed, for which purpose the edges of the metals are made chemically clean, or quite bright, before the application of the solders and heat; and as during this period their affinity for oxygen is violent, they are covered with some flux which defends them from the air, as with a varnish, and tends to reduce any portion of oxide accidentally existing.

The solders are broadly distinguished as *hard-solders* and *soft-solders;* the former only fuse at the red heat, and are consequently suitable alone to metals and alloys which will endure that temperature; the soft-solders melt at very low degrees of heat, and may be used for nearly all the metals.

The attachment is in every case the stronger the more nearly the metals and solders respectively agree in hardness and malleability. Thus, if two pieces of brass or copper, or one of each, are brazed together, or united with spelter solder, an alloy nearly as tough as the brass, the work may be hammered, bent, and rolled, almost as freely as the same metals when not soldered, because of the nearly equal cohesive strength of the three parts.

Lead, tin, or pewter, united with soft-solder, are also malleable from the near agreement of these substances; whereas when copper, brass, and iron are soft-soldered, a blow of the hammer or any accidental violence, is almost certain to break the joint asunder, so long as the joint is weaker than the metal generally; and therefore the joint is only safe when the surrounding metal from its *thinness* is no stronger than the solder, so that the two may yield in common to any disturbing cause.

When the spaces between the works to be joined are wide and coarse, the fluid solder will probably fall out, simply from the effect of gravity; but when the crevices are fine and close, the solder will be as it were sucked up by capillary attraction. All soldered works should be kept under motionless restraint for a period, as any movement of the parts during the transition of the solder from the fluid to the solid state, disturbs its crystallization and the strict unity of the several parts.

In hard-soldering it is frequently necessary to bind the works together in their respective positions; this is done with soft iron *binding wire*, which for delicate jewelry work is exceedingly fine, and for stronger works is the twentieth or thirtieth of an inch in diameter; it is passed round the work in loops, the ends of which are twisted together with the pliers. The Asiatics seldom use binding wire.

In soft-soldering the binding wire is scarcely ever used, as from the moderate and local application of the heat, the hands may in general be freely used in retaining most thin works in position during the process. Thick works are handled with pliers or tongs whilst being soft-soldered, and they are often treated much like glue joints, if we conceive the wood to be replaced by metal, and the glue by solder, as the two surfaces are frequently coated or tinned whilst separated, and then rubbed together to distribute and exclude the greater part of the solder.

The succeeding "Tabular View of the Processes of Soldering" may be considered as the index to the entire subject; which refers to the ordinary methods of soldering most metals. The article is arranged under three divisions, illustrated in distinct sections, preceded by one section on the modes of applying heat.

Tabular view of the processes of soldering.—To avoid continual repetition, references are made to the lists on the succeeding page, in which some of the solders, fluxes, and modes of applying heat are enumerated.

Hard soldering.—Applicable to nearly all metals less fusible than the solders; the modes of treatment nearly similar throughout.

The hard-solders most commonly used are the spelter solders and silver solders. The general flux is borax marked A, on next page; and the modes of heating are the naked fire, the furnace or muffle, and the blowpipe, marked *a, b, g.*

Note.—The examples commence with the solders, (the least fusible first,) followed by the metals for which they are commonly employed.

Fine gold, laminated and cut into shreds, is used as the solder for joining chemical vessels made of platinum.

Silver is by many considered as much the best solder for German silver.

Copper in shreds is sometimes similarly used for iron.

Gold solders laminated are used for gold alloys.

Spelter solders, granulated whilst hot, are used for iron, copper, brass, gun-metal, German silver, &c.

Silver solders laminated are employed for all silver works and for common gold work, also for German silver, gilding metal, iron, steel, brass, gun-metal, &c., when greater neatness is required than is obtained with spelter solder.

White or button solders granulated are employed for the white alloys called button metals; they were introduced as cheap substitutes for silver solder.

Soft-soldering.—Applicable to nearly all the metals; the modes of treatment very different.

The soft-solder mostly used is 2 parts tin and 1 part lead; sometimes from motives of economy much more lead is employed, and 1½ tin to 1 lead is the most fusible of the group unless bismuth is used The fluxes B to G, and the modes of heating, *a* to *i*, are all used with the soft-solders.

NOTE.—The examples commence with the metals to be soldered. Thus in the list, zinc, 8, C, *f*, implies that zinc is soldered with No. 8 alloy, by the aid of the muriate or chloride of zinc and the copper bit. Lead, 4 to 8, F, *d*, *e*, implies that lead is soldered with alloys varying from No. 4 to 8, and that it is fluxed with tallow, the heat being applied by pouring on melted solder, and the subsequent use of the heated iron not tinned; but in general one only of the modes of heating is selected, according to circumstances.

Iron, cast-iron, and steel, 8, B, D, if thick, heated by *a*, *b*, or *c*, and also by *g*.

Tinned iron, 8, C, D, *f*.

Silver and gold are soldered with pure tin or else with 8, E, *a*, *g*, or *h*.

Copper and many of its alloys, namely, brass, gilding metal, gun-metal, &c., 8, B, C, D; when thick, heated by *a*, *b*, *c*, *e*, or *g*, and when thin by *f* or *g*.

Speculum metal, 8, B, C, D, the heat should be most cautiously applied; the sand-bath is perhaps the best mode.

Zinc, 8 C, *f*.

Lead and lead pipes, or ordinary plumbers' work, 4 to 8, F, *d*, or *e*.

Lead and tin pipes, 8 D and G mixed, *g*, and also *f*.

Britannia metal, 8, C, D, *g*.

Pewters: the solders must vary in fusibility according to the fusibility of the metal, generally G and *i* are used, sometimes also G and *g*, or *f*.

Tinning the metals, and washing them with lead, zinc, &c.

Soldering per se, or burning together.—Applicable to some few of the metals only, and which in general require no flux.

Iron, brass, &c., are sometimes burned, or united by partial fusion, by pouring very hot metal over or around them, *d*.

Lead is united without solder, by pouring on red-hot lead, and employing a red-hot iron, *d*, *e*, and also by the autogenous process.

*Alloys and their Melting Heats.**

No. 1.	1 Tin, 25 Lead	558 Fahr.
2.	1 " 10 "	541 "
3.	1 " 5 "	511 "
4.	1 " 3 "	482 "
5.	1 " 2 "	441 "
6.	1 " 1 "	370 "
7.	1½ " 1 "	334 "
8.	2 " 1 "	340 "
9.	3 " 1 "	356 "
10.	4 " 1 "	365 "
11.	5 " 1 "	378 "
12.	6 " 1 "	381 "
13.	4 Lead, 4 Tin, 1 Bismuth	320 "
14.	3 " 3 " 1 "	310 "
15.	2 " 2 " 1 "	292 "
16.	1 " 1 " 1 "	254 "
17.	2 " 1 " 2 "	236 "
18.	3 " 5 " 3 "	202 "

Fluxes.

A. Borax.
B. Sal-ammoniac, or muriate of ammonia.
C. Muriate, or chloride of zinc.
D. Common resin.
E. Venice Turpentine.
F. Tallow.
G. Gallipoli oil, a common sweet oil.

Modes of Applying Heat.

a. Naked fire.
b. Hollow furnace or muffle.
c. Immersion in melted solder.
d. Melted solder or metal poured on.
e. Heated iron not tinned.
f. Heated copper tool, tinned.
g. Blowpipe flame.
h. Flame alone, generally alcohol.
i. Stream of heated air.

The modes of applying heat in soldering.—The modes of heating works for soldering are extremely varied, and depend jointly upon the magnitude of the objects, the general or local manner in which they are to be soldered, and the fusibility of the solders. It appears to be now desirable to advert to such of the modes of applying heat enumerated in the tabular view, as are of more general application, leaving the modes specifically employed in heating works to their respective sections.

In hard-soldered works, the fires bear a general resemblance to those employed in forging iron and steel; in fact, the blacksmith's forge is frequently used for brazing, although the process is injurious to the fuel as regards its ordinary use. Coppersmiths, silversmiths, and others, use a similar hearth, but which stands further away from the upright wall, so as to allow of the central parts of large objects being soldered; the bellows are always worked by the foot, either by a treadle, or more commonly by a chain from the rocking staff terminating in a stirrup.

The brazier's hearth for large and long works, is a flat plate of iron, about four feet by three, which stands in the middle of the shop upon four legs: the surface of the plate serves for the support of long tubes and works over the central aperture in the plate which contains the fuel, and measures about

* By the addition of 3 parts of mercury to No. 16 it melts at 122° F., and may be used for anatomical injections and for stopping teeth.

two feet by one, and five or six inches deep. The revolving fan is commonly used for the blast, and the tuyere irons, which have larger apertures than usual, are fitted loosely into grooves at the ends, to admit of easy renewal, as they are destroyed rather quickly. The fire is sometimes used of the full length of the hearth, but is more generally contracted by a loose iron plate; occasionally two separate fires are made, or the two blast-pipes are used upon one. The hood is suspended from the ceiling, with counterpoise weights, so as to be raised or depressed according to the magnitude of the works; and it has large sliding tubes for conducting the smoke to the chimney.

Furnaces are occasionally used in soldering, or the common fire is temporarily converted into the condition of a furnace from being built hollow, or by the insertion of iron tubes or muffles amidst the ignited fuel, as already explained in reference to forging and hardening. For want of any of these means, the amateur may use the ordinary grate, or it is better to employ a brazier or chafing-dish containing charcoal, and urged with hand-bellows blown by an assistant, as then both hands are at liberty to manage the work and fuel.

Fresh coals are highly improper for soldering on account of the sulphur they always contain; the best fuel is charcoal, but in general coke or cinders are used. Lead is equally as prejudicial to the fire in soldering as it is in welding iron and steel, or in forging gold, silver, or copper; as the lead readily oxidizes and attaches itself to the metals that are being soldered or welded, preventing the union of the parts, and in almost all cases rendering the metals brittle and unserviceable.

There are many purposes in the arts which require the application of heat having the intensity of the forge-fire or of the furnace, but with the power of observation, guidance, and definition of the artist's pencil. These conditions are most efficiently obtained by the blowpipe, an instrument by which a stream of air is driven forcibly through a flame, so as to direct it either as a well-defined cone, or as a broad jet of flame, against the object to be heated, which is in many cases supported upon charcoal, by way of concentrating the heat.

The blowpipe is largely used—namely, in soldering, in hardening and tempering small tools, in glass-blowing for philosophical instruments and toys, in glass-pinching with metal moulds made like pliers, in enamelling, and by the chemist and mineralogist, as an important means of analysis: the instrument has consequently received very great attention both from artisans and distinguished philosophers.

Most of the blowpipes are supplied with common air, and generally by the respiratory organs of the operator; sometimes by bellows moved with the foot, by vessels in which the air is condensed by a syringe, or by pneumatic apparatus with water pressure. In some few cases oxygen or hydrogen, or the same gases when mixed, are employed; they are little used in the arts.

The ordinary blowpipe is a light conical brass tube, about 10 or 12 inches long, from one-half to one-fourth of an inch diameter at the end for the mouth, and from one-sixteenth to one-fiftieth at the aperture or jet; the end is bent as a quadrant, that the flame may be immediately under observation.

The lungs may be used for the blowpipe with much more effect than might be expected, and with a little practice a constant stream may be maintained for many minutes if the cheeks are kept fully distended with wind, so that their elasticity alone shall serve to impel a part of the air, whilst the ordinary breathing is carried on through the nostrils for a fresh supply.

The most intense heat of the common blowpipe is that of the pointed flame; with a thick wax candle, and a blowpipe with a small aperture placed slightly within the flame, the mineralogist succeeds in melting small fragments of all the metals, when they are supported upon charcoal and exposed to the extreme point of the inner or blue cone, which is the hottest part of the flame; that is, fragments of all metals which do not require the oxyhydrogen blowpipe.

Larger particles, requiring less heat, are brought somewhat nearer to the candle, so as to receive a greater portion of the flame; and when a very mild degree of heat is needed, the object is removed further away, sometimes as in melting the fluxes preparatory to soldering, even to the stream of hot air beyond the point of the external yellowish flame.

The first, or the silent pointed flame, is used by the chemist and mineralogist for reducing the metallic oxides to the metallic state, and is called the *deoxidizing* flame; the second, or the noisy, brush-like flame, is less intense, and is called the *oxidizing* flame.

The artisan employs in soldering a much larger flame than the chemist, namely, that of a lamp the wick of which is from a quarter to one inch diameter: this must be plentifully supplied with oil; the blowpipe in such cases is selected with a larger aperture, it is blown vigorously, and held a little distant from the flame, so as to spread it in a broad stream of light, extending over a large surface of the work, which is in most cases supported upon charcoal. When any minute portion alone is to be heated, the pointed flame is used, with a milder blast of air and a decreased distance.

The following method is much employed by the cheap jewelry manufacturers at Birmingham. A stream of air from a pair of bellows directs a gas flame through a trough or shoot, the third of a cylindrical tube placed at a small angle below the flame. Instead of a charcoal support they employ a wooden handle, upon which is fixed a flat disk of sheet-iron, about three or four inches diameter, covered with a matting of waste fragments of binding wire, entangled together and beaten into a sheet about three-eighths or half an inch thick; some few of the larger pieces of wire extend round the edge of the disk to attach the remainder. The work to be soldered is placed upon the wire, which becomes partially red-hot from the flame, and retains the heat somewhat as the charcoal, but without the inconvenience of burning away, so that the broad level surface is always maintained. Small cinders are frequently placed upon the tool, either instead of, or upon the wire.

Sometimes the gas-pipe is surmounted by a square hood, open at both ends, and two blast-pipes are directed through it; the latter arrangement is used by the makers of glass toys and seals; these are pinched in moulds something like bullet-moulds; the devices on the seals are produced by inserting in the moulds dried casts, made in plaster of Paris.

Makers of thermometers and other philosophical instruments generally use a table blowpipe, with a shallow oval, or rather a kidney-shaped lamp, with a loop placed lengthways upon the short diameter for holding the cotton, which is sometimes an inch long and half an inch wide. The wick is plentifully supplied with tallow or hog's lard, and a furrow is made through it with a wire to afford a free passage for the blast from the fixed nozzle, by the size of which, and its distance from the flame, the latter is made to assume the pointed or brush-like character. This lamp is more cleanly, and emits less smell than those supplied with oil; any overflow of the tallow is caught in the outer vessel or tray, and when cold, the fat solidifies.

Many blowpipes have been invented for the employment of oxygen and hydrogen; the mixed gases were first used by Dr. Hare, of Philadelphia, who has been followed in various ways by Clark, Gurney, Cumming, Hemming, Marcet, Leeson, and many others. Two subsequent modifications of gas blowpipes which have been invented for the workshop will alone be here described, namely, Sir John Robison's Workshop Blowpipe, intended for soldering, hardening, and other purposes; and the Count de Richemont's Airo-hydrogen Blowpipe.

The general form of the "workshop blowpipe" is that of a tube open at the one end, and supported on trunnions in a wooden pedestal, so that it may be pointed vertically, horizontally, or at any angle as desired. Common street gas is supplied through the one hollow trunnion, and it escapes through an *annular* opening; whilst oxygen gas, or more usually common air, is admitted through the other trunnion which is also hollow, and is discharged in the centre of the hydrogen through a central conical tube; the magnitude and intensity of the flame being determined by the relative quantities of gas and air, and by the greater or less protrusion of the inner cone, by which the annular space for the hydrogen is contracted in any required degree.

From amongst numerous other small applications of heat, Mr. Gill's portable blowpipe furnace may be noticed; it consists of a lump of pumice-stone three or four inches diameter, scooped out like a pan or crucible, and filled with small fragments of charcoal; sometimes a conical perforated cover is added; the inside may be intensely ignited, whilst the slow conducting power of the pumice-stone guards the hand from inconvenient heat.

Examples of hard-soldering.—It was mentioned in the tabular view that the several works united with hard-solders receive nearly the same treatment; a few examples will therefore serve to convey a general idea of hard-soldering—a process commonly attended with some risk of partially melting the works, because the fusing points of the metals and their respective solders often approach very nearly together.

Several of the hard-solders contain zinc, which appears to be useful in different ways: first, it increases their fusibility; in cases where the solder cannot be seen it serves as an index to denote the completion of the process, for when the solder is melted the zinc volatilizes, and burns with the well-known blue flame; and as at this moment some of the zinc is consumed, the alloy left behind becomes tougher, and more nearly approaches to the condition of the metal which it is desired to unite. The zinc may be therefore considered to act as a flux, and so likewise does the arsenic occasionally introduced into the gold and silver solders, as the arsenic is for the most part lost between the processes of making and using the solders; but this metal being of a noxious quality, it is but little resorted to, and besides, it renders the other metals very brittle.

In every case of soldering, a general regard to cleanliness in the manipulation is important, and for the most part the edges of the metals are filed or scraped prior to their being soldered, as before observed; in those cases in which the red-heat is employed, filing or scraping are less imperative, as any greasy or combustible matters are burned away, and the borax has the property of combining with nearly all the metallic oxides and earthy bases, thereby cleansing the edges of the metals, should that proceeding have been previously omitted.

The works in copper, iron, brass, &c., having been prepared for *brazing*, (or soldering with a fusible brass,) and the joints secured in position by binding wire where needful, the granulated spelter and pounded borax are mixed in a cup with a very little water, and spread along the joint by a slip of sheet-metal or a small spoon.

The work, if sufficiently large, is now placed above the clear fire, first at a small distance so as gradually to evaporate the moisture, and likewise to drive off the water of crystallization of the borax; during this process the latter boils up with the appearance of froth or snow, and if hastily heated it sometimes displaces the solder. The heat is now increased, and when the metal becomes faintly red, the borax fuses quietly like glass; shortly after, that is at a bright red, the solder also fuses, the indication of which is a small blue flame from the ignition of the zinc. Just at this time some works are tapped slightly with the poker to put the whole in vibration, and cause the solder to run through the joint to the lower surface, but generally the solder *flushes*, or is absorbed in the joint, and nearly disappears without the necessity for tapping the work.

It is of course necessary to apply the heat as uniformly as possible by moving the work about so as to avoid melting the object as well as the solder; the work is withdrawn from the fire as soon as the solder has flushed, and when the latter is set, the work may be cooled in water without mischief.

Tubes are generally secured by loops of binding wire twisted together with the pliers; and those soldered upon the open fire are almost always soldered from within, as otherwise the heat would have to be transmitted across the tube with greater risk of melting the work, air being a bad conductor of heat; it is necessary to look *through* the tube to watch for the melting of the solder. Long tubes are rested upon the flat plate of the brazier's hearth, and portions equal to the extent of the fire are soldered in succession. The common Birmingham tubes for gas works, bedsteads, and numerous other purposes, are soldered from the outside; but this is done in short furnaces open at both ends and level with the floor, by which the heat is applied more uniformly around the tubes.

Works in iron require much less precaution in point of the heat, as there is little or no risk of fusion; thus in soldering the spiral wires to form the internal screw within the boxes of ordinary tail vices, the work is coated with loam, and strips of sheet brass are used as solder; the fire is urged until the blue flame appears at the end of the tube when the fusion is complete; the work is withdrawn from the fire and rolled backwards and forwards on the ground to distribute the solder equally at every part. Other common works in iron, such as locks, are in like manner covered with loam to prevent the iron from scaling off. Sheet iron may be soldered by filings of soft cast-iron, applied in the usual way of soldering with borax, which has been gradually dried in a crucible and powdered, and a solution of sal-ammoniac."

The finer works in iron and steel, those in the light-colored metals generally, and also the works in brass which are required to be very neatly done, are soldered with silver-solder. From the superior fusibility of silver-solder, and from its combining so well with the different metals without "*gnawing them* or *eating them away*," or wasting part of the edges of the joints, silver-solder is very desirable for a great many cases; and from the more careful and sparing manner in which it is used, many objects require but little or no finishing subsequently to the soldering, so that the more expensive solder is not only better, but likewise in reality more economical.

The practice of silver-soldering is essentially the same as brazing. The joint is first moistened with borax and water; the solder, (which is generally laminated and cut into little squares with the shears,) is then placed on the joint with forceps. In heating the work additional care is given not to displace the solder; and for which reason some persons *boil* the borax, or drive off its water of crystallization at the red-heat, then pulverize it and apply it in the dry state along with the solder; others fuse the borax upon the joint before putting on the solder.

Numerous small works united with hard-solders, such as mathematical and drawing instruments, buttons, and jewelry, are soldered with the blowpipe; in almost all cases the work is supported upon charcoal, and sometimes for the greater concentration of the heat it is also covered with charcoal. The management of the blowpipe having been explained, it is only necessary to add that the magnitude and shape of the flame are proportioned to those of the works.

In soldering gold and silver the borax is rubbed with water upon a slate to the consistence of cream, and is laid upon the work with a camel's hair pencil, and the solders although generally laminated are also drawn into wire or filed into dust; but it will be remembered, the more minute the particles of the granulated metals the greater is the degree of heat required in fusing them.

In many of the jewelry works the solder is so delicately applied, that it is not necessary to file or scrape off any portion, none being in excess, and the borax is removed by immersing the works in the various pickling and coloring preparations.

Examples of soft-soldering.—In this section the employment of the less fusible of the soft-solders will be first noticed; the plumbers' sealed-solder, 2 parts lead and 1 of tin, melts at about 440° F.; the usual or fine tin-solder, 2 parts tin and 1 of lead, melts at 340°; and the bismuth-solders at from 250° to 270°: the modes of applying the heat consequently differ very much, as will be shown.

The soft-solders are prepared in different forms suited to the nature of the various works. No. 5, p. 590, the plumber's-solder, is cast in iron moulds into triangular ingots measuring from 1 to 6 superficial inches in the section. No. 8, the fine tin-solder, is cast in cakes about 4 by 6 inches, and $\frac{1}{4}$ to $\frac{1}{2}$ inch thick; and this and the more fusible kinds are trailed from the ladle upon an iron plate or flat stone, to make slight bars, ribbons, and even threads, that the magnitude of the solder may be always proportioned to the magnitude and circumstances of the work.

It is very essential that all soft-soldered joints should be particularly clean and free from metallic oxides; and except where oil is exclusively used as the flux, greasy matters should be avoided, as they prevent the ready attachment of the aqueous fluxes. It is therefore usual with all the metals, except clean tinned plate, and clean tin alloys, to scrape the edges immediately before the process, so far as the solder is desired to adhere.

Lead works are first smeared or soiled around the intended joints with a mixture of size and lampblack, called *soil*, to prevent the adhesion of the melted solder; next the parts intended to receive the solder are shaved quite clean with the *shave-hook*, (a triangular disk of steel riveted on a wire stem,) and the clean metal is then rubbed over with tallow. Some joints are *wiped*, without the employment of the soldering-iron; that is, the solder is heated rather beyond its melting point, and poured somewhat plentifully upon the joint to heat it; the solder is then smoothed with the cloth, or several folds of thick bed-tick well greased, with which the superfluous solder is finally removed.

Other lead joints are *striped*, or left in ridges, from the bulbous end of the plumber's crooked soldering-iron, which is heated nearly to redness, and not tinned; the iron and cloth are jointly used at the commencement for moulding the solder and heating the joint. In this case less solder is poured on, and a smaller quantity remains upon the work; and although the striped-joints are less neat in appearance, they are by many considered sounder from the solder having been left undisturbed in the act of cooling. The vertical joints, and those for pipes, whether finished with the cloth or iron, require the cloth to support the fluid solder when it is poured on the lead.

Slight works in lead, such as lattices, requiring more neatness than ordinary plumbing, are soldered with the *copper-bit* or *copper-bolt;* they are pieces of copper weighing from three or four ounces to as many pounds, riveted into iron shanks and fitted with wooden handles. All the works in tinned iron, sheet-zinc, and many of those in copper and other thin metals, are soldered with this tool, frequently misnamed a soldering-*iron*, which in general suffices to convey all the heat required to melt the more fusible solders now employed.

If the copper-bit have not been previously tinned, it is heated in a small charcoal stove or otherwise to a dull red, and hastily filed to a clean metallic surface; it is then rubbed immediately, first upon a lump of sal-ammoniac, and next upon a copper or tin plate, upon which a few drops of solder have been placed; this will completely coat the tool; it is then wiped clean with a piece of tow and is ready for use.

In soldering coarse works, when their edges are brought together they are slightly strewed with powdered resin, or it is spread on the work with a small spoon; the copper-bit is held in the right hand, the cake of solder in the left, and a few drops of the latter are melted along the joint at short intervals

The iron is then used to heat the edges of the metal, both to fuse and to distribute the solder along the joint, so as entirely to fill up the interval between the two parts; only a short portion of the joint, rarely exceeding six or eight inches, is done at once. Sometimes the parts are held in contact with a broad chisel-formed tool, or a hatchet stake, whilst the solder is melted and cooled, or a few distant parts are first *tacked* together or united by a drop of solder, but mostly the hands alone suffice without the tacking.

Two soldering-tools are generally used, so that whilst the one is in the hand the other may be reheating in the stove; the temperature of the bit is very important; if it be not hot enough to raise the edges of the metal to the melting heat of the solder, it must be returned to the fire; but unless by mismanagement it is made too hot and the coating is burned off, the process of tinning the bit need not be repeated, it is simply wiped on tow on removal from the fire. If the tool be overheated it will make the solder unnecessarily fluid, and entirely prevent the main purpose of the *copper*-bit, which is intended to act both as a heating tool and as a *brush*, first to pick up a small quantity or drop from the cake of solder which is fixed upright in a tray, and then to distribute it alone the edge of the joint.

The tool is sometimes passed only *once* slowly along the work, being guided in contact with the fold or edge of the metal. This supposes the operator to possess that dexterity of hand which is abundantly exhibited in many of the best tin wares; in these the line of solder is very fine and regular. The soldering-tool is then thin and keen on the edge, and the flux instead of being resin is mostly the muriate of zinc, with which the joint is moistened by means of a small wire or a stick prior to the application of the heated tool; sometimes the workman cools the part just finished by blowing upon it as the bit proceeds in its course; and the iron if overheated is cooled upon a moistened rag placed in the empty space of the tray containing the solder.

Copper works are more commonly fluxed with powdered sal-ammoniac, and so likewise sheet-iron, although some mix powdered resin and sal-ammoniac; others moisten the edges of the work with a saturated solution of sal-ammoniac, using a piece of cane, the end of which is split into filaments to make a stubby brush, and they subsequently apply resin: each method has its advocates, but so long as the metals are well defended from oxidation any mode will suffice, and in general management the processes are the same.

Zinc is more difficult to solder than the other metals, and the joints are not generally so neatly executed; the zinc seems to remove the coating of tin from the copper soldering-tool; this probably arises from the superior affinity of copper for zinc than for tin. The flux sometimes used for zinc is sal ammoniac, but the muriate of zinc, made by dissolving fragments of zinc in muriatic acid diluted with about an equal quantity of water, is much superior; and the muriate of zinc serves admirably likewise for all the other metals, without such strict necessity for clean surfaces as when the other fluxes are used.

The copper tool is only applicable to *thin* metals, because it requires such a degree of heat as will allow it to raise the temperature of the work to be joined to the melting point of the solder; and the excess of heat thus required for *stout* metals, is apt either to burn off the coating of solder, or to cause it to be absorbed as a process of superficial alloying. It requires some tact to keep the heat of the tool within proper limits by means of the charcoal or cinder fire, but with the airo hydrogen blowpipe it is easy to maintain any required temperature for an indefinite period.

Thicker pieces of metal, such as the parts of philosophical apparatus, gas-fittings, and others which cannot be conveniently managed with the copper-bit, are first prepared by filing or turning, and each piece is then separately tinned in one of the following ways. Small pieces, immediately after being cleaned with the file or other tool, and without being touched with the fingers, are dipped into a ladle containing melted solder, which is covered with a little powdered sal-ammoniac. The flux meets the work before it is subjected to the heat, and the tinning is then readily done; sometimes the work is in the first instance sprinkled with resin, or rubbed over with sal-ammoniac water; the latter is rather a dangerous practice, as the moisture is apt to drive the melted metal in the face of the operator.

Thin pieces of brass or of copper alloys, if submitted to this method, must be quickly dipped, or their is risk of their being attacked and partly dissolved by the solder. There is some little uncertainty as to iron, and especially as to steel, being well coated by dipping; sometimes a forcible jar or a hard rub will remove most of the tin, and it is therefore safer to rub these works with a piece of heated copper shaped like a file, immediately on their removal from the melted solder, which makes the adhesion more certain.

Larger pieces of metal, or those it is inconvenient to dip into the ladle, are first moistened with sal-ammoniac water, or dusted with the dry powder or resin, and heated on a clear fire either of charcoal, coke, or cinders, until the strip of solder held against them is melted and adheres; as the lowest heat should be always used. Another cleanly way of applying the heat, and which is also employed in tempering tools, varnishing, and cementing, is to make red hot a few inches of the end of a flat iron bar about two feet long, to pinch it in the vice by the cold part, and to lay the work upon that spot which is at a suitable temperature; the work can be thus very conveniently managed, especially as it may be likewise placed in a good light.

Until the two parts of the work are thoroughly tinned, they must be well defended from the air by the flux to prevent oxidation; they are next made a little hotter than is required for tinning, and placed in contact while the solder is quite fluid, and a little additional solder is also used; when practicable the two surfaces are rubbed together to perfect the tinning and spread the alloy evenly through the joint, the work is then allowed to cool under pressure applied by the hammer handle, the blunt end of a tool, the tail vice, or in any convenient manner. The stages of this practice are similar to those of the carpenter, who having brushed the glue over the two pieces of wood, rubs them together and fixes them with the hand screws until cold, as before adverted to.

Small works are sometimes united by cleaning the respective surfaces, moistening them with sal-ammoniac water, or applying the dry powder or resin, then placing between the pieces a slip of tin foil, previously cleaned with emery-paper, and pinching the whole between a pair of heated tongs to melt the foil; or other similar modifications combining heat and pressure are used.

Many workmen who are accustomed to the blowpipe, as jewelers, mathematical instrument makers, and others, apply the blowpipe with great success in soft-soldering; but as the methods are in other respects similar to those given, they do not require particular notice, except that in some cases there is no choice but to tie the works together with binding wire, as in hard-soldering; but the preference is always given to detached tinning and rubbing together.

The modern gas-fitters are remarkably expert in joining tin and lead pipes with the blowpipe; they do not employ the method of the plumbers and pewterers, or the *spigot* and *faucet* joint surrounded by a bulb of solder, but they cut off the ends of the pipes with a saw, and file the surfaces to meet in butt-joints, in mitres, or in T-form joints, as required. In confined situations they apply the heat from one side only with the blowpipe and rushes; they employ a rich tin-solder, with oil and resin mixed in equal parts as the flux; the work looks like carpentry rather than soldering.

An ingenious workman assured us that he had employed this mode, for lead pipes measuring externally one inch and a half diameter and situated in angles, by placing pieces of slate against the floor and the perpendicular partition to defend them from the flame, the action of which was assisted by two pieces of charcoal inserted in the corners. And also that as a trial of skill, he had made fifteen joints in three-quarter inch tin pipe, five of each kind, namely, plain, mitre, and T form, including the preparations, in the exceedingly short period of twenty-five minutes.

Iron, copper, and alloys of the latter metal, are frequently coated with tin, and occasionally with lead and zinc, to present surfaces less subject to oxidation; gilding and silvering are partly adopted from similar motives.

Copper and brass vessels are first pickled with sulphuric acid, mostly diluted with about three times its bulk of water; they are then scrubbed with sand and water, washed clean and dried; they are next sprinkled with dry sal-ammoniac in powder, and heated slightly over the fire; then a small quantity of melted block-tin is thrown in, the vessel is swung and twisted about to apply the tin on all sides, and when it has well adhered the portion in excess is returned to the ladle, and the object is cooled in water. When cleverly performed very little tin is taken up, and the surface looks almost as bright as silver; some objects require to be dipped into a ladle full of tin.

Iron presents rather more difficulty, the affinity of the tin being less strong for iron than for copper; but the treatment is in general nearly the same. Old works require that the grease should be removed with concentrated muriatic acid, before the other processes are commenced; and in cast-iron vessels the grease often penetrates so deeply, owing to the porous nature of the metal, that the retinning is sometimes scarcely possible, and it is often more economical to obtain a new vessel.

An alloy of nickel, iron, and tin, has been introduced as an improvement in tinning the metals. Mr. G. M. Braithwaite, one of the patentees, says that "the nickel and tin compound is harder than tin, and endures a much longer time; it is less fusible, and will not run or melt at a heat that would cause the ordinary tinning of pans to forsake the sides and lie in a mass at the bottom. Also that as an experiment to show the tenacity of the nickel, a piece of cast-iron tinned with the compound had been subjected by him for a few minutes to the white heat under a blast, and although the tin was consumed, the nickel remained as a permanent coating upon the iron."

The proportions of nickel and iron mixed with the tin in order to produce the best tinning, are ten ounces of the best nickel and seven ounces of sheet-iron to ten pounds of tin. These metals are mixed in a crucible, and to prevent the oxidation of the tin by the high temperature necessary for the fusion of the nickel, the metals are covered with one ounce of borax and three ounces of pounded glass. The fusion is completed in about half an hour, when the composition is run off through a hole made in the flux. In tinning metals with this composition the workman proceeds in the ordinary manner.

There is also another method, that of *cold-tinning*, by aid of the amalgam of mercury; but this process, when applied to utensils employed for preparing or receiving food, appears questionable both as regards effectiveness and wholesomeness, and the activity of the muriatic acid must not be forgotten; it should be therefore washed carefully off with water. The tin adheres, however, sufficiently well to allow other pieces of metal to be afterwards attached by the ordinary copper soldering-bit.

Soldering per se, or burning together.—This principally differs from ordinary soldering, in the circumstance that the uniting or intermediate metal is the same as those to be joined, and that in general no fluxes are employed.

The method of burning together, although it only admits of limited application, is in many cases of great importance, as when successfully performed the works assume the condition of greatest strength, from all parts being alike. There is no dissimilarity between the several parts as when ordinary solders are used, which are open to an objection, that the solders expand and contract by heat either more or less than the metals to which they are attached. There is another objection of far greater moment: the solders *oxidize* either more or less freely than the metals, and upon which circumstances hinge some galvanic or electrical phenomena; and thence the soldered joints constitute galvanic circuits, which in some cases cause the more oxidizable of the two metals to waste with the greater rapidity, especially when heat, moisture, or acids are present.

In chemical works this is a most serious inconvenience, and therefore leaden vessels and chambers for sulphuric acid must not be soldered with tin-solder, the tin being so much more freely dissolved than the lead. Such works were formerly burned together by pouring red-hot lead on the joint, and fusing the parts into one mass, by means of a red-hot soldering-iron. This is troublesome and tedious, and it is now replaced by the autogenous soldering.

Pewter is sometimes burned together at the external angles of works, simply that no difference of color may exist; the one edge is allowed to stand a little above the other, a strip of the same pewter is laid in the angle, and the whole are melted together, with a large copper-bit heated almost to redness the superfluous metal is then filed off, leaving a well-defined angle without any visible joint.

Brass is likewise burned together; for instance, the rims of large mural circles for observatories, that are five, six, or seven feet diameter, are sometimes cast in six or more segments, and attached by burning. The ends of the segments are filed clean, two pieces are fixed vertically in a sand mould in their relative positions, a shallow space is left around the joint, and the entire charge of a crucible, say thirty or forty pounds of the melted brass a little hotter than usual, is then poured on the joint to heat it to the melting point. The metal overflows the shallow chamber or hole, and runs into a pit prepared for it in the sand; but the last quantity of metal that remains, solidifies with the ends of the segments, and forms a joint almost or quite as perfect as the general substance of the metal; the process is repeated for every joint of the circle.

The compensation balance of the chronometer and superior watches is an interesting example of natural soldering. The balance is a small fly-wheel made of one piece of steel, covered with a hoop of brass; the rim consisting of the two metals, is divided at the two extremities of the one diametrical arm of the balance, so that the increase of temperature which weakens the balance-spring contracts in a proportionate degree the diameter of the balance, leaving the spring less resistance to overcome. This occurs from the brass expanding much more by heat than steel, and it therefore curls the semicircular arcs inwards, an action that will be immediately understood if we conceive the compound bar of brass and steel to be straight, as the heat would render the brass side longer and convex, and in the balance it renders it more curved.

In the compensation balance, the two metals are thus united: the disk of steel when turned and pierced with a central hole, is fixed by a little screw-bolt and nut at the bottom of a small crucible with a central elevation, smaller than the disk; the brass is now melted and the whole allowed to cool. The crucible is broken, the excess of brass is turned off in the lathe, the arms are made with the file as usual, the rim is tapped to receive the compensation screws or weights, and lastly the hoop is divided in two places, at opposite ends of its diametrical arm.

A little black-lead is generally introduced between the steel and the crucible; and other but less exact modes of combining the metals are also employed.

Cast-iron is likewise united by burning, as will be explained by the following example: to add a flange to an iron pipe, a sand mould is made from a wood model of the required pipe, but the gusset or chamfered band between the flange and tube is made rather fuller than usual, to afford a little extra base for the flange. The mould is furnished with an ingate, entering exactly on the horizontal parting of the mould, at the edge of the flange, and with a waste-head or runner proceeding upwards from the top of the flange, and leading over the edge of the flask to a hollow or pit sunk in the sand of the floor.

The end of the pipe is filed quite clean at the place of junction, and a shallow nick is filed at the inner edge to assist in keying on the flange; lastly the pipe is plugged with sand and laid in the mould. After the mould is closed, about six or eight times as much hot metal as the flange requires is poured through the mould; this heats the pipe to the temperature of the fluid iron, so that on cooling the flange is attached sufficiently firm to bear the ordinary pressure of screw-bolts, steam, &c.*

The method of burning is occasionally employed in most of the metals and alloys, in making small additions to old castings, and also in repairing trifling holes and defects in new ones; it is only successful, however, when the pieces are filed quite clean, and abundance of fluid metal is employed, in order to impart sufficient heat to make a natural soldering: a process which is also, although differently accomplished, in plating copper with silver, as the two metals are raised to a heat just short of the melting-point of the silver, and the metals then unite without solder by partial alloying.

To conclude the description of soldering processes, we have to refer to the *airo-hydrogen*† blowpipe, invented in France by the Count de Richemont. It is in a great measure converting the oxy-hydrogen blowpipe, invented by Dr. Hare, to the service of the workshop, and it is done with great simplicity and safety. An elastic tube supplies hydrogen from the generator, and a pipe supplies atmospheric air from a small pair of double bellows worked by the foot of the operator, and compressed by a constant weight; the two pipes meet in an arch, and proceed through the third pipe to a small jet, from whence proceeds the flame. All the connections are by elastic tubes, which allow perfect freedom of motion, so that the portable blowpipe is carried to the work.

In soldering by the autogenous process, the works are first prepared and scraped clean as usual, the hydrogen is ignited, and the size of the flame is proportioned by a stop-cock; the air is then admitted through the air-pipe until the flame assumes a fine pointed character, with which the work is united after the general method of blowpipe soldering, except that a strip of lead is used instead of solder, and generally without any flux.

This mode is described as being suitable to most of the metals, but its best application appears to be to plumber's work. The weight of lead consumed in making the joints is a mere fraction of the weight of ordinary solder, which is both more expensive and more oxidizable, from the tin it contains. The gas soldering, as it is called, removes likewise the risk of accidents from the plumber's fires, as the gas gen

* Steam and water-tight joints, in cast-iron works not requiring the power of after-separation, are often made by means of iron cement in the following proportions: 112 lbs. of cast-iron filings or borings, 1 lb. of sal-ammoniac, 1 lb. of sulphur, and 4 lbs. of whitening. Small quantities of the materials are mixed together with a little water shortly before use.

For minute cracks the cement is laid on externally as a thin seam, or for larger spaces it is driven in with caulking irons. The edges of the metal and the cement shortly commence one common process of rusting, and at the end of a week or ten days the joints will be found hard, dry, and permanent.

† The following is the broad difference between the airo-hydrogen and the oxy-hydrogen blowpipes. In the oxy-hydrogen blowpipe, the pure gases are mixed in the exact proportions of two volumes of hydrogen to one of oxygen, which quantities when combined constitute water, and in this particular case there is the greatest condensation of volume, and the greatest evolution of latent as well as of sensible heat.

The airo-hydrogen blowpipe is supplied with common air and with pure hydrogen; this instrument is also the most effective when the oxygen and hydrogen are mixed in the proportions of 1 to 2; but the nitrogen, which constitutes four fifths of our atmosphere, is now in the way and detracts from the intensity of the effect.

erator which is in itself harmless, may be allowed to remain on the ground whilst the workman ascends to the roof, or elsewhere, with the pipe.

Lead is interposed as solder in uniting zinc to zinc, and it is also used in soldering the brass nozzles and cocks to the vessels of lead, and those of copper coated with lead, used as generators. Another very practical application of the gas flame is for keeping the copper soldering tool at one temperature, which is done by leading the mixed gases through a tube in the handle, so that the flame plays on the back of the copper bit. This mode seems to be very well adapted to tin-plate and zinc works, especially as the common street-gas may be used, thereby dispensing with the necessity for a gas generator

SPANDRIL. An irregular triangular space formed between the outer curve or extrados of an arch and a line tangent at or near the crown, and the perpendicular line from the springing of the arch.

SPARK ARRESTER—Cutting's patent. Fig. 3339 is a vertical section of the machine.

Fig. 3341, a view of the diaphragm with its curved and inclined planes, separating the outer chamber from the inner chambers, and exhibiting a view of the ventilators, or air-flues, in the lower or inclined section.

Fig. 3342 is a horizontal view of the under side of Fig. 3341, showing a series of ventilators or air flues, and the curved plane.

Fig. 3340 is a perspective view of a section, showing the combination of the different parts.

Fig. 3343 is a horizontal view, taken at the line *a a* of Fig. 3344, showing the air-flue, and the entrance of the ventilating tubes.

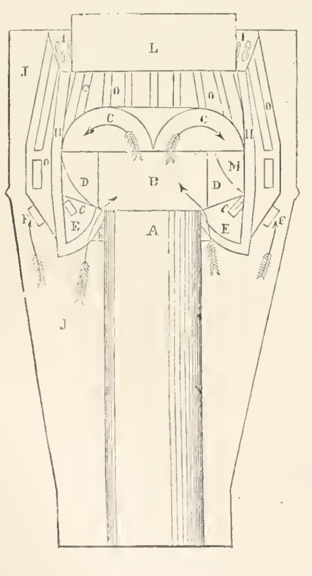
Fig. 3344 is a vertical section of the chimney in combination with the ventilating tubes and air-chambers.

The same letters in the several figures represent the same parts.

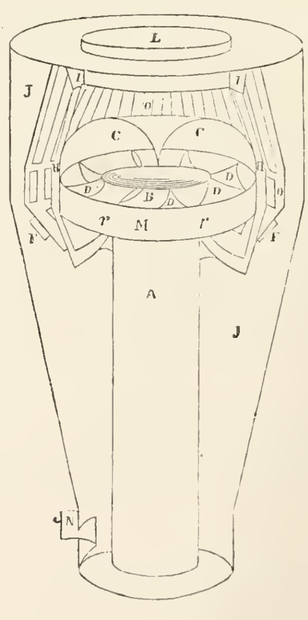
The nature of the first part of this invention consists in arranging upon the outside of the inclined plane, at the base of the diaphragm, a series of air-flues, extending from the spark-chamber through the diaphragm, the mouths of said flues being in the spark-chamber, and their exits in the diaphragm, so that the rotary current of steam, &c., through a series of curved flues in said diaphragm, will pass over the exits of said air-flues, causing a current of air to be drawn from said spark-chamber through said air-flues in the direction of the current of steam, &c., for the purpose of creating a partial vacuum in said spark-chamber into which the sparks fall. And in order to effect the deposit of such light particles as may possibly reach the top of the diaphragm, the nature of the second part of the invention consists in arranging an air-chamber within the diaphragm at the top of the stack, which chamber is ventilated or exhausted by means of tubes connecting that chamber with the air-flue at the bottom of the chamber at the top of the chimney.

To enable others skilled in the art to make and use this invention, we will proceed to describe the same with reference to the drawings.

3339.



3340.



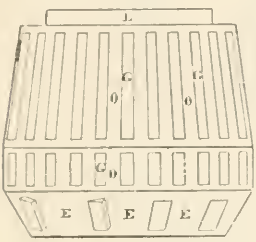
At the top of the chimney A is placed an air-chamber B, over which is placed a deflecting cone C, in the form of a funnel, with the outer edges turned down all around uniformly, to reverberate the steam, gases, and particles, and throw them into a series of curved and inclined flues D, surrounding the air-chamber B, by which a whirling or rotary motion is produced within the diaphragm O. This diaphragm is provided with a series of apertures G. The exhaust steam, in passing through the chimney A into the air-chamber B, has the effect of drawing a current of air between the curved plane K, and the chimney A, through the air-flues F, out of the spark-chamber J.

The air-flues F are arranged on the outer side of the inclined plane E, at the base of the diaphragm, and extend from the chamber J through the diaphragm O. The mouths of the flues F are in the spark-chamber J, and their exits *c* in the diaphragm O, the current of air through them being in the direction of the current of steam, passing through the inclined flues D, as shown by the arrows, so as to allow the air to pass out from, and prevent the sparks, &c., from passing into the spark-chamber through said flues F.

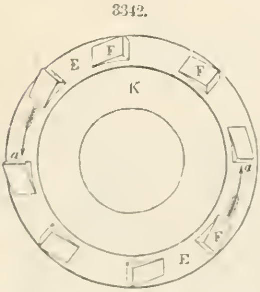
At the bottom of the diaphragm O, under the series of curved and inclined flues D, is a curved plane K, and an inclined plane E. In the inclined plane E is placed the series of flues F above described. The effect of the passage of the circular current of steam, &c., within the diaphragm O, and over the air-flues F, is to still further exhaust the spark-chamber J of its air, on the same principle that the spark-chamber J is ventilated by the passage of steam, &c., over the air-flue P, (shown by dotted lines in Fig. 3344,) at the bottom of the air-chamber B.

The circular current has the tendency by its centrifugal force to throw the particles off in a tangent, against the inner walls of the diaphragm O, and through the apertures G into the outer or spark-chamber J. The deposit of the sparks, &c., in the spark-chamber J is greatly facilitated by the action of the partial vacuum in the spark-chamber J, by which a draught is occasioned through the apertures G of the diaphragm O, towards said spark-chamber J.

3341.



3342.



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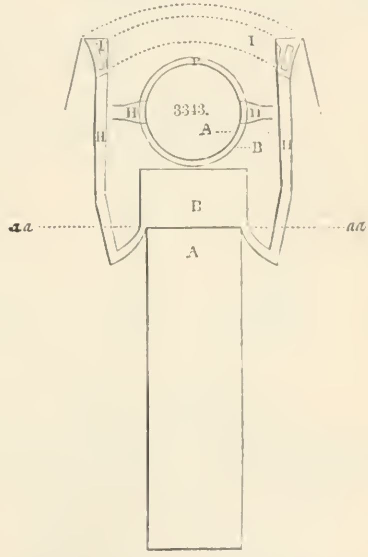

It will be seen that the spark-chamber J is exhausted of its air, in part, by every pulsation of exhaust steam, consequently between every pulsation there will be a draught towards the spark-chamber J through the air-flue as well as through the aperture G of the diaphragm O. This draught through the air-flue towards the spark-chamber J will have the effect to create a draught upwards through the chimney A, by which the draught of the furnace will be to a great extent regulated, and the heat correspondingly increased.

Fig. 3344 represents the chimney A, with air-chamber B, in connection with the pipes H, which pass to another air-chamber I, at the top of the stack. The passage of the steam through the chimney A tends to draw a current of air through the pipes H, in the same manner in which the ventilation of the spark-chamber J is effected, the result of which is to exhaust the air-chamber I of a portion of its air. This air-chamber I is provided with apertures, the object of which is to arrest such light particles as may possibly reach the top of the stack, and cause them to pass around again with the view of their being deposited. L is the general outlet of the steam and such gases as may be evolved.

SPECIFIC GRAVITY. See Gravity.

SPEEDER. After cotton in the course of preparation for yarn has passed through the drawing-frame, the next operation is the making of roving; this is effected in most American mills by the speeder. Of speeders there is some variety; as the Taunton speeder, the Eclipse speeder, the Plate speeder, and the Double speeder. The rovings produced from the first three are alike, having no twist and wound on bobbins or spools with conical ends. In the first the roving passes through a revolving tube; in the second between two opposing surfaces of a travelling endless belt; in the third, between two plate surfaces revolving in opposite directions. The double speeder is somewhat similar to the English bobbin and fly frame. The double speeder is made in two different forms, the first of which receives the arm-direct from the drawing frame, and has only one row of spindles on one side of the frame; these are usually called speeders: the other receives the bobbins from the speeders and still further reduces the rovings; these are called stretchers, and have rows of spindles on each side like the throstle. The roving from these machines, unlike the first varieties, has a little twist: the chief objection to them lies in the power required to drive them, and on this account chiefly, they have been superseded by the bobbin and fly frame in the finer mills; two machines being commonly used, corresponding to the speeder and stretcher, a coarse and fine frame. In their general action they may be said to unite the drawing and spinning frame, performing both processes, and being the connecting link between the two.

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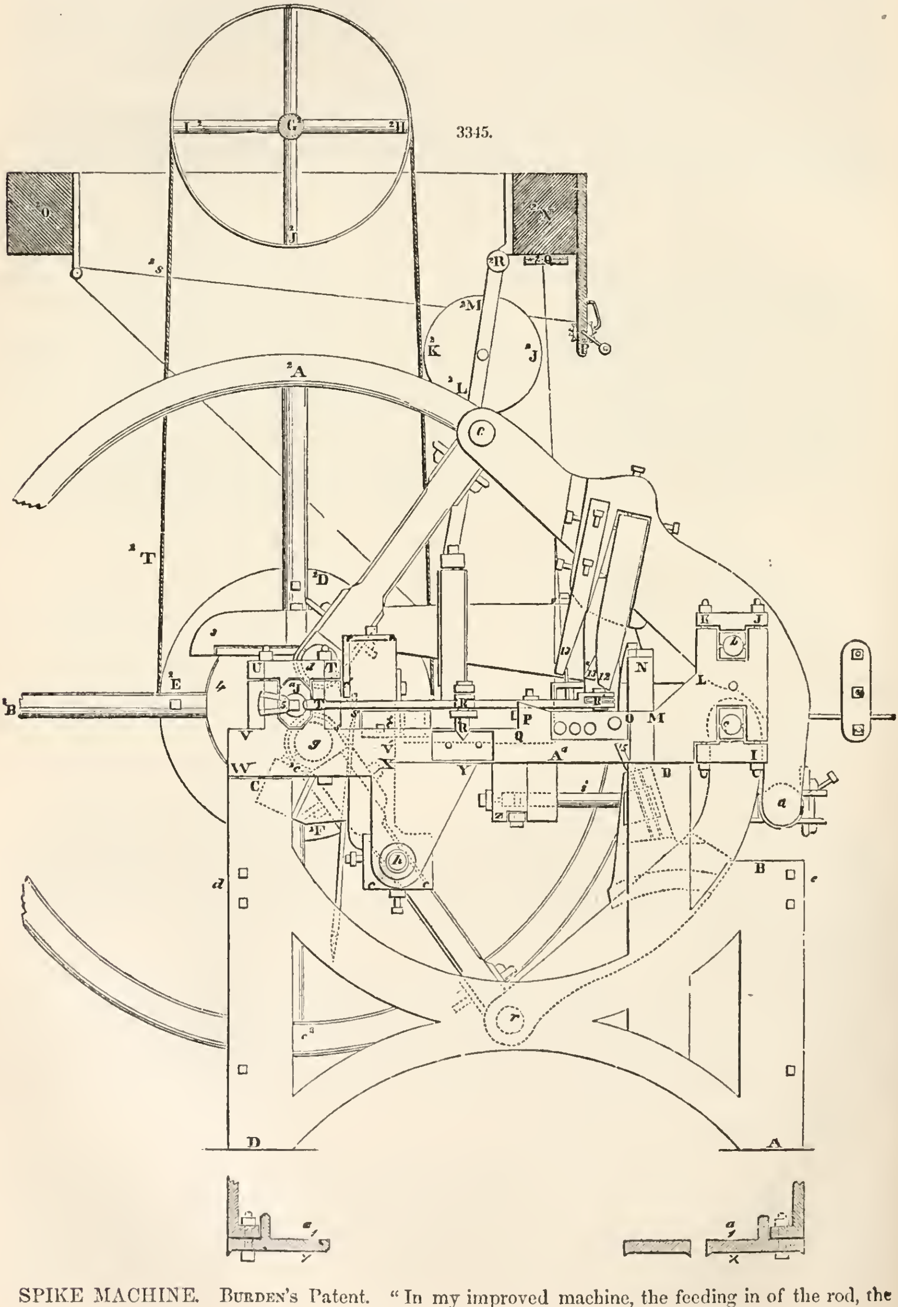

SPIKE MACHINE. Burden's Patent. "In my improved machine, the feeding in of the rod, the cutting it off, and the pointing the spike, are effected in the way previously used by me for performing

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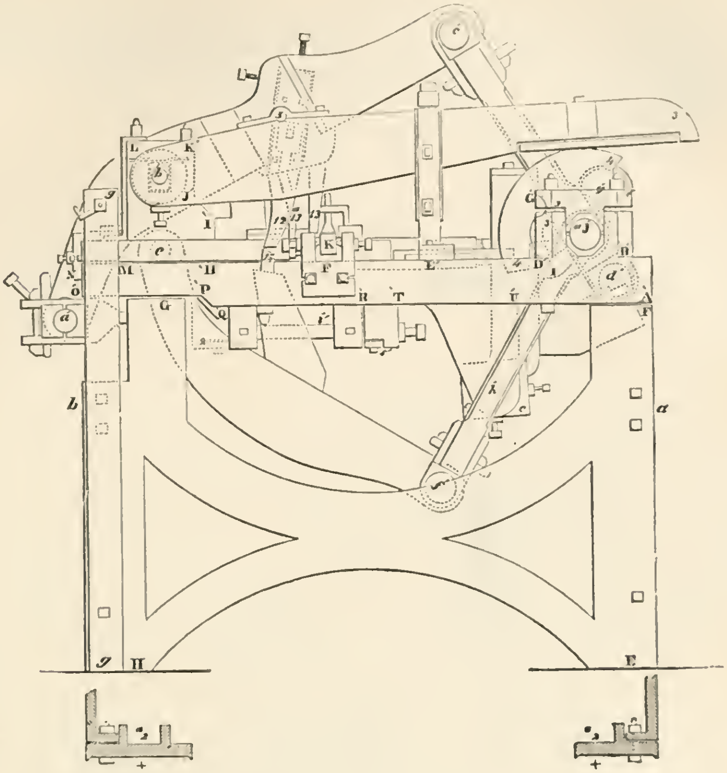

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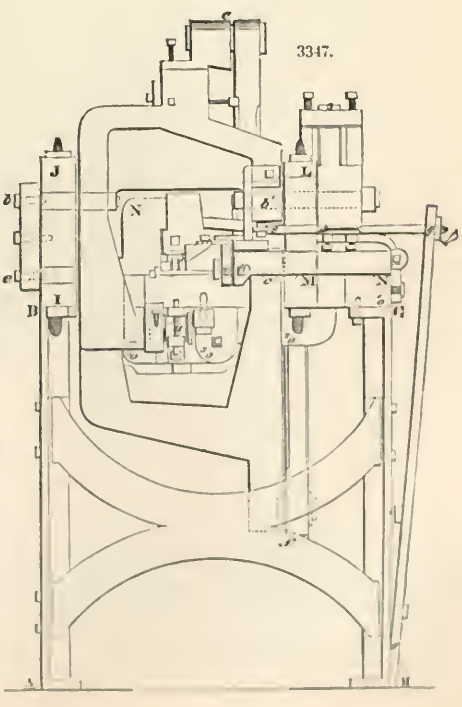
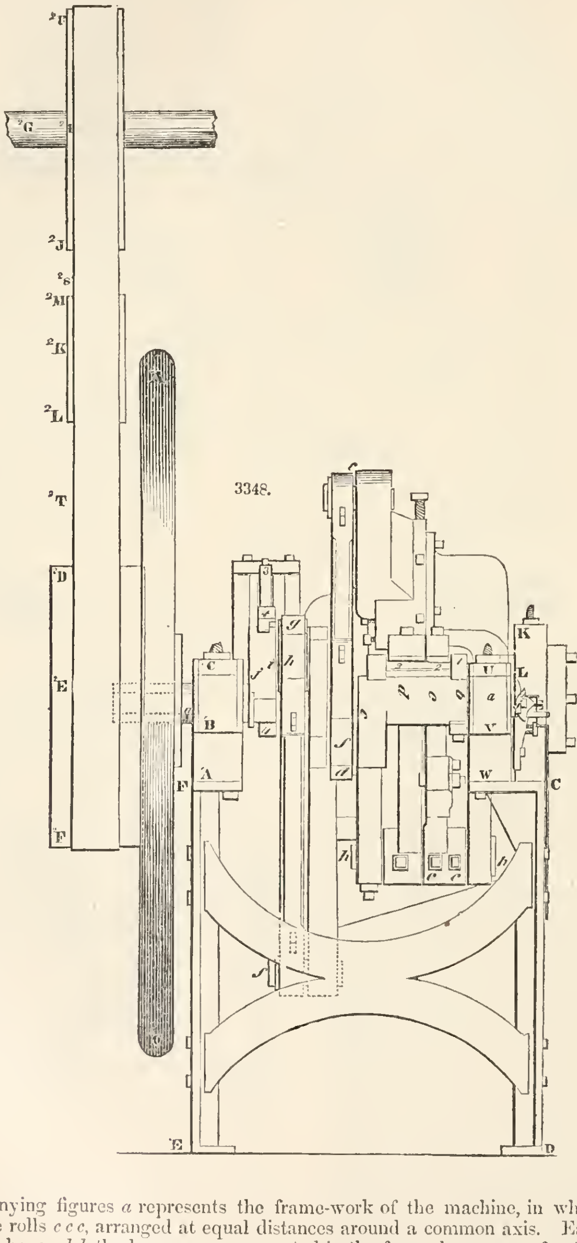


the same offices in my ordinary spike machines, or adopted by others; and my improvement for forming the spikes with hook or brad heads, may be applied to spike machines of various constructions.

Before the introduction of my improvement, the heads of hook or brad-headed spikes were, so far as I am informed, always made by hand, and they were necessarily imperfect, being deficient in that uniformity in shape and strength which are important requisites. My improvement in manufacturing them consists principally in the employment of what I denominate a bending lever, or some analogous device, by means of which the portion of the rod which is to constitute the head is bent down so as to form an angle with the shank, and in then forcing up a heading die, properly formed, so as to upset the bent portion, and to cause it to assume the desired shape.

In each of these figures, where like parts are shown, they are designated by the same letters of reference. A A is the bed plate upon which most of the operating parts of the machine are sustained. B B are the dies which grip and hold the spike-rod during the time the bending and heading are effected. C is a lever by which the die B is closed, the die B being stationary. This lever is acted on by the segmental cam D on the driving-shaft E of the machine; the frame F F, which holds the die H, works on a joint-rod *c c*, and is lifted by the strap *d d*, attached by the joint-pin *e* to the lever C. The spike-rod *f* is to be fed into the dies in the usual way, and as soon as the dies are closed upon the piece to be headed, the bending lever G has its outer end *h* raised by the cam H on the shaft E, which causes its end *g* to descend upon the projecting end of the spike-rod, and to bend it down in the manner shown. I is the heading-slide which carries the heading-die J, and as soon as the cam H escapes from the outer end of the bending lever *h*, and that end descends, the cam K comes in contact with the end L of the heading-slide, which it forces.



In the accompanying figures *a* represents the frame-work of the machine, in which are hung the shafts *b b b* of three rolls *c c c*, arranged at equal distances around a common axis. Each shaft has two journals running in boxes *d d*, the lower one so mounted in the frame by means of set-screws *e* the axis of the rollers can be adjusted in a radial direction from or towards the central line around which they are arranged. The rolls are frustums of cones from the lines 1 to 2, and 2 to 3, which is the extremity of the rolls; they are in the form of the frustum of a flatter or more obtuse cone, so that in the plane of the radii of the common centre, the latter part will be parallel with the common axis around which the three rolls are arranged.

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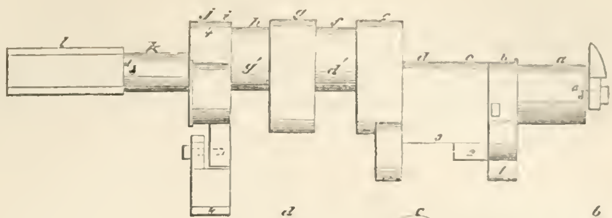

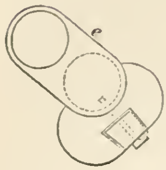

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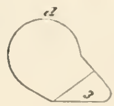

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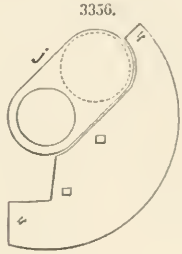

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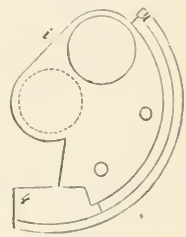

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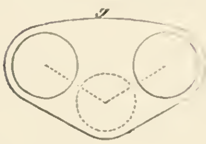

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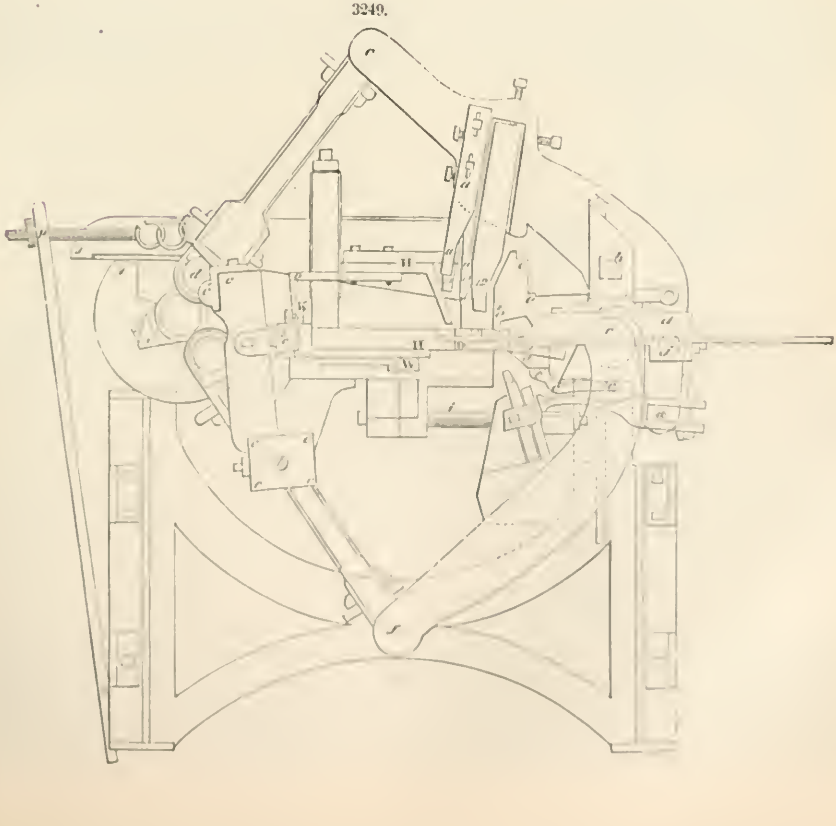

There is a cog-wheel *f* on the shaft of each of the rolls, the three being of equal diameter, and these three are caused to rotate in the same direction by means of two intermediate cog-wheels *g g*. The driving power should be applied to the shaft *h* of one of the rolls in any desired manner, although it may be applied to the shafts of one of the intermediate wheels. The dotted lines *i j* in sections, represent the inclination of the axis of the rolls, and the intermediate wheels form the axis round which they are arranged, and the dotted lines *k k k* represent vertical planes radiating from this common axis, and the dotted lines *l l l* the lines of the axis of the three rolls which are slightly inclined thereto

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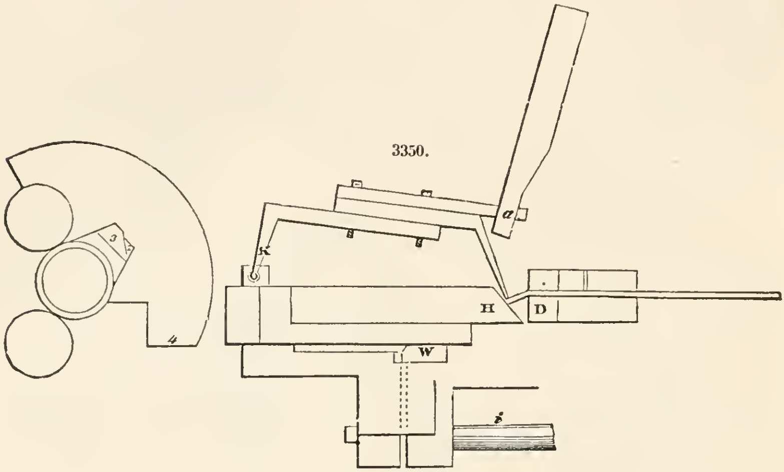

When the rolls are set in motion a loop or ball of iron *m*, in a highly heated state, is dropped in between them, at their upper end, the frame-work being left open above for that purpose, and the slight inclination of the axis of the three rolls from the vertical plane, as indicated by the dotted lines *b b b*, causes the rolls gradually to carry down between them the ball of iron towards their lower end, where they are nearer together by reason of the inclination of their axis from the vertical line being greater than the lines of the cones.

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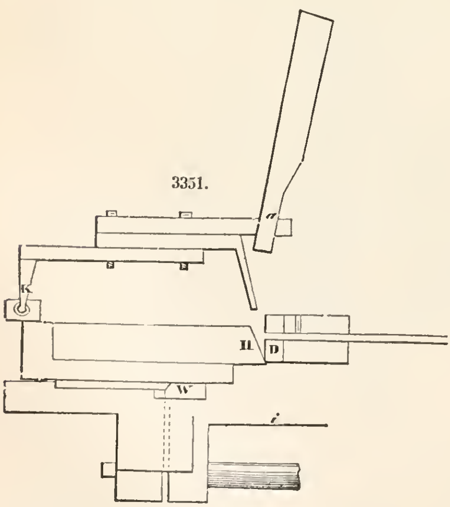

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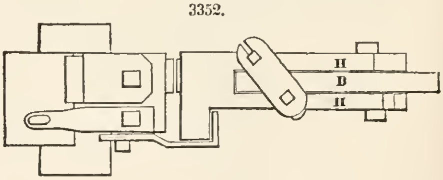

By this means not only is the mass of iron gradually drawn down in the direction of the common axis, around which the rolls are arranged, but by the action of the rotating surface of the rolls, in a line nearly at right angles to this common centre, the iron is rotated on its axis and squeezed in a spiral direction, and the mass gradually elongated and carried out at the bottom in a round bar *n*, of a diameter equal to the space between the lower end of the three rolls, where the cones are so flat as to reduce the bar to a cylindrical form. For the purpose of preventing the rolls from being overheated by contact with the highly heated mass of iron under treatment, the rolls may be made hollow as indicated by the dotted lines, with a central water-tube *o*, extending down to near the bottom, through which water is introduced, and which flows out around the tube, and is discharged at the top.

Fig. 3345 elevation of right side of machine, showing the fly-wheel, pulleys, bands, and fixtures, to apply the moving power.

Fig. 3345*a* section of same through *c d*.

Fig. 3346 elevation of left side of machine when closed in the act of finishing a spike.

Fig. 3346*a* section of same through *a b*.

Fig. 3347 front elevation, with pointing-levers closed.

Fig. 3348 rear elevation, with pointing-levers closed.

Fig. 3349 longitudinal section and elevation of machine, prepared for making hook-head spikes, the machine open, and immediately after forwarding the nail-road, and ready for the downward motion of the upper lever and hooker.

Fig. 3350 section after the downward motion of upper lever and hooker.

Fig. 3351 section after the downward motion of upper lever and hooker, with the header home and the spike headed and pointed.

Fig. 3352 plan of heading-box and heading-lever B, heading-bolt H.

SPINNING FRAME. See Mule and Throstle.

SPINNING-FRAME BANDING, MACHINE FOR MAKING. Applicable to the making of small cord for any purpose.

Description.—A, Fig. 3361, is the combination of fixed loose pulleys receiving the driving-band. B is a cone, from which a band leads to a round cone directly in the rear of B on the shaft *b*; thence by another band to the pulley *c* motion is communicated to shaft *c*, which takes up the banding as it is laid, which from thence passes to a bobbin, and is wound by the friction of a drum on which the bobbin lies, which is driven by a band from the pulley *i*, but which are not shown in the drawing. E is the machine which lays the banding. A revolving motion is given by the band-geer C around the fixed spindle D, while the upper is steadied in a socket at *d*, and the whole is supported by the point *l* bearing on the top of D. The twist to be made into banding is wound on two bobbins *p* placed within the flyers *h*, held between two disks, which disks are kept together firmly by two rods, not shown in the figure. The twist, as it leaves the bobbins, passes round the rim of the flyer, or through a staple in the conical weight *i*, thence through a hole in the end of the bar *f*, thence through the centre of the flyer twice or thrice round the geered rolls *k*, thence through the centre of the spindle of the machine E, when the two strands are twisted together or laid. The shaft E takes up and delivers the banding. It is evident that in laying the banding, if the bobbins were stationary, a portion of the twist would be taken out; to remedy this by means of the geer *m* fixed on the spindle D and an intermediate *n*, motion is given to the geer *o* to which the flyer is fastened; by this means, as much or more twist is put into the strands as would be lost in the laying. The bobbins of twist *p* are held on spindles, which spindles fit into a socket in the bottom of the flyer, and the upper end passing through the bar *f* is held by a small screw. To take out the spindle, the bar *f* can be revolved.

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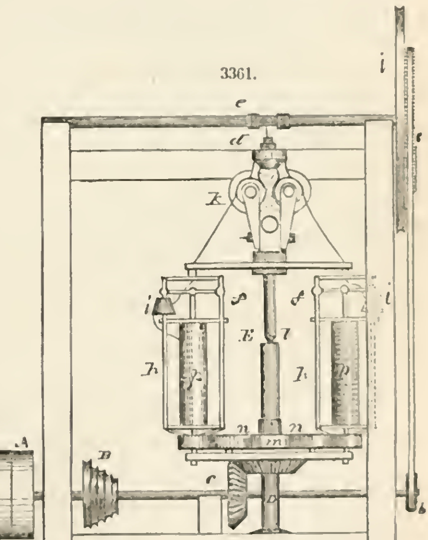


STATIONARY STEAM ENGINE. Under the head of "Engine" will be found the usual varieties of Stationary Engines. By far the largest class in this country are horizontal cylinders, with every variety of valve and cut off. Of late years it has been found economical to avoid wire drawing, to open and close the steam ports as suddenly as possible, and to attach the governor directly to the steam valve. Of this class of engines Mr. Geo. H. Corliss, of Providence, has been the most successful builder and inventor. Plate VII represents one of his engines: in this case a vertical engine, but the improvements are equally adapted to horizontal engines.

Stationary Steam Engine, Corliss Patent. The chief peculiarities lie in the method of working the valves, and in controlling the valve motion by the governor, so as to regulate the motion of the engine with perfection, and use the steam to the best advantage under all conditions.

The valves employed are rotary sliding valves. Their motion is similar to that of the common plug-cock or faucet, but the form adopted is such that they fill a portion only of the cylindrical cavities in which they are mounted. The connection of each valve to its spindle or stem is such that it is free to adapt itself to all conditions. It works freely and yet remains tight, precisely like an ordinary slide valve. There are two steam valves *c d*, and two exhaust valves *e f*, all worked independently, yet by simple mechanism. The exhaust valves are held open during the whole stroke of the piston, but the steam valves are opened at the proper time and allowed to shut automatically at some point in the early portion of the stroke. The precise point at which this shutting of the steam valve occurs, and consequently the volume of steam admitted into the cylinder in any given stroke, depends on the position of the governor balls *l*, and the speed of the engine is regulated by the variations in the quantity of steam thus admitted. The principal improvements in this engine are therefore twofold.

First: There is a peculiar device for moving each steam valve and each exhaust valve, with a distinct and independent motion, by means of a crank-wrist. A series of crank wrists, a^1 a^2 a^3 a^4, are attached to a common disc or plate, *a*, which latter is secured to a rock shaft connected with the main eccentric. Each wrist operates through a distinct lever upon its proper valve; and all of the wrists are so arranged on the common wrist-plate, with reference to their levers, that they act like cranks, each of which vibrates near its *dead point* or point of slowest throw, and therefore imparts but little movement to the valve it actuates, while that valve is closed, and moves with its fastest throw, and therefore imparts the greatest movement to its valve, during the opening and closing motions. This is a substitute for the common slide valve arrangement. As commonly constructed, a steam valve and an exhaust valve are rigidly connected together, so that when one is moved the other is forced to move equally with it.

The whole amount of force consumed in unnecessarily moving a valve while closed, is expended to no good purpose, and tends to increase the wear of the engine. The new device therefore, secures two advantages: *first*, it saves much of the power which was injuriously expended in moving the closed valve; *second*, it prevents wire-drawing or waste of the expansive force of the steam, because the valves are moved with increased speed while opening and closing their ports.

The second improvement in this engine consists in a method of automatic regulation of the steam in its passage into the cylinder, so that, by means of the steam valves only, the entire expansive force of the steam is saved and applied. This is effected by combining the governor—all its sensibility being completely preserved—through the agency of stops or cams, with the catches that liberate the steam valves for the purpose of cutting off the flow of steam into the cylinder.

The Corliss engine then, is a steam engine with sliding or circular valves, and with a new valve-gear adapted to perfect automatic regulation and to the saving of fuel. The regulation in this engine is purely automatic, and practically perfect, as it acts without impairing the effect of the steam. The common method of regulation is by the employment of a throttle valve, a kind of damper in the steam pipe, described on page . This is connected to the governor, so that as the speed of the engine is increased the aperture through which the steam passes is diminished; by thus retarding its flow, the pressure of the steam in the cylinder is diminished, and the velocity of the engine is consequently checked. The action is a continual choking of the engine, which is increased and diminished according to circumstances, but is always a tax on the power. The loss by the use of the throttle-valve is universally acknowledged to be very serious. Maudsley, in Great Britain, and several others, succeeded in regulating by varying the cut-off by the hand of an attendant, but the adjustments could not be successfully effected *by the governor* prior to this invention, as the power required to change the parts exhausted the sensibility of the governor and made the motion very irregular. Even the slight resistance experienced in turning a throttle-valve—as it is necessarily effected through the intervention of a steam-tight stuffing box—is sufficient to affect the action of the governor, and make the throttle regulation not only wasteful, but imperfect. In the method here represented, there is practically no resistance to the rise and fall of the governor balls, and the engine is found to work with apparent uniformity, even in driving such machinery as large rolling mills, where the resistance varies suddenly from 60 to 360 horse power.

In the engraving, the letters *c* and *d* as before observed, indicate the steam valves, or rather indicate levers, keyed on the stems of such, and by which they are worked. Near the extremity of each rod *j* and *k*, is provided a suitable hook or catch, which at each rocking movement of the plate, *a*, seizes the respective lever *c* or *d*, and opens the valve, but by a movement which necessarily presses the polished side of *j* or *k* against the end of one of the light and loosely mounted slides *n n*. This contact, as the circular motion of the wrist pin a^1 or a^2 continues, aided by the curvilinear motion of the extremity of the lever, compels the hook to slip off and release its valve, which is then immediately closed by a weight suspended to the rod *r* or *s*. The slight rods or slides *n n*, are free to slip endwise until their opposite extremities press against the side of the pieces *o o*, mounted for the purpose on the rod *m* of the governor. The sides of *o o* are inclined slightly, and as they are elevated by the rise of the governor balls, they urge *n n* forward, and cause the hooks to detach and the steam valves to shut at an earlier point in the stroke. When, on the other hand, the engine inclines to run too slow, and the balls sink, the slides *n n*, yield to the slight pressure of *j* and *k*, and slip back until they are in contact with *o*, and thus more steam is admitted into the cylinder, the steam valves not being detached until a later period in the stroke. In case either the resistance to the motion of the engine becomes very great, or the pressure of the steam becomes very slight, the slides *n n* retreat so far that they fail to detach the hooks and the steam valves consequently remain open during the whole stroke, like the exhaust valves.

It will be observed that in this engine the governor nowhere performs any labor, and, on the contrary, only indicates the change required to the levers which move the valves. This does not task its powers: it puts forth only the force necessary to move the small stops *n n*. This movement is attended with the least possible friction, and the stop presents absolutely no resistance to the governor, except at the very instant when it is in actual contact with *j* or *k*.

In puppet-valve engines, the valves must be started from their seats or places of rest at the moment of opening their ports. In this engine, as we have seen, the sliding or circular valves have a rapid motion at that point, analogous to, but faster than, that in the common slide valve arrangement. This allows the ports to be uncovered and covered very rapidly, without involving any accompanying sudden motions and concussions. It allows the valves to be opened very widely with great rapidity, a point of considerable importance in the motion of the exhaust valves, as it is always desirable to discharge the steam as freely and rapidly as possible when its work is performed. But its greatest merit lies in the fact that it prevents a wire-drawing of steam at the closing of the steam valves, by means of the suddenness of the motion; a result which cannot be obtained in an engine having puppet-valves, because the descent of the valves by gravity, must, in such engines, be very moderate at the termination of the motion, to prevent their slamming on their seats.

The alternations in the action of the steam, as ordinarily effected, are constantly in progress. The opening for the admission of the steam enlarges gradually, and is no sooner fully and freely open than it commences to close: the same is true of the opening for the exhaust. In order to so effect the operations of admitting and discharging the steam that the *mean* of each shall be at the proper time, it is necessary to commence a certain time in advance. Thus the steam begins to enter the cylinder to produce a movement of the piston in one direction before the previous stroke has been fully completed, and consequently acts for a brief period in the wrong direction, or as a retarding force; and subsequently begins to escape, and to lose its effect before the piston has completed its proper movement. These imperfections in the action of the steam are unavoidable in the common varieties of the steam engine, whether using slide valves or puppet valves, but are completely avoided in this style of engine; the steam being admitted and discharged very freely, and at the moment the piston is at the ends of the stroke. The construction allows of the adjusting of the valve motion so as to receive and discharge a little in advance or a little behind this period if preferred, and in fact, these engines are frequently adjusted in various conditions in this respect: but the *necessity* for commencing either operation in advance, or giving "lead" to the valves, is entirely removed by the rapidity with which it is effected.

Perfection of economy in the use of steam is to admit it freely at a high pressure at the moment the piston commences its stroke, and allow it to follow at full pressure through such a fraction of the stroke that the subsequent expansion shall, during the remainder of the stroke, reduce it to the lowest pressure at which it can be useful. A certain amount of pressure, varying from one to three or four, pounds is always required to overcome the friction of the engine. Whenever steam is discharged from a cylinder at a higher effective pressure than this, it proves that there is still power remaining in it which might have been utilized by a better arrangement and proportion of the engine. It might seem reasonable to suppose that the gain of effect due to expansion, explained on page , may be increased indefinitely by increasing the initial or boiler pressure, and cutting off at a proportionably early period in the stroke; but there are other considerations, due to the strains on the parts, the friction of the surfaces, and the leakage of steam, which limit it. In the Corliss engine, the average expansion allowed is that found most economical in practice.

It should be premised that it requires a higher *temperature*, but only a very little greater *amount* of heat, to evaporate a given quantity of water at a high pressure than at a low. Recent elaborate scientific experiments, as also the results of general experience, assure us that there is a little, and *but* a little difference in the amount of fuel consumed, in evaporating a cubic foot of water at 100 pounds pressure or at 1 pound pressure, while the power derivable is much greater from the steam of highest pressure, used expansively as above described. The actual cost for fuel to obtain any given power, is a subject which has not received the attention it deserves. The following condensed tabular statement indicates the actual performances of these engines. The data are from large mills in ordinary and constant use, and in this respect differ very widely from experiments conducted for short periods and with miniature apparatus,—good common engines had been previously employed in each.

☞ The quantities marked with an asterisk (*) indicate the amount used for heating and dressing in addition to that required for power.

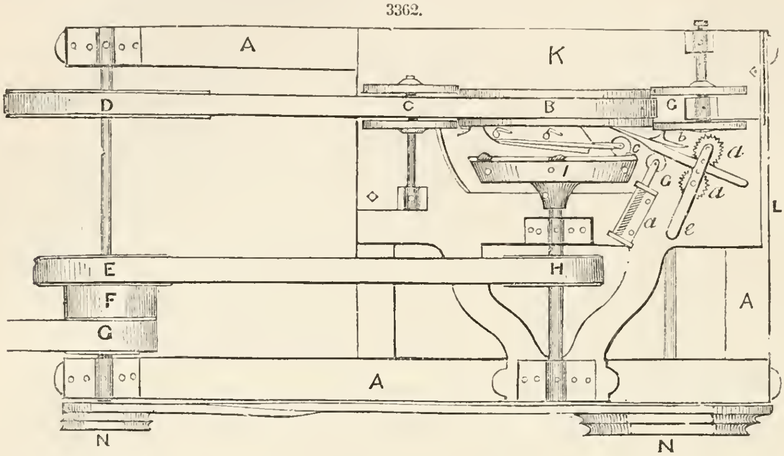
Establishment.	Horse power by Indicator.	lbs. Coal consumed per day with Corliss Engine.	lbs. Coal per Horse per Hour.	Ounces Coal per day per Spindle.	lbs. Coal consumed with former Engines.
Atlantic Mil, Providence R. I.	270	6,000	1·88	3·912	——
Bartlett Mils New-buryport, Mass.	200	6,000*	2·5*	5·690*	9,250*
James Mills, do.	190	5,690*	2·5*	5·27*	10,18[illegible]*
Globe Mills, do.	294	8,800*	2·49*	——	11,000*
Crocker & Bro's, (Rolling Mill,) Taunton, Mass.	60 to 260	4,000	——	......	10,000

STAVE-DRESSING MACHINE. Fig. 3362 gives only a representation of this machine in the manner of looking down upon the face of the frame, therefore the geering underneath cannot be seen; but from this vertical view a good mechanic will be able to trace the relation of the different parts, and perceive the beauties of the whole machine and its adaptations to the purpose, so much to be desired and so essential to the great and rising trade of American cooperage.

A A A is the frame; K is the iron bed plate represented by the dark shading. B represents the large knife or cutting roller, somewhat hid by the belt which drives it from the power roller D. C C are friction-rollers, edged, as it were, to run upon a rail to keep the large knife-roller steady, and underneath is another for the same purpose, all three set equidistant, like at the points of a triangle. E H are rollers connected with another belt to drive the small knife roller I. G is a driving belt on an idle roller near the motion or drive pulley F. N N are pulleys which are driven by a cross rope belt to drive a horizontal shaft, on which is the notched wheel which moves the two vertical shafts or feeding rollers (two biting wheels) *a a*, and which are now represented as feeding a stave into the knife-rollers. E is a spiral spring which makes the feeders accommodate themselves to the bendings of the staves. *b* is a rest on a straight line which keeps the stave up to the other two smooth rollers with springs *c d*, which act as subordinate to the biting feeders. C is another rest and roller to keep firm the small cutting roller I, between which and the large knife roller B the stave passes and comes out shaved through the centre of B, the large cutting-roller, which is open. L is the lever or handle to set the feed-geer in motion, by lifting the wheel which drives the feed-shafts.

The nature of this invention and improvement consists in combining and arranging two revolving rings or wheels having cutters on their opposing surfaces next each other, for shaving the stave transversely on both sides at once, producing a stave the cross-section of which is the segment of a circle, the diameter of which is to be greater than the diameters of the wheels, and the curve of the stave being variable at pleasure for all kinds of casks. The position of the whole geering can be changed to suit the angle of the stave's curvature, as the stave moves on the cutters it being the hypothenuse of a right-angled triangle formed by the parallel lines on which the cutters are placed. The whole machine is constructed on the principle of considering a circle (for the curvature) to be a regular polygon of an indefinite number of sides, the sum of the sides being the perimeter of the circle.

3362.

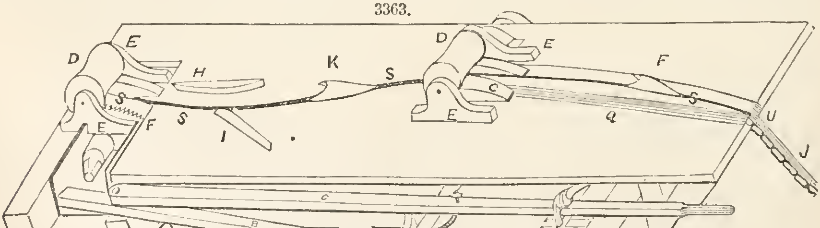


A patent was granted for this machine to Judson & Pardee, New Haven, Conn. It cannot but be of great benefit to our country, as it destroys at once the rough, slavish work of cooperage, and lets the cooper occupy his hands with the most light and easy parts of his trade.

STAVE-JOINTING MACHINE. Fig. 3363 is an engraving of a stave jointer, the invention of Mr. H. Law, of Wilmington, North Carolina, who has taken measures to secure a patent for the same. Its utility, nature, and mode of operation will be fully understood by the following description:

A A A, frame. B, lever, which moves the frame L L, together with the saw and roller D, which are all attached to frame L L. C, lever, by means of which lever B is moved. D D, concave rollers under which the stave passes. E E E E, standards to support D D. F F, circular saws, standing in a raking position, verging in opposite directions, so as to give the proper bevel to the edges of the stave. G G G G, raised pieces over which the stave passes, which raised pieces together with the concave rollers D D form throats or slots just the thickness of the stave, and through which the stave is made to pass H, a guide-piece to conduct the stave to the second saw. I, a light spring to press the stave against the guide-piece H. J, the end of the feed-chain which connects with the dresser. K K, dogs or hooks, attached to the endless chain and traversing in the curved slot S S S to carry forward the stave—the chain

3363.



is underneath, and does not appear in the engraving except at J. L L, movable frame that supports the saw, and that is attached to and acted upon by lever B to adjust the saw to the width of the stave. M, journal-box. P P, pulleys to drive the circular saw. O, pawls, or hold-fasts, to lever C. N N, weight and rope that move lever B. Q Q, index beds. R, curved piece attached to lever B. ......, dotted curved line ranging with the saw, and governing the feed of stave on that side.

Operation.—The stave is deposited by the machine on the floor of the jointer, and is placed by hand with the back of the stave up, with one edge on the dotted lines, being the proper position for that edge to be jointed by the first saw, and with a single glance of the eye on the index lines on the near side the tender can see what width the stave will bear; if it is described, for instance, by the first line, the lever C is immediately placed on the corresponding first line, and held fast by pulley O, or if the stave is of some other width it is readily seen, and the lever C placed in the proper position; but it is not convenient that the saw should take that position immediately, therefore lever B is still held fast in its former position by ratchets underneath and attached to circular piece R, which circular piece is attached to and traverses with lever B. There is a ketch attached to the frame of the machine, which is pressed into the ratchets and holds fast lever B. This hold-fast is tripped by one of the dogs passing through a throat under the floor at the proper time, when the weight N immediately shifts lever B to lever C, and places the saw in its proper position. The dog that carries the stave forward traverses in a curved line corresponding to the bilge or taper of the stave, giving to the stave its taper, and both saws standing in a raking position corresponding to the bevel of the stave, gives to the stave its proper bevel, the stave passing between the raised pieces G G G G and the concave roller D D, which together form a slot just the thickness of a stave, must of necessity bring every crook or twist fair to the saw, jointing to correspond with the crooks and twists, and making a more perfectly shaped stave than can possibly be done by the hand. The staves are pressed by springs (which do not appear in the engraving) up against the rollers D D, and as the rollers are more concave than the stave is convex, one edge of a narrow stave is forced into this concavity and presents an edge less bevelling to the saw than a wide stave does, so that without any alteration of machinery the bevel is made to correspond to the width of the stave; to accomplish this with the second saw the concave roller, together with the near standard E and raised piece G, is attached to the frame and shifts with the saw.

STEAM. The elastic fluid into which water is converted by the continued application of heat.

All liquids whatever, when exposed to a sufficiently high temperature, are converted into vapor. The mechanical properties of vapor are similar to those of gases in general. The property which is most important to be considered, in the case of steam, is the elastic pressure. When a vapor or gas is contained in a close vessel, the inner surface of the vessel will sustain a pressure arising from the *elasticity* of the fluid. This pressure is produced by the mutual repulsion of the particles, which gives them a tendency to fly asunder, and causes the mass of the fluid to exert a force tending to burst any vessel within which it is confined. This pressure is uniformly diffused over every part of the surface of the vessel in which such a fluid is contained: it is to this quality that all the mechanical power of steam is due.

To render the chief properties of steam intelligible, it will only be necessary to explain the phenomena which attend the conversion of water into vapor by the continued application of heat, under the various circumstances of external pressure which present themselves in the processes of nature and art.

3364.

Let A B, Fig. 3364, be a tube or cylinder, the magnitude of whose base is a square inch, and let a piston move steam-tight in it; let it be imagined that under this piston, in the bottom of the cylinder, there is an inch depth of water, which will therefore be in quantity a cubic inch; let the piston be counterbalanced by a weight W acting over a pulley, which shall be sufficient to counterpoise the weight of the piston and its friction in the cylinder; and let the weight W be so arranged that from time to time its amount may be diminished to any required extent. Under the circumstances here supposed, the piston being in contact with the water, and all air being excluded from beneath it, it will be pressed down by the weight of the atmosphere, which we shall assume to be 14¾ lbs. Let it be also supposed that a thermometer is placed in the water under the piston, and that the tube A B is transparent, so that the indications of the thermometer may be observed. The temperature of the water under the piston being reduced to that of melting ice, which is 32° of the common thermometer, let the flame of a lamp be applied under the tube, and let the time of its application be noted. If the thermometer be now observed, it will be seen slowly and gradually to indicate an increasing temperature of the water, the piston maintaining its position in contact with the water unchanged. This augmentation of the temperature will continue until the thermometer indicates the temperature of 212°. Let the time be then noted. It will be found that after that epoch, the water will cease to increase in temperature, notwithstanding the continued application of the lamp, the thermometer not rising above 212°. But another effect will begin to be manifested; the piston will be observed gradually to rise, leaving a space apparently vacant between it and the water. The depth of the water will, however, be at the same time gradually diminished, and the diminution of its depth will be found to bear constantly the same proportion to the ascent of the piston. This proportion will render the circumstances here supposed to be that of 1700 to 1. If the application of the lamp be continued, and the tube have sufficient length, the water will, after the lapse of a certain time, altogether disappear from the bottom of the tube; and when that occurs, the piston will have risen to the height of 1700 inches, being 1700 times the original depth of the water.

The tube will now, to all appearance, be empty; but if the apparatus were weighed, it would be found to have the same weight as at the commencement of the experiment. The water, therefore, must still be contained in the tube, though it has assumed an invisible form. To demonstrate its presence, let the lamp be removed; immediately the piston will begin to descend, and the inner surface of the tube will be covered with a dew, which speedily increasing, will fall to the bottom in drops of water. The piston meanwhile will continue to move downwards, sweeping before it the water from the sides of the tube, and at length will recover its first position, having under it, as at the beginning, a cubic inch of water.

In the above process, the elevation of the piston is produced by the elastic force of the steam, into which the water was gradually converted by the lamp. The space between the piston and the water during its ascent, though apparently empty, was filled with steam; which, like air and most other gases, is a colorless and invisible fluid. The proportion of the elevation of the piston to the diminution of depth of the water being 1700 to 1, proves that the water in passing into steam increases its volume in that proportion. When the water altogether disappeared, the height of the piston from the bottom of the tube was 1700 inches; and as the tube under the piston was then filled with the steam into which the water had been converted, it is apparent that the cubic inch of water, in this case, was converted into 1700 inches of steam.

The pressure of the atmosphere above the piston was, in this case, overcome by the elastic force of the steam, and the piston, bearing that pressure upon it, was raised to a height of 1700 inches. In the evaporation, therefore, of this cubic inch of water, a mechanical force has been evolved equivalent to 14¾ lbs. raised to the height of 1700 inches.

From the moment at which the water began to be converted into steam the thermometer, having then attained 212°, ceased to rise. Nevertheless, the application of the lamp was continued, and therefore the same quantity of heat per minute was still supplied to the water. Since the water did not increase in temperature, it may be asked what became of this continued supply of heat received from the lamp? It may be said that it was imparted to the steam into which the water was converted; but if the thermometer were raised out of the water, and held in the steam between the water and the piston, it would still indicate the same temperature of 212°. We thus arrive at the extraordinary and unexpected fact, that notwithstanding a large supply of heat imparted to water during its evaporation, that heat is sensible neither in the water itself nor in the vapor into which the water is converted.

The quantity of heat which is thus absorbed in converting water into steam is easily determined, the interval of time being noted which elapsed between the first application of the lamp and the moment at which the thermometer ceased to rise. Let us suppose that interval to be an hour; the interval being also noted between the moment the thermometer ceases to rise and the process of evaporation begins, and the moment at which the last particle of water disappears from the bottom of the tube and the evaporation is completed, it will be found that this interval is 5½ hours; and in general, whatever may be the length of time necessary to raise the temperature of the water from 32° to 212°, 5½ times that interval will be necessary for the same source of heat to evaporate the same quantity of water. It follows, therefore, that *to evaporate water under a pressure of* 14¾ *pounds per square inch requires* 5½ *times as much heat as is necessary and sufficient to raise the same water from* 32° to 212°.

Since the difference between 212° and 32° is 180°, and since 5½ times 180° is 990°, it follows that to convert the water into steam after it has attained the temperature of 212°, as much heat must be supplied to it as would be sufficient, if it were not evaporated, to raise it 990° higher. The heat thus absorbed in evaporation, and not sensible to the thermometer, is said to be latent in the steam; and the phenomena which have been just described form the foundation of the whole theory of *latent heat.* That this large quantity of heat is actually contained in the steam, though not sensible to the thermometer, admits of easy demonstration, by showing that it may be reproduced by converting the steam into water. If a cubic inch of water, in the form of steam at the temperature of 212°, be introduced into the same vessel with 5½ cubic inches of water at the temperature of 32°, the steam will be immediately converted into water; the temperature of the 5½ inches of ice-cold water will be raised to 212°, and there will be found in the vessel 6½ cubic inches of water at 212°. Thus, while the steam, in reassuming the liquid form, has lost none of its temperature, it has nevertheless given up as much heat as has raised 5½ cubic inches of water from 32° to 212°. It is therefore demonstrated that this quantity of heat was actually in the steam; and that it was its presence there in the latent state, by some agency not yet explained, that conferred upon the water in the vaporous form the property of elasticity.

We have here supposed that the pressure under which the water in the tube was evaporated was the mean pressure of the atmosphere, or 14¾ lbs. per square inch. Let us now suppose that the piston resting on the water is loaded with a force of 14¾ lbs., besides the pressure of the atmosphere, which may be done by taking 14¾ lbs. from the counterpoise W. If the same process be followed as before, it will now be found that the thermometer will not cease to rise when it has attained 212°; nor will the piston then begin to ascend. The thermometer will, on the other hand, continue to rise until it has attained 250°. It will then, as in the former case, cease to rise; the piston will ascend, and the water will begin to be converted into steam; the proportion, however, between the ascent of the piston and the diminished depth of the water, or, in other words, between the volume of steam produced and the volume of water producing it, instead of being 1700 to 1, will now be about 930 to 1, being little more than half the former proportion. The force against which the elasticity of the steam, in the present case, acts, is 29½ lbs.; and this force is raised about 930 inches by the evaporation of a cubic inch of water. In the former case, a force of 14¾ lbs., being half the present force, was raised to 1700 inches by the evaporation of the same quantity of water. If the double force, instead of being raised 930 inches, had been raised only 850 inches, or half the first elevation, then the mechanical effect evolved would in both cases be precisely the same, the double resistance being raised through only half the space; but the actual height through which the double resistance is raised being 930 inches instead of 850, a greater mechanical effect is produced in the one case than in the other, in the proportion of 930 to 850, being an advantage on the part of the steam of greater pressure of about 8 per cent.

If the pressure under which the evaporation is produced were further varied, it would be found that with every increase of pressure the temperature at which the evaporation would commence would be augmented, and that with every diminution of pressure that temperature would be diminished. It would be also found that the volume of steam produced by a cubic inch of water would be less with every increase of pressure under which the evaporation is made; and that the diminution of volume would be nearly, but not in quite so great a proportion, as the increase of pressure. In like manner, if the pressure be diminished, the volume of steam produced by a cubic inch of water will be augmented in nearly, but not quite so great a proportion, as that of the diminution of pressure. From all this, it obviously follows that the mechanical effect evolved by the evaporation of a given volume of water under different pressures is very nearly the same; greater pressures, however, having a slight advantage over lesser ones.

It has been seen that 14¾ lbs. are raised to a height of 1700 inches by the evaporation of a cubic inch of water under the pressure of 14¾ lbs. per square inch. Now, 1700 inches are nearly equal to 142 feet; and 14¾ lbs. raised 142 feet is equivalent to 142 times 14¾ lbs. raised one foot, which is equal to very nearly 2100 lbs. raised one foot. To use round numbers, it may then be stated, that by the evaporation of a cubic inch of water a mechanical force is produced equivalent to a ton weight raised a foot high; and that this force is very nearly the same, whatever be the temperature or pressure under which the evaporation takes place.

In the following table, calculated by Dr. Lardner, and given by him in the Appendix to the 7th edition of his work on the *Steam-Engine*, is exhibited the temperatures at which water is evaporated under different pressures, the volume into which the water expands by evaporation, the mechanical effect evolved expressed in lbs. raised one foot.

Total pressure in pounds per square inch.	Corresponding Temperature.	Volume of the steam compared to the volume of the water that has produced it.	Mechanical effect of a cubic inch of water evaporated, in pounds raised one foot.	Total pressure in pounds per square inch.	Corresponding Temperature.	Volume of the steam compared to the volume of the water that has produced it.	Mechanical effect of a cubic inch of water evaporated, in pounds raised one foot.
1	102·9	20868	1739	58	292·9	484	2339
2	126·1	10874	1812	59	294·2	477	2343
3	141·0	7437	1859	60	295·6	470	2347
4	152·3	5685	1895	61	296·9	463	2351
5	161·4	4617	1924	62	298·1	456	2355
6	169·2	3897	1948	63	299·2	449	2359
7	175·9	3376	1969	64	300·3	443	2362
8	182·0	2983	1989	65	301·3	437	2365
9	187·4	2674	2006	66	202·4	431	2369
10	192·4	2426	2022	67	303·4	425	2372
11	197·0	2221	2036	68	304·4	419	2375
12	201·3	2050	2050	69	305·4	414	2378
13	205·3	1904	2063	70	306·4	408	2382
14	209·1	1778	2074	71	307·4	403	2385
15	212·8	1669	2086	72	308·4	398	2388
16	216·3	1573	2097	73	309·3	393	2391
17	219·6	1488	2107	74	310·3	388	2394
18	222·7	1411	2117	75	311·2	383	2397
19	225·6	1343	2126	76	312·2	379	2400
20	228·5	1281	2135	77	313·1	374	2403
21	231·2	1225	2144	78	314·0	370	2405
22	233·8	1174	2152	79	314·9	366	2408
23	236·3	1127	2160	80	315·8	362	2411
24	238·7	1084	2168	81	316·7	358	2414
25	241·0	1044	2175	82	317·6	354	2417
26	243·3	1007	2182	83	318·4	350	2419
27	245·5	973	2189	84	319·3	346	2422
28	247·6	941	2196	85	320·1	342	2425
29	249·6	911	2202	86	321·0	339	2427
30	251·6	883	2209	87	321·8	335	2430
31	253·6	857	2215	88	322·6	332	2432
32	255·5	833	2221	89	323·5	328	2435
33	257·3	810	2226	90	324·3	325	2438
34	259·1	788	2232	91	325·1	322	2440
35	260·9	767	2238	92	325·9	319	2443
36	262·6	743	2243	93	326·7	316	2445
37	264·3	729	2248	94	327·5	313	2448
38	265·9	712	2253	95	328·2	310	2450
39	267·5	695	2259	96	329·0	307	2453
40	269·1	679	2226	97	329·8	304	2455
41	270·6	661	2268	98	330·5	301	2457
42	272·1	649	2273	99	331·3	298	2460
43	273·6	635	2278	100	332·0	295	2462
44	275·0	622	2282	110	339·2	271	2486
45	276·4	610	2287	120	345·8	251	2507
46	277·8	598	2291	130	352·1	233	2527
47	279·2	586	2296	140	357·9	218	2545
48	280·5	575	2300	150	363·4	205	2561
49	281·9	564	2304	160	368·7	193	2577
50	283·2	554	2308	170	373·6	183	2593
51	284·4	544	2312	180	378·4	174	2608
52	285·7	534	2316	190	382·9	166	2622
53	286·9	525	2320	200	387·3	158	2636
54	288·1	516	2324	210	391·5	151	2650
55	289·3	508	2327	220	395·5	145	2663
56	290·5	500	2331	230	399·4	140	2675
57	291·7	492	2335	240	403·1	134	2687

From what has been above explained, it is apparent that the quantity of sensible heat in steam is augmented with every increase of pressure under which the evaporation takes place; but if the interval of time be observed which elapses between the first application of the lamp to the ice-cold water in the experiment above described, and the moment at which the last particle of water disappears by evaporation from the bottom of the tube, it will be found that this interval is exactly the same, whatever be the temperature or pressure under which the evaporation takes place. It follows, therefore, that the actual quantity of heat necessary to convert ice-cold water into steam is the same, whatever be the pressure of the steam; but as the temperature of steam increases and diminishes as the pressure is increased or diminished, it follows that this given quantity of heat is differently distributed between sensible and latent heat in steam of different pressures. As the pressure is increased the sensible heat is augmented, and the latent heat undergoes a corresponding diminution, and *vice versa*. The sum of the sensible and latent heats is, in fact, a constant quantity; the one being always increased at the expense of the other. It has been shown that in converting water at 32° of temperature, and under a pressure of 14¾ lbs. per square inch, it was necessary first to give it 180° additional sensible heat, and afterwards 990° of latent heat, the total heat imparted to it being 1170°. Such, then, is the actual quantity of heat which must be imparted to ice-cold water to convert it into steam. The actual temperature to which water would be raised by the heat necessary to evaporate it, if its evaporation could be prevented by confining it in a close vessel, will be found by adding 32° to 1170°. It may, therefore, be stated that the heat necessary for the evaporation of ice-cold water is as much as would raise it to the temperature of 1202°, if its evaporation were prevented. If the temperature of red-hot iron be, as is supposed, about 800°, and that all bodies become incandescent at the same temperature, it follows that to evaporate water it is necessary to impart to it 400° more heat than would be sufficient to render it red-hot if its evaporation were prevented. As the mechanical effect evolved by water evaporated at all pressures is nearly the same, and as the quantity of heat necessary to effect that evaporation is also the same, it follows that the same quantity of fuel employed in the evaporation of water is productive of very nearly the same mechanical effect, whatever be the pressure of the steam.

Since the heat imparted to water in evaporation is necessary to sustain it in the form of vapor, it follows that if any portion of that heat be taken from it, the steam will not be lowered in temperature, but a portion of it will be reconverted into water; a process which is called *condensation*. To illustrate this, let us suppose the tube A B to be filled with steam of 212° of temperature, produced from a cubic inch of water evaporated under the pressure of 14¾ lbs. on the piston. If, by the application of external cold, or any other means, a quantity of heat be extracted from this steam, say as much as would be sufficient to evaporate the tenth of a cubic inch of water, then a tenth part of the steam in the tube will be condensed and deposited in the liquid state in the bottom, the piston will descend through a tenth of its entire height, and the steam remaining uncondensed will still have the temperature of 212° and the pressure of 14¾ lbs. per square inch, while the water in the bottom of the tube produced by the condensation will also have a temperature of 212°. The heat, therefore, which has been thus abstracted, is the heat which was latent in the steam formed by the water thus deposited. And in the same manner, any heat which is drawn from the steam will be latent heat; a corresponding condensation will take place until all the steam has been condensed, and the piston brought into contact with the bottom of the tube. After that, any abstraction of heat must be made at the expense of the sensible heat of the water.

It has, in some works, been stated that by mere mechanical compression steam will be converted into water. This is, however, an error, since steam, in whatever state it may exist, must possess at least 212° of heat; and as this quantity of heat is sufficient to maintain it in the vaporous form, under whatever pressure it may be placed, it is clear that no compression or increase of pressure can diminish the actual quantity of heat contained in the steam; and it cannot, therefore, convert any portion of the steam into water.

If steam, by mechanical pressure, be forced into a diminished volume, it will undergo an augmentation both of temperature and pressure, the increase of pressure being greater than the diminution of volume; in fact, any change of volume which it undergoes will be attended with the change of temperature and pressure indicated in the above table. The steam, after its volume has been changed, will assume exactly the pressure and temperature which it would have in the same volume if it were immediately evolved from water. Thus, let us suppose a cubic inch of water converted into steam under a pressure of 14¾ lbs. per square inch, and at the temperature of 212°. Let its volume be then reduced by compression in the proportion of 1700 to 930. When so reduced, its temperature will be found to have risen from 212° to 250°, and its pressure will be increased from 14¾ lbs. per square inch to 29½ lbs. per square inch; but this is exactly the state, as to pressure, temperature, and density, as the steam would be in if it were immediately raised from water under the pressure of 29½ lbs. per square inch. It appears, therefore, that in whatever manner, after evaporation, the density of steam be changed, whether by expansion or contraction, it will still remain the same as if it were immediately raised from water in its actual state.

The circumstance which has given rise to the erroneous notion that mere mechanical compression will produce a condensation of steam is, that the vessel in which steam is contained must necessarily have the same temperature as the steam itself. If then the steam contained in the vessel be suddenly compressed, it will undergo as sudden an elevation of temperature; and the vessel containing it not receiving at the same time, from any external source, a corresponding increase of temperature, it will rob the steam of a portion of its heat, and a partial condensation will be produced, and will be continued until the temperatures of the steam and the vessel containing it shall be equalized.

While water, in passing into steam, suffers a great enlargement of volume, steam, on the other hand, in being converted into water undergoes a corresponding diminution of volume. It has been seen that a cubic inch of water, evaporated at the temperature of 212°, swells into 1700 cubic inches of steam. It follows therefore, that if a close vessel, containing 1700 cubic inches of such steam, be exposed to cold sufficient to take from the steam all its latent heat, the steam will be reconverted into water, will shrink into its original dimensions, and will leave the remainder of the vessel a vacuum. This property of steam has supplied the means, in practical mechanics, of obtaining that amount of mechanical power which the properties of the atmosphere confer upon a vacuum. If by any means whatever the space in a cylinder under the piston be rendered a vacuum, the atmospheric pressure will take effect above the piston, and will urge the piston downwards with a force amounting to about 15 lbs. on each square inch of the surface of the piston. To render steam available for this purpose, it is only necessary to inject it into the cylinder until it expels from the cylinder all the atmospheric air or other uncondensable gases which the cylinder contains; and when that is effected, the pure steam which remains in the cylinder being suddenly condensed by the application of cold, leaves the cylinder a vacuum, and gives effect to the atmospheric pressure above the piston, as before explained. This is, in fact, the principle of the atmospheric engine.

The temperature and pressure of steam produced by immediate evaporation, when it has received no heat, save that which it takes from the water, have a fixed relation one to the other. If this relation were known, and expressed by a mathematical formula, the temperature might always be inferred from the pressure, or *vice versa*. But physical science has not yet supplied any principles by which such a formula can be deduced from any known properties of liquids. In the absence, therefore, of any general relation established by direct reasoning, empyrical formulæ have been proposed which express, with more or less precision, this relation in different parts of the thermometric scale.

When the pressure under which the evaporation takes place does not exceed one atmosphere, or 15 lbs. per square inch, the relation between the temperature and the pressure will be expressed with sufficient accuracy by the following formulæ, proposed by Southern:

$$P = 0{\cdot}04948 + \left(\frac{51{\cdot}3 + T}{155{\cdot}7256}\right)^{5{\cdot}13}$$

$$T = 155{\cdot}7256 \times \sqrt{P - 0{\cdot}04948} - 51{\cdot}3\,,$$

where P expresses the pressure in pounds per square inch, and T the temperature by Fahrenheit's thermometer.

For pressures exceeding one atmosphere and not exceeding four, the relation is expressed by the following formulæ, proposed by Tredgold:

$$P = \left(\frac{103 + T}{201{\cdot}18}\right)^{6}$$

$$T = 201{\cdot}18\,\sqrt[6]{P} - 103\,;$$

or by the following formulæ,

$$P = \left(\frac{98{\cdot}206 + T}{198{\cdot}562}\right)^{6}$$

$$T = 198{\cdot}562\,\sqrt[6]{P} - 98{\cdot}806.$$

For pressures extending from four to fifty atmospheres, the following formulæ have been proposed by Messrs. Dulong and Arago:

$$P = (0{\cdot}26793 + 0{\cdot}0067585\,T)^{5}$$

$$T = 147{\cdot}961\,\sqrt{P} - 39{\cdot}614.$$

Biot has proposed a more general formula, which expresses the relation between the pressure and the temperature, whatever be the pressure under which the evaporation takes place. Let p be the pressure, expressed in millimètres, of mercury at the temperature of melting ice; let t be the temperature of the water taken on the centesimal air thermometer; and let a, a_1, a_2, b_1, b_2 be constant quantities, whose values shall be determined by the following conditions:

$$a = 5{\cdot}96131330259$$
$$\text{Log. } a_1 = \bar{1}{\cdot}82340688193$$
$$\text{Log. } b_1 = -\,0{\cdot}01309734295$$
$$\text{Log. } a_2 = 0{\cdot}74110951837$$
$$\text{Log. } b_2 = -\,0{\cdot}00212510583.$$

The relation between p and t will then be expressed by the following formula,

$$\text{Log. } p = a - a_1\,b_1^{\,20+t} - a_2\,b_2^{\,20+t}.$$

M. Biot compared the temperature and corresponding pressures, calculated by this formula, with the series determined by an extensive course of experiments undertaken by MM. Arago and Dulong by order of the French government, to those of the experiments of Taylor at lower temperatures, and to a numerous series of MSS. observations of M. Gay Lussac, extending from the boiling point to temperature considerably below that of melting ice, and found that the calculated and observed results corresponded within the limits of error of the experiments themselves. The formulæ first given above offer, however, much greater facility for practical calculation, and afford as accurate results as are required for all ordinary purposes.

The same difficulty which attends the establishment of a general formula expressing the relation between the temperatures and pressures of steam, also attends the determination of one expressing the relation between the pressure and the augmented volume into which the water expands by evaporation. Empirical formulæ have accordingly been likewise proposed to express this relation. The late Professor Navier proposed the following formula for this purpose

Let V express the number of cubic inches of steam produced by one cubic inch of water, and let P express the pressure of this steam in kilograms per square metre; then we shall have

$$V = \frac{1000}{0{\cdot}09 + 0{\cdot}0000484\ P}.$$

This formula gives sufficiently accurate results when applied to pressures much above one atmosphere. It fails to give the same accuracy, however, when applied to lower pressures.

The following formulæ have been proposed by M. de Pambour:

$$V = \frac{10{,}000}{0{\cdot}4227 + 0{\cdot}00258\ P},$$

which will apply to low pressures; and

$$V = \frac{10{,}000}{1{\cdot}421 + 0{\cdot}0023\ P},$$

which will be applicable to high pressures. In each of these P is expressed in pounds per square foot.

Dr. Lardner proposes the following modified formula, V and P retaining their signification:

$$V = \frac{3875969}{164 + P},$$

which may be used in reference to low-pressure engines of every form, as well as for high-pressure engines which work expansively.

When the pressure is not less than 30 lbs. per square inch, the following formula will be more accurate:

$$V = \frac{4347826}{618 + P}.$$

In the preceding observations steam has been considered as receiving no heat except that which it takes from the water during the process of evaporation, the amount of which, as has been shown, is 1170° more than the heat contained in ice-cold water. But steam, after having been formed from water by evaporation, may, like all other material substances, receive an accession of heat from any external source, and its temperature may thereby be elevated. If the steam to which such additional heat is imparted be so confined as to be incapable of enlarging its dimensions, the effect produced upon it by the increase of temperature will be an increase of pressure; but if, on the other hand, it be confined under a given pressure, with power to enlarge its volume, subject to the preservation of that pressure, as would be the case if it were contained in a cylinder under a movable piston loaded with a given pressure, then the effect of the augmented temperature will be, not an increase of pressure, but an increase of volume; and the increase of volume in this latter case will be in exactly the same proportion as the increase of pressure in the former case.

These effects of elevated temperature are common, not only to the vapors of all liquids, but also to all permanent gases; but, what is much more remarkable, the numerical amount of the augmentation of pressure or volume produced by a given increase of temperature is the same for all vapors and gases. If the pressure which any gas or vapor would have were it reduced to the temperature of melting ice be expressed by 100,000, then the pressure which it will receive for every degree of temperature by which it is raised will be expressed by $208\frac{1}{3}$; or, what amounts to the same, the additional pressure produced by each degree of temperature will be the 480th part of its pressure at the temperature of melting ice. From these data it is easy to obtain an algebraical expression by which the augmentation of pressure in a given volume, or, what is the same, the augmentation of volume under a given pressure for every increase of temperature, may be calculated.

Let v be the volume of any elastic fluid at the temperature of 32°; and let it be then supposed to be raised by the application of heat to the temperature T, if under a given pressure. Let its augmented volume be V. The increase of volume will then be $V - v$, while the increase of temperature will be $T^\circ - 32^\circ$. But since the increase of volume for *one* degree of temperature is $\frac{v}{480}$, the increase for $T^\circ - 32^\circ$ will be $\frac{v}{480} \times (T^\circ - 32^\circ)$; and therefore the augmented volume V will be

$$V = v + \frac{v}{480}(T^\circ - 32^\circ). \qquad = v\left\{1 + \frac{T^\circ - 32^\circ}{480}\right\}.$$

If V' be the volume at any other temperature T', we shall have

$$V' = v\left\{1 + \frac{T'^\circ - 32^\circ}{480}\right\}.$$

From whence we infer

$$\frac{V}{V'} = \frac{T + 448}{T' + 448},$$

by which, when the volume of steam at any one temperature is known, the volume at any other temperature may be found, supposing that the steam receives no accession of water by evaporation.

Steam which thus receives additional heat after its separation from the water from which it is evolved has been called by Dr. Lardner *superheated steam*, to distinguish it from *common steam*, which is that usually employed in steam-engines. *Superheated steam* admits of losing a part of its heat without suffering partial condensation; but *common steam* is *always* partially condensed if any portion of heat be withdrawn from it. For further details on these properties, see *Lardner on the Steam-Engine* 7th ed. p. 168, *et. seq*; also Appendix. See also *Lardner on Heat*, chap. viii.; *Cabinet Cyclopædia*.

In the mechanical operation of steam, which has been already explained, the pressure, density, and temperature of the steam are supposed to remain the same during its action, and the mechanical effect is produced by the continual increase of the quantity of steam produced by evaporation. Thus, the piston in the apparatus represented in the figure is moved upwards, not by any change in the temperature, density, or pressure, but by the increased volume required by the continual production of steam. It has been proved that by this process alone the evaporation of a cubic inch of water, whatever be the pressure under which it takes place, evolves a mechanical force equivalent to a ton weight raised a foot high. But if, after this evaporation has been completed, the steam be separated from the water which produced it, and the load on the piston be gradually diminished, the steam would expand by moving the piston upwards in virtue of its excess of pressure, and this expansion will continue until the pressure of the steam shall be reduced to equality with the load on the piston. All mechanical effect developed in this process is due to the steam itself, independently of any further evaporation.

To make this important quality of the expansive action of steam understood, let us suppose the piston loaded with a pressure amounting to four times that of the atmosphere, including that of the atmosphere itself. If the water under the piston be evaporated under this pressure, it will have a temperature of about 291°, and by its evaporation the piston will be raised 40 feet. This will, therefore, be the whole mechanical effect arising from the immediate evaporation of the water. But when the evaporation has been completed, and the piston, with its load of four atmospheres, stands suspended at 40 feet above the bottom of the tube, let a pressure equal to that of one atmosphere be removed from the piston. The remaining pressure of three atmospheres being less than that of the steam below the piston, the piston will be raised, and will continue to rise until it has attained a height of about 50 feet, and the temperature of the steam thus expanded will fall to about 275°; and its pressure being reduced to that of three atmospheres, it will cease to rise. By this process, therefore, a mechanical force has been obtained from the steam equal to the weight of three atmospheres raised 10 feet, in addition to the effect obtained by immediate evaporation; but the expansive action does not stop here. Let it be supposed that the piston is again relieved from the pressure of another atmosphere, the superior pressure of three atmospheres below will cause it to rise, and it will ascend to the height of about 75 feet, the temperature of the steam falling to about 250°, and its pressure being reduced to two atmospheres. A further mechanical effect equivalent to the weight of two atmospheres raised to about 25 feet, has thus been obtained; and it is evident that by constantly and gradually diminishing the load on the piston, an additional effect may be always obtained from a given amount of evaporation, to an extent which is only limited by practical circumstances which restrain the application of this expansive principle. Since the cost of producing steam as a mechanical agent depends chiefly on the quantity of fuel necessary to effect the evaporation of a given volume of water, it follows that all the mechanical effect obtained by this principle of expansion is so much power added to the steam without further expense. Its importance, therefore, will be obvious in the economy of steam-power. For the manner of rendering it available in steam machinery, see Steam-Engine.

Table No. 1 exhibits the temperatures and corresponding pressures of steam as determined by the experiments of the committee of the French Institute up to fifty atmospheres—the atmosphere being measured by a column of mercury 29·922 inches high.

The last six temperatures in table No. 1 are deduced by calculation from the formula $e = (1 + 0{\cdot}7153\, t)^5$, in which e expresses the elasticity in atmospheres, and t the temperatures in centième degrees, beginning from 100°, and proceeding upwards.

Table I.

Pressure in Atmospheres.	Temperature.	Pressure in Atmospheres.	Temperature.
1	212°	13	380·66°
1½	234	14	386·94
2	250·5	15	392·86
2½	263·8	16	398·48
3	275·2	17	403·83
3½	285	18	408·92
4	293·7	19	413·78
4½	300·3	20	418·46
5	307·5	21	422·96
5½	314·24	22	427·28
6	320·36	23	431·42
6½	326·26	24	435·56
7	331·7	25	439·34
7½	336·86	30	457·16
8	341·78	35	472·73
9	350·78	40	486·59
10	358·88	45	499·14
11	366·85	50	510·6
12	374		

The most recent experiments on the elastic force of steam are those by a committee of the Franklin Institute. The object of the committee was to inquire into the causes of the explosion of steam-boilers, to investigate which they were requested to make experiments on the properties of steam, the expense of which was defrayed out of the treasury of the United States.

The results are contained in the following table, No. 2, arranged as in table No. 1, up to ten atmospheres.

Table II.

Pressure in Atmospheres.	Temperature.	Pressure in Atmospheres.	Temperature.
1	212°	6	315½°
1½	235	6½	321
2	250	7	326
2½	264	7½	331
3	275	8	336
3½	284	8½	340½
4	291½	9	315
4½	298½	9½	[illegible]19
5	304½	10	352½
5½	310		

We add the following table, calculated, we believe, by Professor Alexander, of Baltimore, on the pressure of steam at various temperatures.

TABLE *of the Pressure of Steam in inches of Mercury at the temperature of melting ice from degree to degree of Fahrenheit's thermometer.*

Temp. in degrees.	Pressure in inches of Merc.	Difference for 1 degree.	Temp. in degrees.	Pressure in inches of Merc.	Difference for 1 degree.	Temp. in degrees.	Pressure in inches of Merc.	Difference for 1 degree.
0	0·040	0·002	91	1·67	......	157	9·54	......
5	0·052	0·003	92	1·72	......	158	9·76	......
10	0·069	0·004	93	1·77	0·06	159	9·98	0·23
15	0·088	0·005	94	1·83	......	160	10·21	0·24
20	0·113	0·006	95	1·89	......	161	10·45	......
25	0·143	0·007	96	1·95	......	162	10·69	......
30	0·179	0·008	97	2·01	......	163	10·93	0·25
32	0·196	......	98	2·07	......	164	11·18	......
33	0·204	0·009	99	2·13	......	165	11·43	......
34	0·213	......	100	2·19	......	166	11·68	0·26
35	0·222	0·010	101	2·25	0·07	167	11·94	0·27
36	0·232	0·011	102	2·32	......	168	12·21	......
37	0·243	0·010	103	2·39	......	169	12·48	0·28
38	0·253	0·011	104	2·46	......	170	12·76	......
39	0·264	......	105	2·53	......	171	13·04	......
40	0·275	......	106	2·60	0·08	172	13·32	0·29
41	0·286	0·012	107	2·68	......	173	13·61	0·30
42	0·298	......	108	2·76	......	174	13·91	......
43	0·310	0·013	109	2·84	......	175	14·21	0·31
44	0·323	0·014	110	2·92	......	176	14·52	.....
45	0·337	......	111	3·	......	177	14·83	0·32
46	0·351	......	112	3·08	0·09	178	15·15	......
47	0·365	......	113	3·17	......	179	15·47	0·33
48	0·379	0·015	114	3·26	......	180	15·80	0·34
49	0·394	0·016	115	3·35	......	181	16·14	......
50	0·410	......	116	3·44	......	182	16·48	0·35
51	0·426	0·017	117	3·53	0·10	183	16·83	......
52	0·443	......	118	3·63	......	184	17·18	0·36
53	0·460	0·018	119	3·73	......	185	17·54	0·37
54	0·478	......	120	3·83	......	186	17·91	......
55	0·496	0·019	121	3·93	0·11	187	18·28	0·38
56	0·515	......	122	4·04	......	188	18·66	......
57	0·534	0·020	123	4·15	......	189	19·04	0·39
58	0·554	0·021	124	4·26	......	190	19·43	0·40
59	0·575	......	125	4·37	0·12	191	19·83	0·41
60	0·596	0·022	126	4·48	......	192	20·24	......
61	0·618	0·023	127	4·60	......	193	20·65	0·42
62	0·641	......	128	4·72	......	194	21·07	0·43
63	0·664	0·024	129	4·84	0·13	195	21·50	......
64	0·688	0·025	130	4·97	......	196	21·93	0·44
65	0·713	0·026	131	5·10	......	197	22·37	0·45
66	0·739	......	132	5·23	......	198	22·82	......
67	0·765	0·027	133	5·36	0·14	199	23·27	0·46
68	0·792	0·028	134	5·50	......	200	23·73	0.47
69	0·820	0·029	135	5·64	......	201	24·20	0·48
70	0·849	......	136	5·78	0·15	202	24·68	0·49
71	0·878	0·030	137	5·93	......	203	25·17	......
72	0·908	0·031	138	6·08	......	204	25·66	0·50
73	0·939	0·033	139	6·23	......	205	26·16	0·51
74	0·972	......	140	6·38	0·16	206	26·67	0·52
75	1·005	0·034	141	6·54	......	207	27·19	0·53
76	1·039	0·035	142	6·70	......	208	27·72	0·54
77	1·074	......	143	6·86	0·17	209	28·26	0·55
78	1·109	0·037	144	7·03	......	210	28·80	......
79	1·146	0·038	145	7·20	0·17	211	29·35	0·56
80	1·184	0·039	146	7·37	0·18	212	29·91	0·57
81	1·223	0·040	147	7·55	......	213	30·48	0·58
82	1·263	......	148	7·73	0·19	214	31·06	0·59
83	1·303	0·043	149	7·92	......	215	31·65	0·60
84	1·346	0·043	150	8·11	......	216	32·25	0·61
85	1·39	0·04	151	8·30	0·20	217	32·86	......
86	1·43	0·05	152	8·50	......	218	33·47	0·63
87	1·48	......	153	8·70	......	219	34·10	......
88	1·53	......	154	8·90	0 21	220	34·73	0·65
89	1·57	......	155	9·11	.....	221	35·38	......
90	1·62	......	156	9·32	0·22	222	36·03	0·67

TABLE *of the Pressure of Steam, &c.,* (Continued.)

Temp. in degrees.	Pressure in inches of Merc.	Difference for 1 degree.	Temp. in degrees.	Pressure in inches of Merc.	Difference for 1 degree.	Temp. in degrees.	Pressure in inches of Merc.	Difference for 1 degree.
223	36·70	......	279	94·47	1·50	335	213·74	2·94
224	37·37	0·69	280	95·97	1·51	336	216·68	2·97
225	38·06	0·70	281	97·48	1·52	337	219·65	3·
226	38·76	0·71	282	99·	1·54	338	222·65	3·03
227	39·47	0·72	283	100·54	1·56	339	225·68	3·07
228	40·19	0·73	284	102·10	1·58	340	228·75	3·10
229	40·92	0·75	285	103·68	1·60	341	231·85	3·13
230	41·67	......	286	105·28	1·63	342	234·98	3·16
231	42·42	0·76	287	106·91	1·65	343	238·14	3·20
232	43·18	0·77	288	108·56	1·67	344	241·34	3·24
233	43·95	0·78	289	110·23	1·69	345	244·58	3·28
234	44·73	0·80	290	111·92	1·71	346	247·86	3·32
235	45·53	0·81	291	113·63	1·72	347	251·18	3·36
236	46·34	0·82	292	115·35	1·75	348	254·54	3·39
237	47·16	0·83	293	117·10	1·77	349	257·93	3·42
238	47·99	0·85	294	118·87	1·80	350	261·35	3·45
239	48·84	0·86	295	120·67	1·83	351	264·80	3·49
240	49·70	0·87	296	122·50	1·85	352	268·29	3·53
241	50·57	0·88	297	124·35	1·87	353	271·82	3·59
242	51·45	0·89	298	126·22	1·89	354	275·39	3·61
243	52·34	0·91	299	128·11	1·91	355	279·	3·66
244	53·25	0·92	300	130·02	1·93	356	282·66	3·71
245	54·17	0·94	301	131·95	1·96	357	286·37	3·75
246	55·11	0·95	302	133·91	1·99	358	290·12	3·79
247	56·06	0·96	303	135·90	2·01	359	293·91	3·83
248	57·02	0·97	304	137·91	2·03	360	297·74	3·87
249	57·99	1·	305	139·94	2·06	361	301·61	3·91
250	58·99	1·01	306	142·	2·09	362	305·52	3·95
251	60·	......	307	144·09	2·11	363	309·47	3·99
252	61·01	1·03	308	146·20	2·13	364	313·46	4·04
253	62·04	1·04	309	148·33	2·16	365	317·50	
254	63·08	1·07	310	150·49	2·20			
255	64·15	1·07	311	152·69	2·22			
256	65·22	1·09	312	154·91	2·24			
257	66·31	......	313	157·15	2·27			
258	67·41	1·10	314	159·42	2·30			
259	68·53	1·12	315	161·72	2·32			
260	69·67	1·14	316	164·04	2·34			
261	70·83	1·16	317	166·38	2·37			
262	71·99	......	318	168·75	2·40			
263	73·18	1·19	319	171·15	2·44			
264	74·37	1·23	320	173·59	2·48			
265	75·60	1·24	321	176·07	2·51			
266	76·84	1·25	322	178·58	2·53			
267	78·09	1·27	323	181·11	2·55			
268	79·36	1·28	324	183·66	2·58			
269	80·64	1·30	325	186·24	2·61			
270	81·94	1·33	326	188·85	2·64			
271	83·27	1·34	327	191·49	2·66			
272	84·61	1·35	328	194·15	2·69			
273	85·96	1·36	329	196·84	2·73			
274	87·32	1·39	330	199·57	2·76			
275	88·71	1·41	331	202·33	2·80			
276	90·12	1·43	332	205·13	2·84			
277	91·55	1·45	333	207·97	2·87			
278	93	1·47	334	210·84	2·90			

Formula.

p = pressure in inches.

t = temp. in deg. Fahr.

$$\therefore p = \left(\frac{t}{180} + \frac{990}{1695}\right)^6 \text{; and}$$

$$t = 180\sqrt[6]{p} - 105°, 13.$$

Also, if

p' = pressure in atmosphere of 29·915 inches at 52° F.

t = temp. as before;

$$\therefore p' = \left(\frac{t}{317{\cdot}13} + \frac{561{\cdot}91}{1695}\right)^6$$

$$= \left(\frac{t}{317{\cdot}13} + \frac{990}{2986{\cdot}33}\right)^6$$

and

$$t = 317{\cdot}13\sqrt[6]{p'} - 105°, 13$$

For a more extended and at the same time practical view of the theory of steam and the steam engine, embracing rules for all the calculations likely to be introduced in the practice of constructing and working steam-engines, the reader cannot do better than consult "Bourne on the Steam Engine," published by the Artisan Club. It should be in the hands of every one using steam, and is recommended to our readers as a standard work on this subject.

STEEL. Steel appears to occupy an intermediate place between cast and malleable iron. The researches of the French academicians, Monge, Berthollet, and Vandermonde, show the distinction between cast-iron and steel to be that the former is charged with a superabundant, the latter with a minute yet sufficient dose of carbon; hammered iron, on the contrary, if pure, consists of iron free from all heterogeneous matter. It is to be regretted that the constituent proportions of steel have not been accurately determined. Vauquelin assumes the average amount of carbon to be 1-150th, and Clouet places it as high as 1-32d. Mr. Parkinson considers the quantity of carbon necessary for making of steel to be very small, indeed the actual amount seldom exceeding 1-200th, or 1-300th, and perhaps never more than 1-100th, the remaining portion of charcoal flying off at the time of cementation in the form of gaseous oxide of carbon. Dr. Thomson analyzed some specimens of cast-steel, from the manufactory of Mr. Buttery, near Glasgow, and the general results of his trials gave the constituents as follows:

Iron	99
Carbon, with some silicon	1
	100

Now this approaches—

Iron, 20 atoms	70
Carbon, 1 atom	0·75
	70·75

And this Dr. Thomson considers as likely to be the constitution of cast-steel. He did not in like manner attempt the analysis of blistered steel, but concludes the proportion of carbon in it to be rather less. It is well ascertained that iron and carbon are capable of combining together in a variety of different proportions: when the carbon exceeds, the compound is carburet of iron; when the iron exceeds, the compound is steel or cast-iron in various states according to the proportion: all these compounds may be considered as subcarburets of iron. The most complete detail of experiments on these compounds which has yet appeared in this country is by Mr. Mushet. This ingenious metallurgical chemist has observed that the hardness of iron increases with the proportion of charcoal with which it combines, till the carbon amounts to about 1-80th of the whole mass. The hardness is then a maximum, the metal acquires the color of silver, loses its granulated appearance, and assumes a crystallized form. If more carbon be added to the compound the hardness diminishes in proportion to the quantity, as appears from the following tabular arrangement, extracted from Mr. Mushet's papers on iron and steel:

Iron, semi-steelified	contains	1-150th	of carbon.
Soft steel, capable of welding	"	1-120th	"
Cast-steel for common purposes	"	1-100th	"
Cast-steel requiring more hardness	"	1-90th	"
Steel capable of standing a few blows, but quite unfit for drawing,	"	1-50th	"
First approach to a steely granulated fracture	"	1-30th / 1-40th	"
White cast-iron	"	1-25th	"
Mottled cast-iron	"	1-20th	"
Carbonated cast-iron	"	1-15th	"
Super-carbonated crude iron	"	1-12th	"

Dr. Schafthaeutl has lately propounded a novel and startling theory, viz., that steel is entirely a mechanical production of the forge-hammer, which tears the molecules of certain species of white cast-iron out of their original positions, into which the forces of attraction, in respect to the centres as well as to the position of the molecules, had arranged those molecules by the slow action of heat, and that steel, as it comes out of the converting-furnace or the crucible, is nothing more or less than white cast-iron, of which Indian steel, called *wootz*, is the fairest specimen.

Steel, as is well known, is made by combining carbon with iron, the atmosphere being excluded and a white heat kept up until the iron has imbibed from the carbonaceous matter with which it is surrounded a sufficient quantity, which may be more or less, according to the use for which the steel is intended. Iron is very slightly, and if pure, not at all, altered or increased in hardness by sudden cooling from a red-heat, but the small amount of carbon which it receives during the process of cementation greatly increases both its strength and toughness, leaving it alike malleable and ductile, and imparts to it that peculiarly valuable property of becoming extremely hard if suddenly cooled from a red-heat. With this first dose of carbon it is denominated *mild steel*, possessing all the distinctive properties of iron with increased strength. A larger dose of carbon renders the metal susceptible of greater hardness, and proportionably more brittle. It is also fusible, and therefore called *cast-steel*, but being less malleable is more difficult to work.

Steel made by cementation is designated *blistered-steel*, because it is supposed, while the carbon is entering it meets with oxygen, hydrogen, or some foreign matter which it causes to become gaseous, and thus blisters the surface of the steel. Dr. Thomson attributes these blisters to a gas evolved in the interior of the bar, which pushes up by its elasticity a film of the metal, and Mr. Gill considers them as indications of the quality of the steel, as "the hardest will be found to be blistered all over its surface while the milder will be smoother." Cast-steel being made by fusion admits of an equal distribution of the carbon, to the expulsion of every other substance, which cannot endure the intense heat: the soundness of this description of steel is obviously a great recommendation, but the excess of carbon renders it harsh and consequently intractable; under the hammer, however, by careful treatment during the operation of forging, the excess of carbon may be dissipated and the quality of the steel ameliorated and greatly improved for general purposes.

The question whether steel contains any thing besides iron and carbon is purely chemical, the consideration of which would form, did space allow, an interesting theoretical illustration of the practical details of the present inquiry. A good workman merely requires steel free from flaws, completely homogeneous, and such as will harden at the lowest heat, for this test supersedes all others in proving its superior quality.

Perfectly pure iron cemented in equally pure carbon would doubtless produce steel free from blisters, but as in practice these blisters are unavoidably evolved, it is needless to inquire into their origin more minutely than we have already done, especially as it seems to be admitted that blistered-steel is unequally carbonized, the outside retaining the larger portion. It is therefore rendered fit for the market by doubling and welding several times, by which means the parts are more intimately blended together, and the carbon more equally distributed; in this state it is called *sheer-steel.* These repeated weldings, although they tend to condense the metal, are apt to produce flaws, 1st. by imperfect union, 2d. by the carbon burning out of the commingling surfaces, thereby interposing a stratum of iron or imperfectly converted steel, and this being softer than the surrounding particles would give way during the extension of the steel. To whatever cause such defects are to be attributed must necessarily remain a matter of conjecture, but that they do very largely accompany this description of steel is certain, and it is a question whether any process short of actual fusion can totally remove them; nevertheless, it is ascertained that long-continued forging essentially conduces to the soundness or homogeneity.

Besides these flaws there is another obstacle frequently met with in steel: it is said to have *pins*, when, in the operation of turning or filing, knots are developed harder than the other portions of the metal; these knots or pins present themselves of almost every degree or hardness, commencing with mere harshness, and advancing to absolute intractability, so that whilst turning in the lathe the pins would remain projecting out and grind or break the edge of the tool rather than submit to be cut away, and it is by no means unusual to find their hardness nearly approach that of a file applied to remove them. Various causes have been assigned for these knots; Mr. Varley thinks they are portions of metal over-steeled, that is, so completely charged with carbon as to be incapable of being annealed by any known process of slow cooling. Mr. Clement states that he broke the steel across these pins, having filed away the back to render it weak enough to part at the right place, when he found a cut or division, on which account he attributes the flaw and its extreme hardness to an oxide of iron, which prevented the union of the parts. It would be a curious and by no means an unprofitable investigation to analyze the condition of the deepest blisters, in order to determine whether they are alloyed or oxidized, or in any way differing in their state of carbonization from the more solid parts. It seems clear that if these pins are induced by the presence of oxygen, then the adjoining metal would be iron, for there would be a gradation from the oxide through iron to the steel, and consequently the circumference of such a spot would be softest.

An excess of carbon renders steel harder and more brittle, therefore an inequality is liable to occur. This may be illustrated by the known fact, that portions of an iron casting intended to be soft are frequently hardened by contact with the moist sand of which the mould is formed, and those parts nearest the outside break with a fracture more glassy than even hard steel. Now good steel hardened by sudden immersion in cold water, when at a red-heat, will invariably return to a soft state by slow cooling from such heat, and more equally so if the external atmosphere be carefully excluded; but this hard cast-iron on the contrary does not; it requires to be exposed for many hours to an intense heat, and must not be smothered by fuel to prevent the escape of the superabundant carbon with which it is charged. The air too should be allowed free access as a means of disengaging some portions of the carbon, while the remainder has a tendency to equalize itself; then, if slowly cooled, the mass will be found to be sufficiently annealed.

The knots or pins in steel are rarely removed by slow cooling alone; there is, however, an opinion prevalent among workmen that *pinny* steel may be rendered uniform in its substance if it be first hardened and then annealed. To burn out these pins would manifestly spoil the steel, because it has no carbon to spare but in the pins, (supposing this to be the cause of their hardness,) and the process of annealing in air-tight vessels is not found to produce equality sufficient for any good purpose. Even cast-steel, which is undeniably purer and more homogeneous than any other description, is liable to long streaks or veins harder than the other portions of the bar. All these show the necessity of greater and more minute attention to the treatment of steel than the subject appears to have received, and for this end two modes of hammering are indispensable. To illustrate our position, let us take any article forged in the usual way, not out of blistered or sheer steel, both of which may be presumed to contain carbon unequally distributed, but of cast-steel, which having been fused and passed through the rolls, or under a ponderous tilt hammer, is characterized as refined, and considered uniform. Yet notwithstanding every precaution, we still see the labor and skill of the machinist defeated by those veins, fissures, and pins, which denote either metal of inferior quality, or that the original texture of the steel has been deteriorated by the ignorance and carelessness of the smith. The first supposition does not apply to cast-steel, in which the dose of carbon is diffused equally throughout the mass, or so nearly so as to render the difference inappreciable. We are therefore compelled to admit the second position, and this, unless we have entirely mistaken the bearings of the case, will enable us to account for past failures and guard against future disappointment.

The two-fold process of hammering, already alluded to, is intended to correct the greater part, if not the whole, of the defects pointed out. It is necessary in the first place to hammer the steel at a forging heat, so as to knead the parts together and keep them moving among themselves. This should be continued till the different constituents are not only intimately blended, but as it were dissolved in each other, so as to insure perfect uniformity, for the carbon being thus spread the metal will be rendered as sound as can be expected of cemented steel; and it is clear that if by mechanical agency all foreign matter be expelled and the carbon alone remain, there is nothing to prevent a perfect union of the parts while under the hammer. Good steel consists of that proportion of carbon and iron, which combined form the strongest and toughest compound; each purer portion, therefore, when brought into contact by the hammer remains in that state and resists its percussive force the more from the greater cohesion of the particles. Hence the redundant or deficient portions suffer most till they become equalized, and the impurities are either beaten out or formed into a homogeneal compound with the entire mass.

Although by this means sound steel may be obtained, it is far from being in a perfect state; it is still very unequal in density, and in a state of distraction; some portions are close and dense, and others are fissured. A second hammering at a particular heat is therefore necessary, and under circumstances required by the shape of the steel—such as recesses in the anvil or blocks laid thereon, technically termed *swedges* and *moulds*. For this purpose the metal is first brought as near as eligible to the required dimensions, and is then to be hammered in order to close and condense the particles equally and throughout, yet leaving every part in a state of rest and ease—a condition very essential for good springs, and indeed every article formed of steel, that has to vibrate or act by tension.

This second hammering is also intended to prepare the steel for receiving the utmost hardness of which it is susceptible—a quality which entitles it to be considered the *master metal*—the one by which we give shape and form to all others. Now steel at a red-heat, when suddenly plunged in cold water, becomes both brittle and hard, but even in this state its toughness greatly exceeds that of any other brittle substance. This characteristic hardness cannot be given in part, but always in full and to its highest limit. So true is this, that in a piece of steel, a portion of which is hard and a portion soft, no gradation of hardness can be detected, the parts adjacent to the hard portion being quite soft, or, as some think, softer than if slowly cooled. This singular fact has been thus accounted for:—Suppose a rod of well-hammered steel to be heated at one end for hardening, there will be a gradation of temperature from the coldest to the hottest extremity, and the annealing or reduction of that hardness which it has received will be in proportion to the heat, consequently the rod will be softer and softer towards the end where the heat is applied. On plunging the bar into cold water, that portion which has become sufficiently hot to harden, is rendered quite hard, but that part immediately adjacent to it will be found to be most annealed, and will endure more twisting and bending than any other. Although this hardness may be imparted in its full extent, it may nevertheless be lowered in any assignable degree—that is, a portion of its brittleness may be removed by the application of moderate heat, a greater portion by more heat, and so on, as the purposes may require. This is called *tempering*. If hard steel be brought to a red-heat and then suffered to cool slowly, it will become as soft as if never hardened: this is called *softening*, and is distinguished from *annealing*, which is a similar process of slow cooling, but applied to steel, iron, or brass, merely to remove all mechanical condensation, whether by hammering or otherwise; for if metal has been altered in shape by the hammer or any other process, as much as it will bear without breaking, then by annealing it will be softened and may again be altered in form as often as requisite. Now as different degrees of heat remove different degrees of condensation received from the hammer, and a white-heat removes all, it is of great importance to harden steel from the lowest possible degree of heat, in order to retain as much condensation as practicable; and it is a fortunate coincidence that the greater the condensation the lower is the heat from which steel will harden, and the stronger and tougher it will be. But should this condensed metal be once over-heated, it will then no longer harden from that lower degree, but only from a heat nearly approaching that to which it was originally raised. In this case, the condensation, with all its attendant advantages, can only be restored by rehammering.

The lowest heat at which steel will generally harden, is a dull or cherry-red, just visible in day-light; therefore, to be safe, the same test, that is, a dull red-heat, just perceptible in the dark, is chosen for the process of hammering; it offers, too, the advantage of coating the article with carbonaceous matter, thereby securing instead of losing by the action of the fire a due supply of carbon, which is of particular consequence. Different modes of performing this part of the process may be adopted. It is desirable that the forge should not be under the influence of a strong light; the anvil should be placed as near as circumstances will permit to the flat bed of the forge, and the fire smothered with small fuel, just kept alive by the bellows, so as never to allow the gas bursting into flame. The pieces of steel under treatment are now placed in the smouldering and partially kindled fuel enveloped in smoke, whence they imbibe a portion of carbon, which the hammering heat is insufficient to expel; they are then brought in succession from the fire to the anvil, and back again to the fire when too cool, the hammer is moved quickly, and every part of the steel subjected to its blow. The position of the article is then slightly changed, and the operation continued and repeated as often as needful, till it has been hammered well in every direction. See Tools, as also Tempering. See also Mushet on Steel.

STRENGTH OF MATERIALS OF CONSTRUCTION. 1. *Direct cohesion.*—The power of cohesion is that resistance which bodies exhibit when force or weight is applied to tear asunder in the direction of their length the fibres or particles of which they are composed.

The strength to resist force or weight that produce fracture is as the area of the cross-section acted upon. Hence, multiply the area of the section in inches by the power in pounds (as in the following table) opposite the name of the material, and the product will be equal to the weight in pounds the rod, bar, or piece will just support; but the greatest constant load should never exceed one-fourth.

TABLE *of the Cohesive Power of Bodies whose Cross-Sectional Areas equal One Square Inch.*

Woods.	Cohesive Power, in lbs.	Cohesive Power, in tons.	Metals.	Cohesive Power, in lbs.	Cohesive Power, in tons.
Lance wood	23,400	10·44	Swedish bar-iron	65,000	29·20
Box	19,980	8·92	Russian do.	59,170	26·70
Turtosa, African teak	17,000	7·58	English do.	56,000	25·00
Ash	15,780	7·01	Cast steel	134,256	59·93
Teak wood, or Indian oak	14,500	6·47	Blistered steel	133,152	59·43
Poona, or Peon	12,350	5·51	Shear do.	127,632	56·97
Beech	12,000	5·35	Wrought copper	33,892	15·08
American fir, or pine	11,800	5·26	Hard gun-metal	36,368	16·23
Oak	11,592	5·17	Cast copper	19,072	8·51
Elm	11,500	5·13	Yellow brass, cast	17,968	8·01
Mahogany, Honduras	11,475	5·12	Cast-iron	17,628	7·87
Sycamore	11,000	4·91	Tin, cast	4,736	2·11
Chestnut, Spanish	10,800	4·82	Bismuth, cast	3,250	1·45
Alder	9,700	4·33	Lead, cast	1,824	0·81
Larch	9,500	4·24	Elastic power, or direct tension of wrought-iron, medium quality	22,400	10·00
Walnut	7,740	3·45			
Mahogany, Spanish	7,560	3·37			
Cedar, Libanus	7,000	3·12			
Poplar	6,500	2·90			

NOTE.—A bar of iron is extended ·000096, or nearly one ten-thousandth part of its length, for every ton of direct strain per square inch of sectional area.

The resistance being proportional to the area, the strength of any given bar or bolt will be found by multiplying the sectional area in inches by the tabular number.

TABLE *of the relative Weight and Strength of Ropes and Chains.*

Circum. of Rope.	Weight per fathom.	Weight of chain per fath.	Proof Strength.		Circum. of rope.	Weight per fathom.	Weight of chain per fath.	Proof Strength.	
Inches.	lbs.	lbs.	tons.	cwt.	Inches.	lbs.	lbs.	tons.	cwt.
3½	2¾	5½	1	5½	10	23	43	10	0
4¼	4¾	8	1	16¾	10¾	28	49	11	11
5	5¾	10½	2	10	11½	30½	56	13	8
5¾	7	14	3	5½	12¼	36	63	14	18
6½	9¾	18	4	3½	13	39	71	16	14
7	11¼	22	5	2	13¾	45	79	18	11
8	15	27	6	4½	14½	48½	87	20	8
8¾	19	32	7	7	15¼	56	96	22	13
9½	21	37	8	13½	16	60	106	24	18

2. *Transverse strength, or resistance to lateral pressure.*—The strength of bodies to resist fracture in this direction is as the breadth and square of the depth, directly, and inversely as the length.

The general formula being

$$S\,a\,d^2 = l\,w,$$

where a is the breadth, d the depth, l the length, w the weight, and S a number determined by experiment on different materials. When the beam is supported at each end and loaded in the middle, the values of S for different materials have been determined by Mr. Barlow as in the following table—the breadth and depth being taken in inches, the length in feet, and the weight in pounds.

Values of S for Different Materials.

Elastic strength of		Elastic strength of	
Good English malleable iron	2050	Pitch pine	544
Cast iron	2548	Red pine	447
Teak	820	Riga fir	[illegible]
English oak	400	Mar forest fir	415
Best Canadian	588	Larch	280
Ash	675		

NOTE.—It must be observed that these numbers indicate the extreme strength. The practical man must not depend upon more than a third of these values.

If the depth is taken, a certain fractional part of the depth as $\frac{1}{n}$th, the above formula becomes

$$S d^3 - n l w,$$

$$\text{or, } d = \sqrt[3]{\frac{n l w}{s}}.$$

Hence the following rule in words:

Rule.—Multiply the length between the bearing in feet by the weight to be supported in pounds and by the number indicating the ratio of the depth to the breadth—divide the product by the tabular value, and the cube root of the quotient equals the depth in inches; and the depth divided by the proportional breadth is the breadth in inches.

Example.—Suppose a uniform beam of cast-iron, 18 feet in length, be required to carry a weight of 20,000 pounds on the middle, between the supports, what must be the breadth and depth, in inches, when the breadth is one-fifth of the depth, and the strain not to exceed one-third of the strength?

We must here take $\frac{1}{3} s = 850$.

Hence, $\frac{88 \times 20000 \times 5}{850} = \sqrt[3]{2117{\cdot}6} = 12{\cdot}8$ in. in depth, and $\frac{12{\cdot}8}{5} = 2{\cdot}56$ in. in breadth or thickness.

2. *Given the length and breadth of a uniform beam, and the weight it is to support in the middle, to find the required depth; or the depth given, to find the breadth required.*

Here, $$d = \sqrt{\frac{l w}{s a}}.$$

Rule.—Multiply the length in feet by the weight in pounds. Also the tabular value of S by the breadth in inches. Divide the former product by the latter, and the square root of the quotient will give the depth in inches.

Or, divide the former product by S times the square of the depth, and the quotient will be the breadth.

Example.—Let it be required to find the breadth of a uniform beam of oak to sustain a weight of 6000 pounds in the middle of its length, the distance between the supports being 20 feet, and the depth of the beam 9 inches. The strain to be half the strength.

$$\frac{6000 \times 20}{200 \times 9^2} = 7{\cdot}4 \text{ inches, the breadth; and } \sqrt{\frac{6000 \times 20}{200 \times 7}} = 9\tfrac{1}{4} \text{ inches, the depth.}$$

Note 1.—When the load is not on the middle of the beam, but placed nearer to one end, divide four times the product of the distance of the weight in feet from each bearing by the whole distance in feet, and the quotient equals the length of the beam to be taken into account.

Example.—Suppose a beam 30 feet in length with a load placed 9 feet from one end; required the length to be taken into calculation as affected by the load.

$$30 - 9 = 21, \text{ and } \frac{21 \times 9 \times 4}{30} = 25{\cdot}2 \text{ feet effective length.}$$

Note 2.—When the load is distributed over the whole length of a beam, it will bear double the assumed load as above; hence, in such cases, the divisors must be doubled.

Note 3.—When a beam is to be fixed at one end and the weight placed on the other, take only one-fourth of the tabular number for the divisor; but if the weight is to be laid uniformly along its whole length, use one-half.

Example to Rule 2.—Required the depth for the cantilevers of a balcony of cast-iron to project 4 feet, and to be placed 5 feet apart, the weight of the stone part being 1000 pounds, the breadth of each cantilever 2 inches, and the greatest possible load that can be collected upon 5 feet in length of the balcony 2200 pounds.

$$1000 + 2200 = 3200 \text{ lbs.; and } 800 \div 2 = 400, \text{ the divisor.}$$

$$\text{Hence, } \sqrt[3]{\frac{3200 \times 4}{400 \times 2}} = 4 \text{ inches, the depth required.}$$

Deflection of rectangular beams.—To ascertain the amount of deflexion of a uniform beam of cast-iron supported at both ends, and loaded in the middle to the extent of its elastic force.

Rule.—Multiply the square of the length in feet by ·02, and the product divided by the depth in inches equals the deflexion.

Example.—Required the deflexion of a cast-iron beam 18 feet long between the supports, 12·8 inches deep, 2·56 inches in breadth, and bearing a weight of 20,000 pounds in the middle of its length.

$$\frac{18^2 \times {\cdot}02}{12{\cdot}8} = {\cdot}506 \text{ inches from a straight line in the middle.}$$

Note.—For beams of a similar description, loaded uniformly, the rule is the same, only multiply by 025 in place of ·02.

To find the deflexion of a beam when fixed at one end and loaded at the other.

Rule.—Divide the length in feet of the fixed part of the beam by the length in feet of the part which yields to the force, and add 1 to the quotient; then multiply the square of the length in feet by the quotient so increased, and also by ·13; divide this product by the middle depth in inches, and the quotient will be the deflexion, in inches also.

Multiply the deflexion so obtained for cast-iron by ·86, the product equals the deflexion for wrought-iron; for oak, multiply by 2·8; and for fir, 2·4.

A TABLE *of the Depths of Square Beams or Bars of Cast-Iron, calculated to support from* 1 *cwt. to* 14 *tons in the Middle, the Deflexion not to exceed* 1-40*th of an inch for each foot in Length.*

Lengths in feet.		4	6	8	10	12	14	16	18	20	22	24	26	28	30
Weight in cwt.	Weight in lbs.	Depth.	Depth.	Depth.	Depth.	Depth.	Depth.	Depth.	Depth.	Depth.	Depth.	Depth.	Depth.	Depth.	Depth.
		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
1 cwt.	112	1·2	1·4	1·7	1·9	2·0	2·2	2·4	2·5	2·6	2·7	2·9	3·0	3·1	3·2
2	224	1·4	1·7	2·0	2·2	2·4	2·6	2·8	3·0	3·1	3·3	3·4	3·6	3·7	3·8
3	336	1·6	1·9	2·2	2·4	2·7	2·9	3·1	3·3	3·4	3·6	3·8	3·9	4·1	4·2
4	448	1·7	2·0	2·4	2·6	2·9	3·1	3·3	3·5	3·7	3·9	4·0	4·2	4·3	4·5
5	560	1·8	2·2	2·5	2·8	3·0	3·3	3·5	3·7	3·9	4·1	4·3	4·4	4·6	4·8
6	672	1·8	2·2	2·6	2·9	3·2	3·4	3·7	3·9	4·1	4·3	4·5	4·6	4·8	5·0
7	784	1·9	2·3	2·7	3·0	3·3	3·6	3·8	4·1	4·2	4·4	4·6	4·8	5·0	5·2
8	896	2·0	2·4	2·8	3·1	3·4	3·7	3·9	4·2	4·4	4·6	4·8	5·0	5·2	5·4
9	1,008	2·0	2·5	2·9	3·2	3·5	3·8	4·0	4·3	4·5	4·7	4·9	5·1	5·3	5·5
10	1,120	2·1	2·6	3·0	3·3	3·6	3·9	4·2	4·4	4·7	4·9	5·2	5·3	5·4	5·7
11	1,232	2·1	2·6	3·0	3·4	3·7	4·0	4·3	4·5	4·8	5·0	5·3	5·4	5·6	5·8
12	1,344	2·2	2·7	3·1	3·5	3·8	4·1	4·4	4·7	4·9	5·1	5·3	5·5	5·7	5·9
13	1,456	2·2	2·7	3·1	3·5	3·8	4·2	4·4	4·7	4·9	5·2	5·4	5·6	5·9	6·0
14	1,568	2·3	2·8	3·2	3·6	3·9	4·2	4·5	4·8	5·0	5·3	5·5	5·7	6·0	6·1
15	1,680	2·3	2·8	3·2	3·6	4·0	4·3	4·6	4·9	5·2	5·4	5·6	5·8	6·1	6·2
16	1,792	2·4	2·9	3·3	3·7	4·0	4·4	4·7	5·0	5·2	5·5	5·7	5·9	6·2	6·4
17	1,904	2·4	2·9	3·4	3·8	4·1	4·4	4·7	5·0	5·3	5·5	5·8	6·0	6·2	6·5
18	2,016	2·4	3·0	3·4	3·8	4·2	4·5	4·8	5·1	5·4	5·6	5·9	6·1	6·4	6·6
19	2,128	2·5	3·0	3·5	3·9	4·2	4·6	4·9	5·2	5·4	5·7	6·0	6·2	6·5	6·7
1 ton.	2,240	2·5	3·0	3·5	3·9	4·3	4·6	4·9	5·2	5·5	5·8	6·0	6·3	6·5	6·8
1¼	2,800	2·6	3·2	3·7	4·1	4·5	4·9	5·2	5·5	5·8	6·1	6·4	6·6	6·9	7·2
1½	3,360	2·8	3·4	3·9	4·3	4·7	5·1	5·5	5·8	6·1	6·4	6·7	7·0	7·2	7·5
1¾	3,920	2·9	3·5	4·0	4·5	4·9	5·3	5·7	6·0	6·3	6·7	6·9	7·2	7·5	7·7
2	4,480	2·9	3·5	4·1	4·7	5·1	5·5	5·9	6·2	6·5	6·8	7·2	7·6	7·7	8·0
2½	5,600	3·1	3·8	4·4	4·9	5·5	5·8	6·2	6·6	6·9	7·3	7·6	7·9	8·2	8·5
3	6,720	3·3	4·0	4·6	5·1	5·7	6·1	6·5	6·9	7·3	7·6	7·9	8·3	8·6	8·9
3½	7,840	3·4	4·1	4·8	5·3	5·8	6·3	6·7	7·1	7·5	7·9	8·2	8·6	8·9	9·2
4	8,960	3·5	4·3	4·9	5·5	6·0	6·5	7·0	7·4	7·8	8·2	8·5	8·9	9·2	9·5
4½	10,080	..	4·4	5·1	5·7	6·2	6·7	7·2	7·6	8·0	8·4	8·8	9·1	9·5	9·8
5	11,200	..	4·5	5·2	5·8	6·4	6·9	7·4	7·8	8·2	8·6	9·0	9·4	9·7	10·1
6	13,440	..	..	5·5	6·1	6·7	7·2	7·7	8·2	8·6	9·0	9·4	9·8	10·2	10·5
7	15,680	..	..	5·7	6·3	6·9	7·5	8·0	8·5	8·9	9·4	9·8	10·2	10·6	11·0
8	17,920	..	..	5·9	6·6	7·2	7·8	8·3	8·8	9·3	9·7	10·1	10·6	10·9	11·3
9	20,160	..	..	6·0	6·8	7·4	8·0	8·5	9·0	9·5	10·0	10·4	10·9	11·3	11·7
10	22,400	..	..	..	6·9	7·6	8·2	8·8	9·3	9·8	10·3	10·7	11·2	11·6	12·0
11	24,640	..	..	..	7·1	7·8	8·4	9·0	9·5	10·0	10·5	11·0	11·5	11·9	12·3
12	26,880	..	..	..	7·2	7·9	8·6	9·2	9·7	10·2	10·8	11·2	11·7	12·1	12·5
13	29,120	..	..	..	7·4	8·1	8·8	9·4	9·9	10·4	11·0	11·5	11·9	12·4	12·8
14	31,369	..	..	..	7·5	8·3	8·9	9·5	10·1	10·6	11·1	11·7	12·1	12·6	13·0
Deflexion in inches..		·1	·15	·2	·25	·3	·35	·4	·45	·5	·55	·6	·65	·7	·75

Lengths in feet.		10	12	14	16	18	20	22	24	26	28	30	32	34	36
15	33,600	7·7	8·4	9·1	9·7	10·3	10·8	11·4	11·9	12·3	12·8	13·2	13·7	14·1	14·5
16	35,840	7·8	8·5	9·2	9·8	10·4	11·0	11·5	12·0	12·5	13·0	13·5	13·9	14·3	14·7
17	38,080	7·9	8·7	9·4	10·0	10·6	11·2	11·7	12·2	12·7	13·2	13·7	14·1	14·5	14·9
18	40,320	8·0	8·8	9·5	10·1	10·8	11·3	11·9	12·4	12·9	13·4	13·9	14·3	14·7	15·1
19	42,560	8·1	8·9	9·6	10·3	10·9	11·5	12·2	12·6	13·1	13·6	14·1	14·5	15·0	15·4
20	44,800	..	9·0	9·7	10·4	11·0	11·6	12·5	12·7	13·2	13·8	14·2	14·7	15·1	15·6
22	49,280	..	9·2	10·0	10·7	11·3	11·9	12·8	13·0	13·6	14·1	14·6	15·1	15·5	15·9
24	53,760	..	9·4	10·2	10·9	11·5	12·2	13·0	13·4	13·9	14·4	14·9	15·4	15·9	16·3
26	58,240	..	9·6	10·4	11·1	11·8	12·4	13·3	13·6	14·2	14·7	15·2	15·7	16·2	16·7
28	62,720	..	9·8	10·6	11·4	12·0	12·7	13·5	13·9	14·4	15·0	15·5	16·0	16·5	17·0
Deflexion in inches..		·25	·3	·35	·4	·45	·5	·55	·6	·66	·7	·75	·8	·85	·9

Lengths in feet.		14	16	18	20	22	24	26	28	30	32	34	36	38	40
30	67,200	10·8	11·5	12·2	12·9	13·5	14·1	14·7	15·2	15·7	16·3	16·8	17·3	17·7	18·2
32	71,680	11·0	11·7	12·4	13·1	13·7	14·3	14·9	15·5	16·0	16·5	17·0	17·5	18·0	18·5
34	76,160	11·1	11·9	12·6	13·3	13·9	14·5	15·1	15·7	16·2	16·8	17·3	17·8	18·3	18·8
36	80,640	11·3	12·0	12·8	13·4	14·1	14·7	15·3	15·9	16·5	17·0	17·5	18·0	18·5	19·0
38	85,120	11·4	12·2	13·0	13·6	14·3	14·9	15·5	16·1	16·7	17·2	17·8	18·3	18·8	19·3
40	89,600	..	12·4	13·1	13·8	14·5	15·1	15·7	16·4	16·9	17·5	18·0	18·5	19·1	19·5
42	94,080	..	12·5	13·3	14·0	14·7	15·3	15·9	16·5	17·1	17·7	18·2	18·7	19·3	19·8
44	98,560	..	12·7	13·5	14·2	14·9	15·5	16·1	16·8	17·4	17·9	18·5	19·0	19·5	20·0
46	103,040	..	12·8	13·6	14·3	15·0	15·7	16·3	17·0	17·6	18·1	18·7	19·2	19·8	20·4
48	107,520	..	13·0	13·7	14·5	15·2	15·9	16·5	17·1	17·7	18·3	18·8	19·4	20·0	20·5
50	112,000	..	..	13·8	14·6	15·3	16·0	16·6	17·3	17·9	18·5	19·0	19·6	20·1	20·7
52	116,480	..	..	14·0	14·7	15·5	16·2	16·8	17·5	18·1	18·7	19·2	19·8	20·3	21·0
54	120,960	..	..	14·1	14·9	15·7	16·3	17·0	17·6	18·2	18·8	19·4	19·9	20·5	21·1
56	125,440	..	..	14·3	15·0	15·8	16·5	17·1	17·8	18·4	19·0	19·6	20·1	20·7	21·3
58	129,920	..	..	14·4	15·1	15·9	16·6	17·3	17·9	18·5	19·2	19·7	20·3	20·9	21·4
60	134,400	..	..	14·5	15·3	16·0	16·7	17·4	18·1	18·7	19·3	19·9	20·5	21·1	21·6
Deflexion in inches..		·35	·4	·45	·5	·55	·6	·65	·7	·75	·8	·85	·9	·95	1·0

Examples illustrative of the Table.—1. To find the depth of a rectangular bar of cast-iron to support a weight of 10 tons in the middle of its length, the deflexion not to exceed 1-40th of an inch per foot in length, and its length 20 feet, also let the depth be 6 times the breadth.

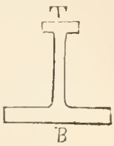
Opposite 6 times the weight and under 20 feet in length is 15·3 inches, the depth, and 1-6th of 15·3 = 2·6 inches, the breadth.

2. To find the diameter for a cast-iron shaft or solid cylinder that will bear a given pressure, the flexure in the middle not to exceed 1-40th of an inch for each foot of its length, the distance of the bearings being 20 feet, and the pressure on the middle equals 10 tons.

Constant multiplier 1·7 for round shafts, then 10 × 1·7 = 17. And opposite 17 tons and under 20 feet is 11·2 inches for the diameter.

But half that flexure is quite enough for revolving shafts: hence 17 × 2 = 34 tons, and opposite 34 tons is 13·3 inches for the diameter.

The preceding tables of the strength of cast-iron bars are the data of recent experiments by Mr Hodgkinson of Manchester, and extracted from his new edition of Tredgold on the strength of cast-iron. This gentleman has also made extensive experiments for obtaining the strongest form of section for beams, the following of which is the strongest form yet obtained.



The bottom flange B is as 6 to 1 of the top flange T, or contains 6 times its sectional area.

He also gives the following rule for ascertaining the ultimate strength of beams of cast-iron of the preceding section and proportions.

Multiply the sectional area of the bottom flange in inches by the depth of the beam in inches, and divide the product by the distance between the supports, also in inches, and 514 times the quotient will give the breaking weight in cwts.

TABLE *of the Weight of Modulus of Elasticity of various Metals*

Name of Metal.	Modulus of Elasticity, in lbs.	Name of Metal.	Modulus of Elasticity, in lbs.
Steel	29,000,000	Gun-metal	9,873,000
Wrought-iron	24,920,000	Brass	8,930,000
Cast-iron	18,400,000	Tin	4,608,000
Zinc	13,680,000	Lead	720,000

NOTE.—Modulus of elasticity, or measure by which the comparative stiffness of bodies may be ascertained: thus, the modulus of elasticity for oak is 1714500, and for cast-iron 18400000, or 10·7 times that of oak; therefore a piece of cast-iron is 10·7 times as stiff as a piece of oak of equal dimensions and bearing.

A hard body is that which yields least to any stroke or impressive force; and in uniform bodies the degree of yielding is always proportioned to the weight of the modulus of elasticity.

Resilience, or toughness of bodies, is strength and flexibility combined; hence any material or body which bears the greatest load, and bends the most at the time of fracture, is the toughest.

Annexed is a TABLE of experiments on rectangular bars of malleable iron by Mr. Barlow, for the purpose of determining the point of neutral axis, the centre of compression, and the greatest deflexion to which railway bars or lines of rail might be submitted without causing permanent injury to the properties of the iron.

NOTE.—Distance between the bearings 33 inches; breadth of bar 1½ inch; depth 3 inches.

The neutral axis was found to be 1-5th of the depth from the top of the bar; the centre of compression ⅔ds of that fifth above the neutral axis; and the rule for obtaining the utmost degree of deflexion as follows:

Divide ·22 by 4-5ths the depth of the bar in inches, and the quotient is the utmost deflexion that can be suffered with safety on bearing 33 inches apart.

Weight in tons.	Deflexion in inches.	Deflexion per half ton.	Remarks.
·125	·043	......	
·500	·059	......	
1·00	·074	·015	
1·50	·083	·009	
2·00	·095	·012	Mean, ·0103.
2·50	·101	·006	$w = 4\frac{1}{4}$. Neutral axis,
3·00	·109	·008	1 : 4·9.
3·50	·120	·011	Elasticity preserved
4·00	·131	·011	at 4¼ tons.
4·50	·148	·017	
·50	·017	......	
1·00	·037	......	
1·50	·052	·015	
2·00	·061	·009	
2·50	·064	·003	Mean, ·0108.
3·00	·078	·014	$w = 4\frac{1}{4}$. Neutral axis,
3·50	·089	·011	1 : 4·9.
4·00	·102	·013	Elasticity injured.
4·50	·124	·022	
·50	·003	......	
1·00	·050	·020	
1·50	·060	·010	The depth of this bar
2·00	·074	·014	only 2½ inches.
2·50	·093	·019	Mean, ·0173.
3·00	·110	·017	
3·50	·149	......	$w = 3$. Neutral axis, 1 : 4·9. Elasticity preserved, 3 tons.
7·50	Bent 8 inches.		

To find the weight that railway bars will support.—Observe, that whatever figure may be given to the transverse section, the head, or top portion of the rail, is generally supposed to occupy the 2-5ths of the whole section; or, in the larger description, to have two inches section, and to be one inch deep, and that the lower web be the same depth as the head

Resistance of the head or upper portion of the rail.—Rule.—Subtract the thickness of the middle rib from 2 inches, and multiply the remainder by 10.—Again, subtract ½ an inch from the whole depth, and multiply the remainder by 12; then divide the former product by the latter and the quotient equals the resistance, in tons, due to the head, not including the continuation of the middle rib.

Resistance of the centre rib.—Rule.—Multiply the whole depth of the rail in inches by the whole depth minus ½ an inch, and that product by 10 times the thickness of the rib; ⅓d of the last product equals the resistance, in tons, of the middle rib continued through the whole depth.

Resistance of lower web.—Rule.—Multiply the whole depth of the rail, minus 1 inch, by the breadth of the bottom web, minus the thickness of the rib, and that product by 10.—Again: from the whole depth of the rail subtract 1 inch, and to 12 times the square of the remainder add 6 times the remainder, and call this the first number. From this subtract twice the remainder, and add 1, and call this the second number. Then say, as the first number is to the second, so is the product obtained in the former part of the rule to the resistance of the lower web, not including the continuation of the middle rib.

Then, the sum of these three resistances multiplied by 4, and divided by the clear bearing length, will be the weight, in tons, that the rail will sustain without injury.

Ex. 1. Let the depth of a rail be 5 inches, with a plain rib, whose thickness is ·9 of an inch; required the greatest weight that it ought to be required to bear.

$$\text{Resistance of head} \left\{ \begin{array}{l} (2 - \cdot 9) \times 10 = 11 \\ (5 - \tfrac{1}{2}) \times 12 = 54 \end{array} \right\} \frac{11}{54} = 0\cdot 2.$$

Resistance of rib $\dfrac{4\frac{1}{2} \times 5 \times \cdot 9 \times 10}{3} = \dfrac{67\cdot 5}{67\cdot 7}$; and, $\dfrac{4 \times 67\cdot 7}{33} = 8\cdot 21$ tons, the greatest weight; and the deflexion with this weight $\dfrac{\cdot 22}{4\cdot 5} = \cdot 05$ of an inch nearly.

Ex. 2. Suppose a rail with bottom web, the depth of rail being 5 inches, the thickness of rib ·6 of an inch, breadth of section of lower web 1·32, and weight 50 lbs.; required the greatest load.

$$\text{Resistance of head} \left\{ \begin{array}{l} (2 - \cdot 6) \times 10 = 14 \\ (5 - \tfrac{1}{2}) \times 12 = 54 \end{array} \right\} \frac{14}{54} \ldots\ldots\ldots\ldots\ldots = 0\cdot 26 \text{ tons.}$$

$$\text{Resistance of rib } \frac{4\frac{1}{2} \times 5 \times \cdot 6 \times 10}{3} \ldots\ldots\ldots\ldots\ldots = 45\cdot 00 \text{ do}$$

$$\text{Lower web} \left\{ \begin{array}{l} (5 - 1) \times \cdot 72 \times 10 \times 28\cdot 8 \\ 12\,(5 - 1)^2 + 24 = 216, \text{ or 1st number} \\ 216 - 7 = 209, \text{ or 2d number} \end{array} \right\}$$

$$\text{Then } 216 : 209 :: 28\cdot 8 : 27\cdot 94 \ldots\ldots\ldots\ldots\ldots = 27\cdot 94$$

$$\overline{73\cdot 20}$$

$$\text{And } \frac{73\cdot 2 \times 4}{33} = 8\cdot 75 \text{ tons, the greatest weight.}$$

ON THE STRENGTH OF COLUMNS, OR POWER OF RESISTANCE TO COMPRESSIVE FORCE.

Table *of Practical Formulæ by which to determine the Amount of Weight a Column of given Dimensions will support in lbs.*

For a rectangular column of cast iron ………………… $W = \dfrac{15300\, l\, b^3}{4\, b^2 + \cdot 18\, l^2}$

For a rectangular column of malleable iron ………………… $W = \dfrac{17800\, l\, b^3}{4\, b^2 + \cdot 16\, l^2}$

For a rectangular column of oak ………………… $W = \dfrac{3960\, l\, b^3}{4\, b^2 + \cdot 5\, l^2}$

For a solid cylinder of cast iron ………………… $W = \dfrac{9562\, d^4}{4\, d^2 + \cdot 18\, l^2}$

For a solid cylinder of malleable iron ………………… $W = \dfrac{11125\, d^4}{4\, d^2 + \cdot 16\, l^2}$

For a solid cylinder of oak ………………… $W = \dfrac{2170\, d^4}{4\, d^2 + \cdot 5\, l^2}$

Note.—W = the weight the column will support in lbs.
b = the breadth in inches.
l = the length in feet.
d = the diameter in inches.

Ex. 1. A rectangular column of oak 6 inches on the side, and 12 feet in length, what weight will it support?

$$\frac{3960 \times 12 \times 6^3}{4 \times 6^2 + \cdot 5 \times 12^2} = \frac{10264320}{216} = 47520 \text{ lbs.}$$

Ex. 2. What weight will a cast-iron cylinder support, whose diameter is 4 inches, and length 10 feet?

$$\frac{9562 \times 5^4}{4 \times 5^2 + \cdot 18 \times 10^2} = \frac{5976250}{118} = 50646 \text{ lbs.}$$

TABLE *to show the Weight or Pressure a Column of Cast-iron will sustain with safety.*

Length or height in feet.	4	6	8	10	12	14	16	18	20	22	24
Diameter.	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.
In.											
2½	119	105	91	77	65	55	47	40	34	29	25
3	178	163	145	128	111	97	84	73	64	56	49
3½	247	232	214	191	172	156	135	119	106	94	83
4	326	310	288	266	242	220	198	178	160	144	130
4½	418	400	379	354	327	301	275	251	229	208	189
5	522	501	479	452	427	394	365	337	310	285	262
6	607	592	573	550	525	497	469	440	413	386	360
7	1032	1013	989	959	924	887	848	808	765	725	686
8	1333	1315	1289	1259	1224	1185	1142	1097	1052	1005	959
9	1716	1697	1672	1640	1603	1561	1515	1467	1416	1364	1311
10	2119	2100	2077	2045	2007	1964	1916	1865	1811	1755	1697
11	2570	2550	2520	2490	2450	2410	2358	2305	2248	2189	2127
12	3050	3040	3020	2970	2930	2900	2830	2780	2730	2670	2600

Relative Strength of Long columns of different materials, Cast-iron being 1000:

Steel	= 2518
Wrought-iron	= 1745
Dantzic oak	= 108·8
Red deal	= 78·5

Elasticity of torsion, or resistance of bodies to being twisted.—The angle of flexure by torsion is as the length and extensibility of the body directly and inversely as the diameter. Hence, the length of a bar or shaft being given, the power, and the leverage the power acts with, being known, and also the number of degrees of torsion that will not affect the action of the machine, to determine the diameter in cast-iron with a given angle of flexure:

RULE.—Multiply the power in pounds by the length of the shaft in feet, and by the leverage in feet; divide the product by 55 times the number of degrees in the angle of torsion, and the fourth root of the quotient equals the shaft's diameter in inches.

Ex. Required the diameter of a series of shafts, 30 feet in length, and to transmit a power equal to 4000 lbs., acting at the circumference of a wheel of 2 feet radius, so that the twist of the shafts on the application of the power may not exceed one degree.

$$\frac{4000 \times 30 \times 2}{55 \times 1} = \sqrt[4]{4364} = 8 \cdot 13 \text{ inches diameter.}$$

NOTE.—The rule is the same for hollow shafts, only using 48 in place of 55, the thickness of metal being 1-5th the shaft's diameter.

To determine the side of a square shaft to resist torsion with a given flexure:

RULE.—Multiply the power in pounds by the leverage it acts with in feet, and also by the length of the shaft in feet; divide this product by 92·5 times the angle of flexure in degrees, and the square root of the quotient equals the area of the shaft in inches.

Ex. Suppose the length of a shaft to be 12 feet, and to be driven by a power equal to 700 lbs., acting at 1 foot from the centre of the shaft; required the area of cross-section, so as it may not exceed 1 degree of flexure.

$$\frac{700 \times 1 \times 12}{92 \cdot 5 \times 1} = \sqrt{90 \cdot 8} = 9 \cdot 53 \text{ inches.}$$

Relative Strength of Bodies to resist Torsion, Lead being 1.

Tin	= 1·4	Swedish iron	= 9·5
Copper	= 4·3	English do.	= 10·1
Yellow brass	= 4·6	Blistered steel	= 16·6
Gun-metal	= 5·0	Shear do.	= 17·0
Cast-iron	= 9·0	Cast do.	= 19·5

Strength of Metals when Pulled in the Direction of their Length.

Names of metals.	Specific Gravity.	Force necessary to tear asunder 1 sq. in. in lbs. Avd.
Antimony, cast	4·500	1·060
Bismuth, cast	9·810	3·250
" cast	9·926	3·008
Copper, cast, Barbary	8·182	22·570
" " Japan	8·726	20·27
" wire	......	61·228
Gold, cast	19·238	20·450
" wire	......	30·888
Iron, cast		
" gray, of Cruzot, 1st fusion.	......	30·162
" " " 2d "	......	30·680
" English	......	52·000
" " soft	......	40·824
" French	......	70·367
" "	......	50·981
" "	......	42·666
" " soft	......	63·622
" " gray	......	37·680
" German	7·807	68·295
Iron, wrought	from 7·600 to 7·800	
" bar, coarse grained		20·460
" " medium fineness		34·081
" " fine-grained		49·982
" " of good quality		55·000
" bar		61·011
" " of best quality		66·000
" bar		80·000
" "		80·333
" "		84·413
" Germ. marked B. R.		61·361
" " " "		93·069
" " common		69·133
" " marked L		69·538
Iron, German, marked L	from 7·600 to 7·800	85·900
" Leige		62·369
" ditto		82·839
" Oosement		68·728
" ditto		76·697
" Spanish		81·901
" Swedish		68·728
" ditto		88·972
" cable		51·513
" cable		73·024
" wire		85·797
" wire		113·077
Lead, cast	11·479	0·885
" wire	......	2·517
" wire	11·282	2·581
" wire	11·348	3·146
" milled	11·407	3·328
Platinum, wire	......	52·987
" wire	20·847	56·473
Silver, cast	11·091	40·902
" wire	......	38·257
Steel, soft	7·780 to	120·000
" razor-tempered	7·840	150·000
Tin, cast, Banca	7·217	3·679
" " English block	7·295	5·322
" " ditto	......	6·650
" " Malacca	6·126	3·211
" wire	......	7·129
Zinc, cast, Goslar	7·215	2·937
" " ditto	7·215	2·689
" patent sheet	......	16·616
" wire	......	22·551

Strength of Alloys when Pulled in the Direction of their Length.

	Parts.		Parts.	Specific Gravity.	Force
Brass				......	45·882
Copper	10	Tin	1	......	32·093
"	8	"	1	......	36·088
"	6	"	1	......	44·071
"	4	"	1	......	35·739
"	2	"	1	......	1·017
"	1	"	1	......	0·725
Gold	5	Copper	1	......	50·000
"	2	Silver	1	......	28·000
Lead, Scotch,	10	Bismuth	1	10·827	2·826
" "	2	"	1	11·090	5·810
" "	1	"	1	10·931	7·319
Silver	5	Copper	1	......	48·500
"	4	Tin	1	......	41·000
Tin, Banca	10	Antimony	1	7·359	11·181
" "	8	"	1	7·276	9·881
" "	6	"	1	7·228	12·652
" "	4	"	1	7·192	13·480
" "	2	"	1	7·105	12·029
" "	1	"	1	7·060	3·184
" "	10	Bismuth	1	7·576	12·688
" "	4	"	1	7·613	16·692
" "	2	"	1	8·070	14·017
Tin, Banca	1	Bismuth	1	8·146	12·020
" "	1	"	2	8·580	10·013
" "	1	"	4	9·009	7·875
" "	1	"	10	9·159	3·871
" "	10	Zinc, Indian	1	7·288	12·914
" "	2	"	1	7·000	15·025
" "	1	"	1	7·321	15·844
" "	1	"	2	7·100	16·023
" "	1	"	10	7·130	5·671
" "	4	Antimony	1	......	11·323
" "	3	"	2	......	8·184
" "	1	"	1	7·000	1·450
Tin, English	10	Lead	1	......	6·904
" "	8	"	1	......	7·922
" "	6	"	1	......	7·997
" "	4	"	1	......	10·607
" "	2	"	1	......	7·470
" "	1	"	1	......	7·074
" "	8	Zinc, Goslar	1	......	10·607
" "	4	" "	1	......	10·258
" "	2	" "	1	......	10·964
" "	1	" "	1	......	9·021

Strength of Woods when Pulled in the Direction of their Length.

Names of woods.	Specific Gravity.	Force necessary to tear asunder 1 sq. in. in lbs. Avd.	Names of woods.	Specific Gravity.	Force necessary to tear asunder 1 sq. in. in lbs. Avd.
Acacia	0·860	16·000	Lemon	......	9·457
Alder	......	14·186	Lignum Vitæ	1·220	11·800
Arbutus	......	7·667	Lime-tree	0·760	23·500
Arbutus	......	17·379	Locust-tree	......	20·582
Ash	0·840	16·700	Mahogany	0·870	21·800
Ash	0·780	19·600	Mahogany	0·800	16·500
Ash	......	17·000	" Spanish	0·753	12·186
Ash	......	12·000	Maple, Norway	0·793	10·584
Ash, red, seasoned	0·812	17·892	Mulberry	0·660	17·400
" white, seasoned	0·685	14·220	Mulberry	0·660	10·600
Bay	......	14·572	Mulberry	......	14·054
Bay	......	10·220	Oak, American, white	......	11·501
Beech	0·720	22·200	" Baltic, seasoned	0·673	11·412
Beech	......	17·709	" Dantzic	......	7·704
Birch	0·640	15·000	" English	......	8·820
Box	0·990	15·500	" ditto	......	10·224
Cane	0·400	6·300	" ditto, old	0·760	14·000
Cedar	0·540	11·400	" ditto	0·760	15·000
Cedar	......	4·973	" ditto	0·700	19·800
Chestnut, horse	0·610	12·100	" pile out of River Cam	0·610	4·500
" sweet	0·610	10·500	" black line. log	0·670	7·700
" do., 100 years in use	0·877	12·168	" dry, cut four years	......	16·079
Citron	......	8·176	" French, unseasoned	......	9·043
Citron	......	12·782	" ditto	1·068	9·985
Cypress	......	5·105	" seasoned	......	13·659
Cypress	......	6·895	" Hamburgh	0·660	16·300
Damson	0·790	14·000	" ditto	0·660	14·000
Deal, Norway spruce	0·340	18·100	" Provence, seasoned	0·771	12·839
" ditto.	......	17·600	" " seasoned	0·828	13·602
" Christiana	0·460	12·400	" " seasoned	1·164	14·685
" ditto.	0·460	12·300	Pine, pitch	......	7·818
" ditto.	0·460	14·000	" pitch	......	12·096
" English	0·470	7·000	" pitch	......	13·176
" Scotch, white	0·498	4·290	" Norway	0·590	12·400
" " yellow	0·472	8·478	" Norway	0·660	14·300
Elder	......	10·230	" St. Petersburg	0·550	13·100
Elm	......	13·489	" St. Petersburg	0·490	13·300
Fir, American	0·416	8·874	Plum-tree	......	11·351
" Riga	......	9·072	Plum-tree	......	12·782
" Russian	0·459	10·008	Pomegranate	......	8·308
" ditto	......	10·000	Pomegranate	......	11·501
" ditto	......	9·792	Poplar	0·360	7·200
" Memel, seasoned	......	10·876	Poplar	......	6·641
" weakest	......	8·280	Poplar	......	4·596
" strong red	......	11·040	Quince	......	5·878
" strongest	......	12·420	Quince	......	8·822
" ditto	......	13·000	Sallow	0·700	18·600
Hawthorn	0·910	10·700	Sycamore	0·690	13·000
Hawthorn	......	9·200	Tamarisk	......	6·895
Holly	0·760	16·000	Tamarisk	......	11·247
Jujube	......	18·915	Teak, old	0·530	8·200
Jasmine	......	12·020	" Java, seasoned	0·697	14·220
Jasmine	......	11·756	" Malabar, seasoned	0·688	13·140
Laburnum	0·920	10·500	" Pegu	0·619	13·194
Lancewood	1·010	23·400	Walnut	0·590	7·800
Lancewood	1·022	24·696	Willow	0·390	14·000
Larch	0·636	11·093	Willow	......	12·782
" Scotch, seasoned	0·496	7·888	Willow, dry	......	7·628
" " very dry	0·470	7·020	Yew	0·790	8·000

Transverse strength of timber.—The following table contains the results of five different series of experiments upon the strength and qualities of different sorts of timber. The experiments are detailed at considerable length in Vol. V. of the Professional Papers of the Royal Engineers. The names of the experimenters are given at the top of the columns in which the mean results of their experiments are contained.

The transverse strength S is calculated from the common formula $\frac{W\,l}{4\,a\,d^2}$, in which W is the weight in pounds necessary to break a beam of l length, a breadth, and d depth, and supported at the ends; or S may be taken as the resistance of a rod an inch square.

TABLE *of the Transverse Strength of Timber.*

Names of woods.	OBSERVERS.										Mean.		Remarks.
	LT. NELSON.		CAPT. YOUNG.		MR. MOORE.		MR. BARLOW.		LT. DENISON.				
	sp. gr.	S.	sp. gr.	S.	sp. gr.	S.	sp. gr.	S.	sp. gr.	S.	sp. gr.	S.	
African Oak	985	2484	....	....	962	2522	982	2493	1024	2595	988	2523	Sp. g. 777, when dry.
Ash, English	....	....	....	....	....	....	760	2026	....	....	760	2026	
" American	611	1550	....	....	....	....	....	....	642	2041	626	1795	
" " Swamp	....	....	....	....	...	....	....	....	925	1165	925	1165	
" " Black	....	....	....	....	....	....	....	....	533	861	533	861	
Beech, English	....	....	....	....	....	....	696	1556	....	....	696	1556	
" American White	....	....	....	....	....	....	....	....	711	1380	711	1380	
" " Red	778	1720	....	....	....	....	....	....	772	1758	775	1759	
Birch, Common	....	....	....	....	....	....	711	1928	....	....	711	1928	
" American Black	682	1848	....	....	....	....	649	1810	679	2525	670	2061	
" " Yellow	....	....	....	....	....	....	....	....	756	1335	756	1335	
Cedar, Bermuda	748	1395	....	1491	....	....	....	....	....	....	748	1443	
" Gaudaloupe	756	2044	....	....	....	....	....	....	....	....	756	2044	
" American White	....	....	....	....	....	....	....	....	354	766	354	766	
" of Lebanon	....	....	....	....	....	....	....	....	330	1493	330	1493	
Elm, English	....	....	....	....	....	....	553	1013	605	551	579	782	
" Canada Rock	700	1869	....	....	....	....	....	....	751	2072	725	1970	
Hickory, American	871	1672	....	2447	786	2192	....	....	836	2205	831	2129	
" " Bitter Nut	....	....	....	....	....	....	....	....	871	1465	871	1465	
Oak, English	834	1629	....	....	816	1919	934	1672	733	1556	829	1694	
" American White	645	1699	....	....	836	1699	872	1766	772	1809	779	1743	
" " Red	940	1709	....	....	....	....	....	....	964	1665	952	1687	
" " Live	1160	1862	....	....	....	....	....	....	....	....	1160	1862	
" Adriatic	....	....	....	....	718	1559	993	1383	....	....	855	1471	
" Dantzic	....	....	....	....	684	1579	756	1457	....	....	720	1518	
" Italian	....	....	....	....	796	1688	....	....	....	....	796	1688	
" Lorraine	....	....	....	....	796	1483	....	....	....	....	796	1483	
" Memel	....	....	....	....	727	1665	....	...	....	....	727	1665	
Pine, American White	453	1456	410	1073	....	....	....	....	432	1160	432	1229	
" " Red	621	1914	....	1799	521	1289	657	1341	506	1261	576	1527	
" " Yellow	....	....	....	....	516	1188	553	1102	456	1266	508	1185	
" " Pitch	....	....	....	....	....	....	660	1632	820	1822	740	1727	
" Virginia	....	....	....	....	590	1456	....	....	...	....	590	1456	
" Archangel	....	....	....	....	551	1370	....	....	....	....	551	1370	
" Dantzic	....	....	....	....	649	1426	....	....	....	....	649	1426	
" Memel	....	....	....	....	601	1348	....	....	....	....	601	1348	
" Prussian	....	....	....	....	596	1445	....	....	....	....	596	1445	
" Riga	....	....	....	....	562	1687	746	1079	....	....	654	1383	
Spruce	....	....	....	....	503	1346	....	....	....	....	503	1346	
" American	....	....	....	....	....	....	....	....	772	1036	772	1036	
Mar-Forest Fir	....	....	....	....	....	....	698	1232	....	....	698	1232	
Norway Spar	....	....	....	....	....	....	577	1474	....	....	577	1474	
Deal, Christiana	....	....	....	....	....	....	689	1562	....	....	689	1562	
Canada Balsam	....	....	....	....	....	....	....	....	548	1123	548	1123	
Hemlock	....	....	....	....	....	....	....	....	911	1142	911	1142	
Larch	....	....	....	....	658	1958	542	995	468	1052	556	1335	The specimen tried by Mr Moore, probably a different kind of timber
" Amer. or Tamarak	....	....	....	....	....	....	....	....	433	911	433	911	
Lignum-Vitæ	1082	2013	....	....	....	....	....	....	....	....	1082	2013	
Mahogany, Nassau	812	1752	....	1994	525	1503	....	....	....	....	668	1719	
Mangrove, Bermuda B'k	1188	1699	....	....	....	....	....	....	....	....	1188	1699	
" " White	951	1985	....	....	....	....	....	....	....	....	951	1985	
Teak	719	1898	....	....	723	1964	745	2462	....	....	729	2108	
Poon	....	....	....	....	768	1687	579	2221	....	....	673	1954	
Acacia	....	....	....	....	....	....	710	1867	....	....	710	1867	
Sneezewood	1066	3305	....	....	....	....	....	....	....	....	1066	3305	S. Africa
Yellow-wood	926	2103	....	....	....	....	....	....	....	....	926	2103	W. I[illegible]
Greenheart	....	....	970	2471	....	....	1000	2759	....	....	985	2615	
Wallaba	....	....	1147	1643	....	....	....	....	....	....	1147	1643	
Bullet-tree	....	....	1075	2733	....	....	1029	2651	....	....	1052	2692	
Kakarally	....	....	1223	2379	....	....	....	....	....	....	1223	2379	D[illegible]
Crab-wood	....	....	648	1875	....	....	....	....	....	....	648	1875	
Locust	....	....	....	....	....	....	954	3430	....	....	954	3430	
Cabacally	....	....	....	....	....	....	900	2518	....	....	900	2518	
Iron-wood	....	....	....	....	....	....	....	....	879	1800	879	1800	Canada.
Soft Maple	....	....	....	....	....	....	....	....	675	1694	675	1694	

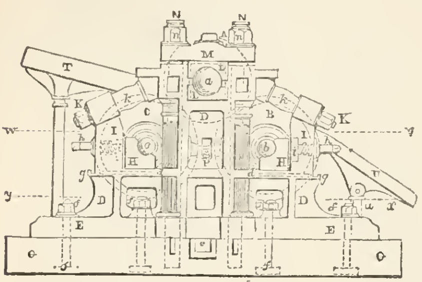
SUGAR-MILL, HORIZONTAL. By M. Nillus, of Havre. The figures furnish a good example of the form of machine used for crushing sugar-canes, as constructed by an eminent French engineer, who has devoted his attention, in an especial manner, to the improvement of the apparatus used in the colonies for the manufacture of sugar. It differs but slightly from the form usually adopted by English makers. Many improvements have been recently proposed, but we have preferred giving engravings of the more simple and compact form which is still mostly in use.

The conformation of the sugar-cane does not render it necessary that, for the extraction of its juice, the cells which contain it should be previously broken, as is the case with sugar obtained from other sources; simple pressure, properly applied, is all that is required for its expulsion. For this purpose the canes are squeezed by being passed successively between rollers disposed somewhat like those of a rolling-mill. In the older form of machines employed for the extraction of the juice, the rollers are placed vertically, and it is only within the last few years that this arrangement has been superseded by the sugar-mill with horizontal cylinders, which is not only cheaper in construction and more easily fixed, but by its use the process of feeding is performed with much less labor, and at the same time more efficiently.

Fig. 3365 represents a front elevation of the entire mill, showing the form of the framing, and the general disposition of the cylinders or rollers, and of the feeding-board, returner, and delivering-board.

Fig. 3366 is an end view of the same, showing the geering by which the rollers are driven.

3365.



3366.

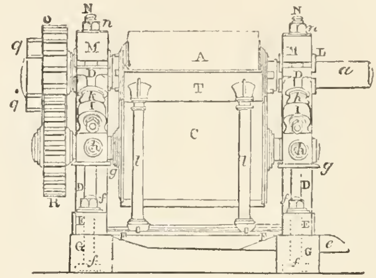


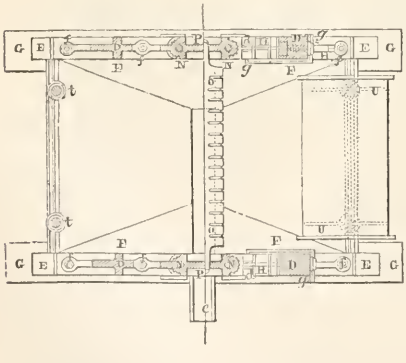
Fig. 3367 is a half-sectional plan taken on the line $v—w$, in Fig. 3365.

Fig. 3368 is a similar half-section taken on the line $x—y$.

Fig. 3369 is a vertical transverse section, through the centre of the mill, exhibiting the form of section of the framing or standards, and the internal construction of the top roller, with its gudgeon and bearings.

Fig. 3370 is a longitudinal section of the entire mill, in which the arrangement and dimensions of the rollers and their gudgeons, and the disposition of the feeding-board, returner, and delivering-board, are most distinctly represented.

3367. 3368.



3369.

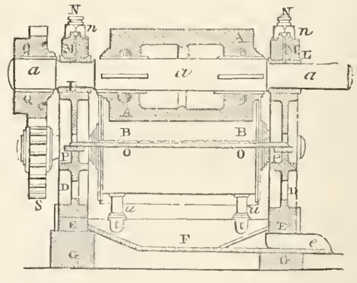


Fig. 3371 is a longitudinal section of one of the lower or feeding and delivering rollers, and of one of the driving pinions.

Fig. 3372 a front elevation of the three driving pinions, corresponding in position with their respective rollers, as shown in Fig. 3370.

Fig. 3373 a detached view of one of the stay-bolts for strengthening the standards.

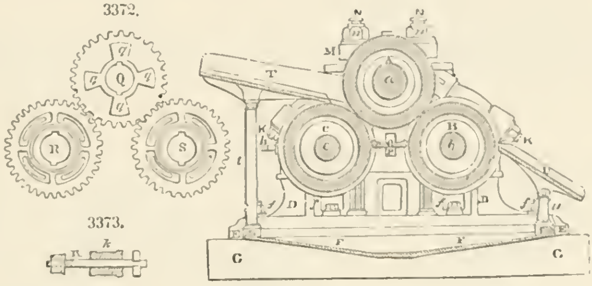
Fig. 3374 is a section of part of the feeding-board, through the socket of one of its supporting columns.

Fig. 3375 is a section of that part of the standard through which passes the screw for adjusting the bearings of the feeding and delivering rollers; and Fig. 3376 shows a face view of one of these bearings themselves.

General description.—The crushing-rollers consist of three strong cast-iron cylinders A B C, mounted between the two massive head-stocks or standards D D, and so disposed that the periphery of the upper roller A is nearly in contact with those of both the others. The rollers are made from $2\frac{1}{2}$ to 3 inches thick, and to give additional strength, are ribbed in the centre. They are traversed by the strong malleable-iron gudgeons *a b c*, fixed into their respective rollers by keys, in the usual manner, and carrying at one extremity the geering by which the rollers are moved. The gudgeon of the upper roller A is made of considerably greater strength than those of the others, as it has to sustain simultaneously the strain of both. The feeding and delivering rollers B and C have small flanges at their ends, between which the top-roller is placed, as shown in Fig. 3369; these flanges are for the purpose of preventing the pressed canes from working into the mill-bed. Some makers still continue the practice, once universally adopted, of fluting the top-roller, in order the better to seize the canes, but it is now very generally abandoned, as it is found that after working some time, the surface of the rollers becomes sufficiently rough to *bite* the canes effectively; and the fluted rollers have this disadvantage, that the grooves carry round with them a considerable portion of the expressed juice, which is speedily absorbed by the spongy canes, besides causing considerable waste by breaking the canes themselves.

The standards D D are securely fixed to the strong cast-iron sole-plate E, which, besides performing this function, is constructed of such a form as to serve as a receptacle for the collection of the expressed juice. For this purpose that part of the sole-plate marked F, which lies between the two standards, is made to slope downwards from all sides, thus forming a species of trough or cistern, the bottom of which communicates with the gutter *e*, also cast of a piece with the sole-plate, and through which the juice runs off into the proper receptacles. The whole mill rests upon, and is bolted firmly to its foundation G, which, in the example before us, consists of two strong beams of timber, but more generally a stone foundation is preferred. The bolts *f f f* which serve this purpose, pass through foundation, sole-plate, and standards, so that the whole are at once bound together.

3370. 3372. 3373.



3375. 3376. 3374. 3371.

The standards D D are formed with indentations for the purpose of receiving the bearings H H of the feeding and delivering rollers. These bearings consist of a single brass bush for each journal, and their form, as well as the mode of their adjustment, is shown detached from the machine in Figs. 3375 and 3376. To regulate the distance of the rollers from each other, and to compensate for the wear and tear of the bearings, these latter are so formed as to be capable of being moved to a greater or less distance from the centre of the mill, and for this last purpose the bearings are made of considerable thickness at the points opposite to which the strain is applied. A projecting tongue on the under side of the brass fits into a corresponding groove in the standard, by which means the bearing is guided laterally, and its motion is circumscribed to the required limits by a small projection *d*, cast upon the standard. A small gutter *g*, which is indicated by the dotted lines in the general elevation, is also cast upon the standard round the sole of the bearing, by which the oil applied for its lubrication is prevented from falling into the mill bed, and is carried round to the outside of the mill. A strong screw *h* passes through the end of the standard opposite to the centre of each bearing, and works into a nut *i* sunk into it for the purpose of adjusting the lower rollers.

The cheeks I I of the standards through which the screws *h h* pass, are united to, and consolidated with, the main body of the head-stocks, by the strong bolts K K, fixed to the latter by cotters, and secured externally by nuts, after traversing the upper extremities of the cheeks I I and the cast-iron fenders *k k*, which serve to fill up the intermediate space. See Fig. 3373.

The axis *a* of the upper roller revolves in the brass bearings L L, which consist of double brass bushes fitted into the upper portion of the standards D D. They are surmounted by the massive caps or covers M M, which are retained in their places by strong bolts N N, traversing the whole height of the standards, and secured under the sole-plate by cotters. These bolts serve likewise, by means of the nuts *n n*, to regulate the pressure to which it may be thought expedient to subject the upper roller.

Between the lower rollers is placed a cast-iron plate O, called the *returner*, . . . concave upon its upper surface, and is . . . at the edges to admit of the free . . . of the liquor to the mill-bed. At each extremity it is furnished with projecting . . . , which pass through . . . in the standards, and are supported by the slips of wood P P, which may be made of greater or less thickness according as it is found necessary to elevate or depress the returner. The use of the returner is to direct the canes which have been crushed between the top-roller A and the feeding-roller C, so that they may be again subjected to pressure between the former and the delivering-roller B.

The three rollers A B C are simultaneously set in motion by the strong spur-pinions Q R S, fixed by keys upon the extremities of their respective gudgeons and geering together, as shown in Fig. 3372. The pinion of the upper roller, which communicates motion to the others, is itself set in motion by the driving-shaft, through the intervention of a clutch or coupling-box, fitting into the teeth *q q q*, which are cast upon it. To provide for the varying resistance arising from irregular feeding, or from the accidental crossing of the canes, by which accidents the engine is liable to be *brought up* so suddenly as to endanger the breaking of the fly-wheel shaft, it is necessary to make all these connections of unusual size and weight. The best surface speed for the rollers is 3·4 or 3·6 feet per minute.

The feed-board P consists of a flat plate of cast-iron, strengthened by feathers on its under surface. It is set at a considerable inclination, and furnished with sheet-iron sides, and its purpose is to convey the canes regularly and equably from the hands of the feeder to the mill. The feed-board rests upon two cast-iron columns *t t*, fixed by cotters at their lower extremities to the edge of the mill-bed. Fig. 3374 shows the mode of their attachment to the feed-board.

On several sugar estates a continuous system of feeding has been recently adopted, and might, we think, be generally employed with advantage. This consists of an endless web of cloth, carried by two parallel rollers, on which the canes are laid. One of the rollers receives motion from the mill itself, and consequently the cloth progresses regularly, carrying the canes with it, and delivering them to be crushed between the feeding and upper rollers. By this means the canes are all presented to the action of the rollers in a longitudinal direction, and in the most equable and regular manner; whereas, when spread on the hopper by the hands of the negroes, the quantity admitted is sometimes too large and sometimes too small, which has the disadvantage, in the one case, of permitting a portion of the canes to pass between the rollers without receiving the due amount of pressure, and in the other of unnecessarily straining the mill.

The delivering-board U, by which the crushed canes are withdrawn from the mill after the juice has been expressed, consists, like the feed-board, of a cast-iron table, set at a great angle, and fitted close to the delivering-roller B, so as to detach any small portions of the canes that may adhere to it, and might otherwise mix with the liquor. It is made so as to turn upon pivots at the top of the small columns *u u* which support it.

Action of the machine.—The action of the sugar-mill is so obvious as scarcely to require to be specially noticed. The sugar-canes, having been previously cut into short lengths of about three feet, are brought to the mill tied up in small bundles; there the feeder unites them, throws them on the feed board T, and spreads them so that they may cross each other as little as possible. They are drawn in between the feeding and top rollers A aud C, where they are split and slightly pressed; the liquor flows down and is received into the mill-bed F, while the returner O guides the canes between the top and delivering rollers A and B, where they receive the final pressure, and sliding down the delivering-board U, are turned out on the floor of the mill, while the liquor runs back and falls into the mill-bed.

When circumstances will admit of it, it is desirable that the mill should be situated at such an elevation above the rest of the sugar apparatus as to render it unnecessary to raise the juice which flows through the gutter *e* by pumping, as the contact of the air occasioned by the agitation of the liquor in the pump-barrels tends to throw it into a state of fermentation. In very many cases, however, a pump is attached to the sugar-mill, and is worked by suitable geering affixed to the gudgeon *a* of the upper roller, which in our figures is shown of sufficient length to effect this purpose if required.

Literal References.

A, the upper roller or cylinder.
a, the gudgeon or shaft of the upper roller, upon which it is fixed by keys.
B C, the delivering and feeding rollers.
b c, their respective gudgeons.
D D, the standards or headstocks of the mill.
d d, small projections thereon for guiding the bearings of the rollers B and C.
E, the sole-plate, to which the standards D D are fitted, and which is also formed intc
F, the mill-bed, into which the expressed liquor flows.
e, the gutter for withdrawing the liquor from the mill-bed.
f f f, the holding-down bolts of the mill.
G G, strong beams, forming the foundation of the mill.
g g, gutters for withdrawing the superfluous oil from the bearings of the rollers B and C.
H H, brass bushes, forming the bearings of the rollers B and C.
h h, regulating screws for the adjustment of the rollers B and C.
i i, their nuts, sunk into the framing.
I I, the cheeks of the framing, traversed by the screws *h h*.
K K, cotter-bolts, for strengthening the cheeks I I.
k k, cast-iron ferules on the bolts K K.
L L, the brass bearings of the top-roller.
M M, the plummer-block covers of the top-roller.
N N, the plummer-block cover bolts, which also regulate the pressure upon the top-roller by means of the nuts *n n*.
O, the returner, fixed between the lower rollers, and serrated at each edge.
P P small slips of wood for supporting the returner.

Q, a strong spur-pinion on the gudgeon of the top-roller. On its face are also cast the projections
q q q, engaging with similar projections on the coupling-box of the driving-shaft.
R S, spur-pinions on the gudgeons of the lower rollers, geering with the pinion Q.
T, the feed-board.
t t, small columns for supporting the feed-board.
U, the delivering-board, fitted with hinge-joints, to admit of its turning upon
u u, the small columns upon which it is supported.

3377.

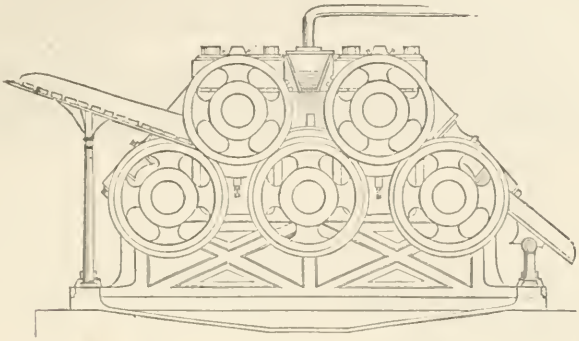
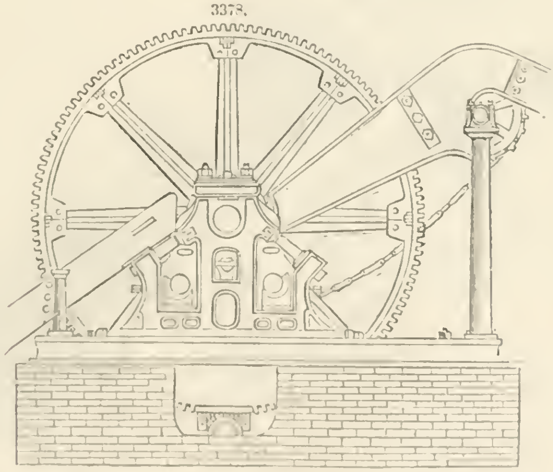


Fig. 3377 represents a five-roller sugar-mill built by Nellius in France for the French colonies.

The mills used for grinding the cane are generally placed ten to twelve feet from the ground, in order to give sufficient fall for the juice to flow into the juice-boxes, and from them into the kettles.

3378.



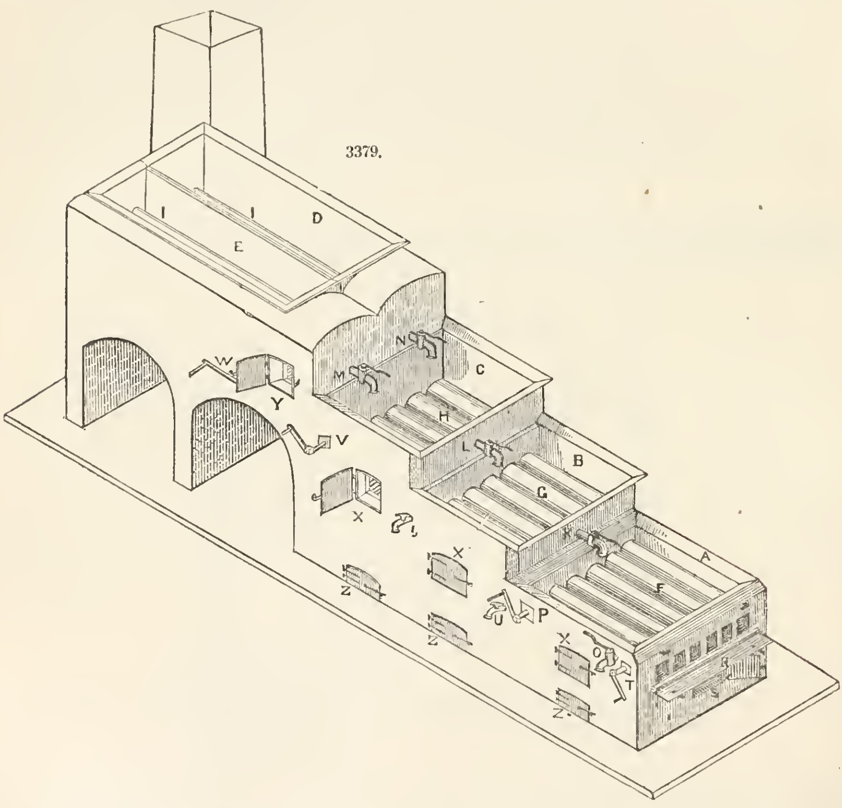
The thickness of the shell of the rollers in those mills constructed by Leeds & Co., New Orleans represented in Fig. 3378, varies from 2½ to 3 inches, according to size; the depth of the eye of the roller is 12 inches in all these mills. The shafts are of wrought iron. The journals vary in size from 7½ to 8½ inches in diameter. The boxes in which the journals revolve are of brass, lined with "Babbitt's metal." The return plates, about which there is a great difference of opinion respecting their proper position, are placed from one to two inches below the top-roller. The cane carrier is from fifty to ninety feet in length, according to the height at which the mill is placed.

SUGAR BOILERS, Reed's improved. The art of making sugar consists in separating the crystallizable sugar from the liquor of the cane. This liquor often contains more than 70 per cent of its weight of sugar, and, in some instances, this amount has been extracted from the cane. Sugar is also obtained from the beet, the maple, the melon, the carrot, the turnip, the green Indian corn plant, and from many other substances. Extensive manufactories of beet sugar are now in operation on the continent of Europe, and in our forests vast quantities of maple sugar are annually manufactured.

Fig. 3379 is a view and description of parts of Mr. Knight Reed's patent Flue Boiling Sugar Pans, to whom was awarded a silver medal, by the American Institute, at the late Fair of October, 1850. A B C, boilers. D E, clarifiers. F G H I I, flues. J K L M N, stop cocks for drawing off syrup. O, stop-cock for drawing off syrup from striking teache. P, damper between striking teache and second boiler. R, damper, closing flues to striking teache. S, door for draft. T, damper for shutting off fire from flues to striking teache. U, stop cock for drawing off washings. V, damper for shutting off the fire from going directly under the clarifiers, sending the draught through the teache and all the boilers. W W dampers for shutting off draught from clarifiers D E. X X X, feeding-doors to the boilers. Y Y, feeding doors to clarifiers. Z Z Z, doors for drawing the ashes from under the boilers.

The sugar-cane is twice subjected to the action of the mills, or is passed through two sets of rollers of which the second pair are adjusted more closely together than the first. By this process, the sugar-cane comes out from the rollers nearly dry, but some juice is still retained by the capillary forces of the plant, and cannot be entirely separated from it by any degree of pressure. The liquor thus produced soon undergoes fermentation if left to itself, and by very slight causes is changed into substances of a nature entirely different from the pure solution of sugar, of which it at first consisted. Among these substances are mucilage, lactic acid, alcohol, and carbonic acid. To prevent this change by fermentation, the liquor, as soon as possible after it is expressed from the cane, is exposed to a high heat. This checks its tendency to ferment.

As it comes from the mill, the juice is passed through a sieve or coarse cloth, to separate the coarse solid feculencies. It then flows from the mill-bed into channels through which it is conducted to receivers. These are generally two in number, placed in a situation as cool as possible, to diminish the tendency of the liquor to ferment. They are also usually on a higher level than the boiling-house.



3379.

The crushed cane-stalks are carried from the mill to the *trash-house*, which, on large plantations, is a building about one hundred feet long, eighteen feet wide, and fourteen feet high. In these the cane-trash is carefully spread out, and means taken to render it perfectly dry. When dry it is employed as fuel.

When the receiver is filled with cane-liquor, a valve is opened, and the liquor flows out through a channel lined with sheet-lead, into the *clarifiers* D and E. Fig. 3379. *In the ordinary method*, a fire is lighted under these clarifiers, and lime is stirred into the cane-juice. The liquor soon becomes heated, and the temperature gradually rises till the thermometer stands at about 210°. As the heat increases, minute bubbles of air make their appearance, and a greenish-gray scum forms upon the surface of the liquor. The temperature is not allowed to rise to the boiling point, as the motion thus produced in the liquor would break the scum at the top, and mingle it again with the fluid by carrying down the feculencies which had risen to the top. In about forty minutes, the scum attains a thickness which causes it to "crack," or to divide into white froth, as watery vapor rises up and forces its way through. When this is observed, the liquor is skimmed for about ten or twelve minutes, after which, if circumstances will admit of the delay, the fire is damped, and the cane-liquor is allowed to remain undisturbed in the clarifiers for twenty or thirty minutes, or even longer, during which period there ensues a more com plete separation and rising of the impurities. This process is called clarifying, because in this way the greater part of the feculencies is removed.

From the clarifiers the liquor is drawn off by stop-cocks M and N, (in Reed's process; various methods are employed in other processes.) These stop-cocks are placed at such a distance from the bottom that about one-twentieth of the liquid will remain in the boiler. In some cases the boiling-house is furnished with only one clarifier; in general, however, two or three, and in some large establishments four are employed. The boiling-house of an estate in Jamaica, which produces 400 hogsheads of sugar annually, is provided with three clarifiers, each of 410 gallons capacity, one grand evaporator of equal magnitude, one of 300 gallons, another of 180 gallons, and another of 90 gallons, wine measure.

From the clarifiers the liquor passes into the first evaporator C, which, in Reed's arrangement, holds about 400 gallons. Here the juice is allowed to boil. This boiling separates a kind of feculencies which could not be separated by gentle heat, and which, therefore, were not removed in the clarifiers. The scum, as it rises, is carefully removed by scummers. When, in this way, the cane-liquor is improved in quality, thickened to a syrup, and reduced about two-thirds in quantity, it is then drawn off into the second and smaller evaporator B. This evaporator holds about 200 gallons. New liquor may now be admitted from the clarifiers into C. The syrup from C. is concentrated still further in B, and then drawn off into the last evaporator A. This evaporator is technically called the *teache*. In this the syrup is concentrated to the requisite degree for crystallizing. This is called the *striking-point*, and the concentrated syrup *the strike*, while *striking* is an operation performed in a set of wooden vessels or wooden vats, not represented in the figure. These are made of cypress planks, and are very shallow, measuring from four to five feet in width, by twelve to fourteen inches in depth. Not less than six of these are used with one set of kettles, and, in general, a sugar-house contains eight or ten, or even a greater number. They are called *coolers*, for the liquor is removed from the teache and poured into these vessels to cool. Their size is such that, when filled, the syrup will cool at that rate which is most favorable to a proper crystallization of the sugar. The more gradually the syrup cools the larger will be "the grain" of the sugar, and the more easily will the molasses be drained from it.

The degree of concentration of the syrup is determined by several methods, of which the best is called the *proof by touch*. A small portion of the syrup is taken from a ladle or stirrer on the end of the thumb, and the middle finger is then brought in contact with it, and again separated from it. If, in this case, two drops of liquid separate, that on the thumb below being the larger, the concentration is as yet weak. If the drops become nearly equal and do not separate until the finger and thumb are drawn widely apart, the concentration is stronger. The third state of concentration is where, by the separation of the finger and the thumb half an inch, a thread is drawn out, which finally breaks below; the end of the thread becomes club-shaped, and rises slowly towards the finger. In the fourth stage, the same thing occurs at a greater distance, the end is folded backwards, and the thread has the form of a ribbon or long strip, which rises more rapidly than before. In the fifth and last degree of concentration, after a greater separation, the thread breaks, being very fine at the end which turns aside and wists up like a cork-screw. It does not fold itself upon the upper part of the thread as before. A ittle more concentration prevents the thread from shrinking at all upon itself.

The scum which is removed from the cane-liquor and syrup is taken, together with the feculencies llected in the clarifiers, to the *still-house*, where it is converted into spirit. The furnace is maintained at a uniform heat, day and night, from the commencement of the grinding season in November, till its conclusion in January, stopping only a few times that the kettles may be scraped from the accumulation of rust, lime, and earthy impurities, which collect upon them, and which, if not occasionally removed, cause them to crack.

From the coolers the sugar is taken to the *curing-house*, which is a large building contiguous to the boiling-house. In a cavity in the lower part of the curing-house is the *molasses cistern*. Over this cistern and on the floor of the boiling-house, is an open frame-work of strong joists, leaving a gangway in the middle. Upon these joists are supported a series of hogsheads, into which the sugar, when sufficiently crystallized in the coolers, is removed, and the molasses drained off through holes in the bottom. This molasses flows through a trough below into the cistern. The curing-house is built so capacious as to hold all the sugar which can be made in three or four weeks, or till it is freed from the greater part of its molasses. Some molasses will always remain entangled in the crystals of sugar, but when tolerably dry, the sugar is removed from the curing house for shipment. The sugar thus manufactured is called *muscovado* or *raw sugar*, and is the material used by sugar-refiners in making white or loaf-sugar.

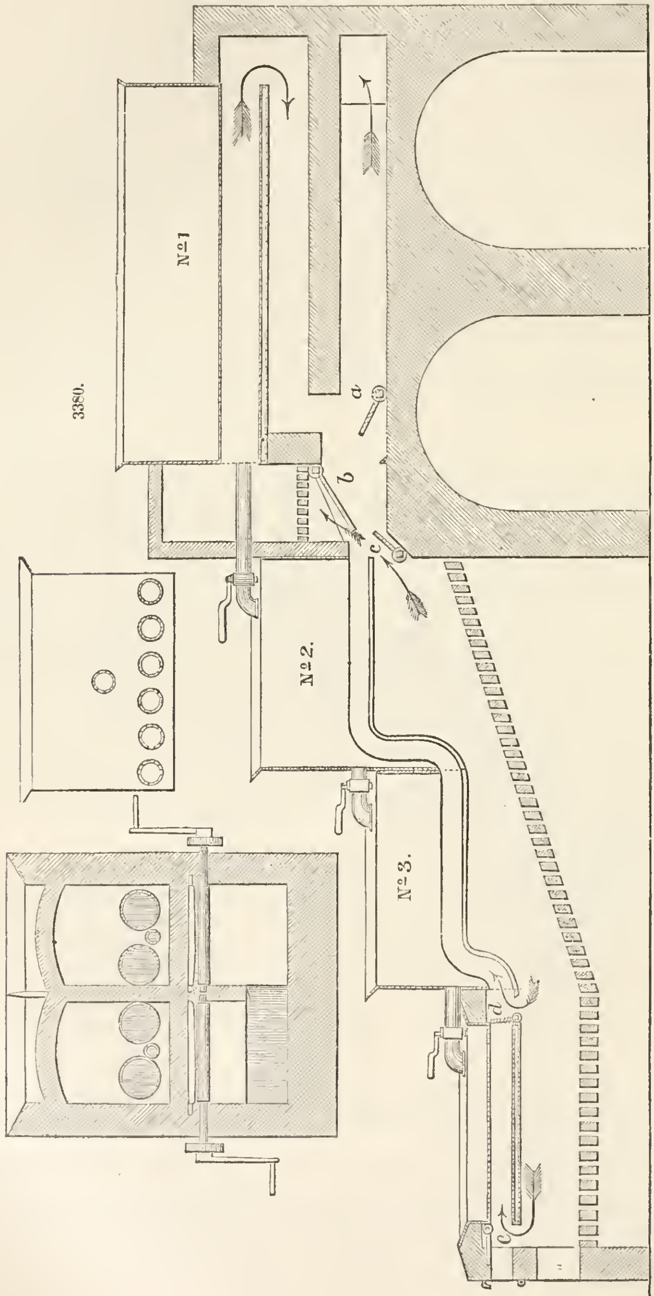
Description of Reed's sugar boilers, with the method of preparing them for use.—In every process for the manufacture of sugar, there must be a series of boilers, evaporators, coolers, and the other arrangements which have already been described. The peculiarity of Reed's boilers consists chiefly in the mode in which the fire is applied.

In Fig. 3389, *d* is a valve which closes either the flue *de* or the open passage represented by the bent arrow. Another valve *e* is represented as open, which, when let down, closes the flue *ed*. The valve *e* affords a direct communication with the chimney through the flue *eah*. The valves *e* and [illegible] being opened, the fire is kindled beneath boilers Nos. 2 and 3, on the grate [illegible]. When the fire is sufficiently kindled, the valve *e* is shut, *c* is opened, as shown in the figure; *d* is shut down over the space represented by the bent arrow, and then the heat from the fire passes down beneath the teache, and then turns upwards, as shown by the bent arrow *c*, through the flue *cd*, and passes on through the flues beneath Nos. 3 and 2.* If the valve *b* is thrown entirely open the heat will ascend through the grate immediately above, and pass around in the flue under No. 1, and descend [illegible] in the direction rep

* These flues pass *through* the boilers.

resented by the bent arrow, will finally pass through the flue *a h* into the chimney. Two valves are represented by the letter *a*, and two by the letter *b*, corresponding to the two clarifiers represented by No. 1. The object of this double arrangement is to shut off the heat from either clarifier, according to circumstances.

3380.



The flue *e d* passes *through* the teache and is composed of a series of pipes, as represented at F. in Fig. 3379. The valve *e* is so constructed as to close all these pipes, and corresponds to the valve R, in Fig. 3379. The valve *d* is made in the same way. The flues beneath Nos. 3 and 2 pass through these boilers, as represented in G and H, in Fig. 3379. The flue beneath No. 1 has a different construction. In this two large pipes pass through each clarifier, as is shown at *f f f f*, Fig. 3380. By the valve *b* the fire may at any time be entirely, or in part, cut off from the clarifiers, and by the valve *c* from the teache.

The remaining arrangements are represented in Fig. 3379. X X X W are doors opening to the furnace, by which a fire may at any time be kindled directly under each of the boilers or under the clarifiers. Z Z Z are doors for removing ashes from under the boilers. O is a stop-cock for drawing off syrup from the teache. The stop-cocks for drawing off the syrup from the other boilers have been already mentioned.

To prepare the boilers for use.—A B and C are at first nearly filled with water, D and E are filled with cane-juice. The fire is then kindled, and the heat is made to pass, as described above, through all the boilers, and one of the clarifiers D, but not through the other, E. When the cane-liquor in D is heated nearly to the boiling point, the heat is cut off from this and made to pass through E. The water is now drawn off from boiler C, and the clarified cane-juice from D is drawn off into this boiler D is then again filled with cane-liquor.

When the cane-liquor in E is sufficiently clarified, the contents of C are drawn off into B, the water of which has been previously removed. The liquor from E is then drawn off into C, and E is filled with fresh cane-juice.

The liquor from D being ready to be drawn off again, the water is removed from the striking-teache A, and the syrup is drawn from B to A, from C to B, and from D to C. D is filled with fresh cane-juice, and all the boilers are now in operation. When the syrup in A is sufficiently concentrated, the fire is cut off from this boiler by raising the valve *d*, Fig. 3380. The syrup is allowed to remain in the teache for a few moments till it is somewhat cooled, and is then drawn off except 3 or 4 inches at the bottom.

Advantages of Reed's Boilers. 1. *Economy of fuel.*—In most of the tropical countries where sugar is made, fuel has become scarce; hence the great object of the planter is so to arrange his works as to economize fuel. The usual arrangement for this purpose, is of a series of boilers in a horizontal flue. The heat of the fire is thus, to a great extent, abstracted before it arrives in the flue. The saving of fuel, in Reed's arrangement, is produced by cutting off the fire when it is not needed.

Mere position cannot adapt the boilers to the different degrees of heat which they require, for there is no gradation in this respect. When the liquor is first introduced into the clarifiers, a great amount of heat is frequently necessary, on account of the large quantity of water which the cane-juice contains. But, as the evaporation proceeds, the amount of heat required diminishes. In the striking-teache, also, it is equally important to be able to diminish or cut off the heat at once. This is easily managed in Reed's method, and, at the same time, the heat is not lost, but is applied immediately to the evaporators Nos. 2 and 3. Fig. 3380.

2. *Economy of time.*—On many plantations, and on all at certain times, it is far more important to hasten the conversion of cane-juice into sugar, even if this is done imperfectly, than to obtain a more perfect article with a greater expenditure of time. It is often far more profitable to make a large quantity of rather inferior sugar, than a smaller amount of the first quality.

Economy of time is important in another respect. It has been ascertained that sugar is rendered dark and uncrystallizable more by the duration of boiling than by the intensity of the heat employed. Slow evaporation by steam, for instance, instead of producing a better result, gives very dark and uncrystallizable syrups. A rapid evaporation in 6 or 8 minutes, in the usual evaporating pan, renders less of the sugar uncrystallizable, than a slow evaporation in the same pan continued for 40 or 50 minutes. The same effect has been found to take place even in the vacuum process, where the sugar is boiled at a very low temperature.

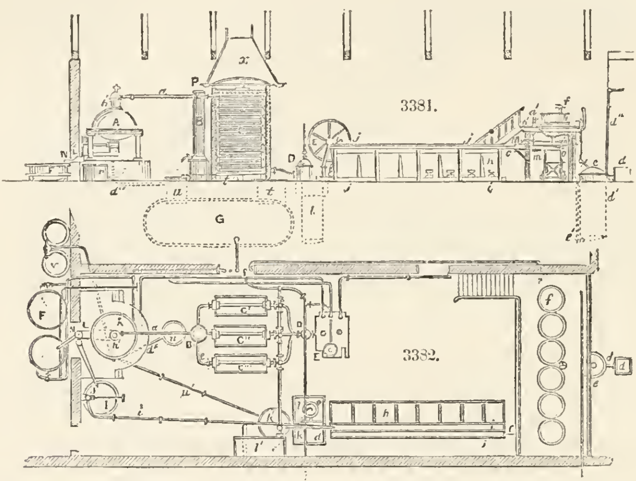
Reed's process secures this advantage in three ways. (1.) Evaporation takes place much faster when the heat is distributed through the syrup by pipes, than when it is applied to the flat or round bottom of the common boiler. For this reason steam-pipes are introduced into the syrup, in the vacuum process, besides the steam which fills the double bottom of the boilers used in this process, and communicates heat from beneath. (2.) A much higher degree of heat can be used in this method than in the one generally employed. In the common boiler, as the heat of the fire acts directly on the flat or round bottom, the greatest care is necessary to prevent the sugar from being burnt, or from being rendered uncrystallizable. If a high heat is employed, it is impossible to prevent this effect from taking place to a greater or less extent. But, by distributing the heat through the syrup, as in Reed's process, the danger from this source is entirely removed. (3.) The whole arrangement is so easily managed by dampers, &c., that the five evaporating pans will require no more attendance than one of the ordinary boilers. Much labor will thus be saved when it is most important to economize labor in the hurry of gathering the crop and converting the cane juice into sugar.

Simplicity of construction.—Compared with the other methods by which sugar is made in tolerable perfection, this is remarkable for the simplicity of its construction. The vacuum processes of Howard and others require a steam-engine, and are very complicated in all their parts. Only large plantations can employ these methods, on account of their great expense, and the skilful hands required to work them. The amount of sugar manufactured must be great to pay the interest on the cost of these arrangements. The entire cost of Reed's boilers will not very greatly exceed that of the arrangements now generally employed, while it will be much less liable to accident. It can be managed by common hands, as it requires less skill than even the common methods of making sugar. (Prof. A. F. Olmsted.)

Two vacuum pans.—This mode of boiling sugar requires a careful defecation and filtration of the juice and syrup through animal charcoal. The cane juice, after having been defecated, is passed through bone-black filters, collected in a vat from which the first vacuum-pan is supplied; when the cane-juice is concentrated therein to 28° or 29° of Beaumé, or thereabouts, it is drawn off into a vat from whence the concentrated juice is passed again through bone black filters, collected into a proper vat from which the second vacuum-pan is supplied, where it is then brought to the striking point. The vacuum-pans used in this mode of boiling are like those described under the mode of boiling in open kettles and vacuum-pans; they are heated with low-pressure steam, and, consequently, the burning of the concentrated saccharine liquid is thereby obviated. When the operations of defecation, filtering, and boiling are well managed, the sugar is equal in every respect to any made in any apparatus of the most improved method. By this mode of boiling sugar the consumption of fuel is as great as with common kettles. These kinds of vacuum-pans require a great quantity of fresh water for condensing; and in places where water is scarce, vacuum-pans of this description cannot be employed.

Degrand's apparatus.—Degrand's system consists of a condenser. The vapors arising from the juice or syrup boiled in a vacuum-pan and condensed by means of a serpentine tube, over which a film of cold juice is continually kept flowing, which absorbs the latent heat of the vapor within the tube, and a portion of the water from the juice passes off as vapor in the air. Degrand's condenser serves the double purpose of a condenser and evaporator.

There are only two of Degrand's apparatus in Louisiana. They were constructed at the Novelty Works, New York, and are more commonly known as Dérosne's apparatus; but Mr. Degrand is the real inventor and patentee of this apparatus, and Dérosne & Cail are only the constructors and assignees of his apparatus for the north of France and the colonies.



The Degrand apparatus in operation in Louisiana have vacuum-pans with a very large heating surface, and heated with low-pressure steam; the air-pumps are larger than those used in the Island of Cuba. The artificial draught of air is not made use of here, but the same result is obtained by the injection of water between the condenser and air-pump; this increases somewhat the consumption of fuel, but the vacuum obtained in that way is as perfect as by means of the draught of air; and the sugar made with this apparatus is as good as any made in Louisiana.

In the beet-sugar manufactories in Germany the manufacturers were beginning to abandon its use, in consequence of the practical difficulties in distributing the beet-juice regularly over the serpentine; and in case one of the many tubes which form the serpentine has the slightest deviation from the straight line, the juice will concentrate more at such depressions, and disturb the regular distribution of juice over the tubes. When a leak happens, the juice or syrup is rapidly absorbed into the interior of the tube on account of the vacuum, and causes a considerable loss. It is likewise found that the economy of water for condensing is not so great as was anticipated, and finally it was concluded to return to the former plan of boiling in common vacuum-pans.

The consumption of fuel by a Degrand's apparatus is 1¾ to 2 cords of wood for every 1000 pounds of sugar produced. In the Island of Cuba this apparatus takes off the whole crop with the bagasse alone; however, some require great quantities of wood besides the bagasse.

Mr. Dérosne obtained a patent in Europe in 1836, and in America in 1845.

The following description of the mode of working his apparatus is taken from his patent.

The juice which is taken from the mills is defecated in pans or boilers, a row of which is shown at *f f f*, Fig. 3382. In Fig. 3381, the elevation of one of these boilers, *f*, is represented. The juice from the mill passes into a reservoir *d*, that is connected by a pipe *d′* with an air-tight cylinder *e*, in which pipe there is a stop-cock that is turned by a long handle *d″*, by turning which the cylinder *e* can be filled, and the communication can be afterwards cut off by admitting steam from the generators or boilers, (shown in Fig. 3382, G, in dotted lines, that supplies steam to the engines and heating apparatus of the whole manufactory,) into the top of the cylinder *e*. The juice is forced through a pipe *e′*, in the bottom of said cylinder, up into the clarifying boilers *f*, which is constructed with a double bottom, between which steam is admitted by the tube *a′* from the generator; the condensed water being returned to the boilers by a force-pump through the pipe *b′*. The construction is common, but the employment of the series of these pans, for this purpose, has never before been done, or the juice clarified, as about to be described.

When the cane-juice has reached the point proper for receiving the clarifying mixture, which point is from 60° to 63° of Beaumé, it is added. This composition is made by a compound of the sulphate of alumine of the cheapest character, either with or without the presence of iron, which is formed by mixing sulphuric acid with aluminous earth, and adding thereto lime, potash, or other similar salt, and a quantity of liquified blood, either fresh or dried, being incorporated into the precipitate. This is united with the juice by carefully stirring it while pouring in the mixture, and clarifies it; or, instead of this, lime alone can be used, as in the former processes, the quantity being much greater than that used in the old colonial mode of proceeding, as, in this system, there is nothing to fear from an excess of lime, which a subsequent part of the process perfectly corrects to any extent that it may have been found necessary to use it, in order to obtain a good clarification. The steam is kept on until the juice begins to boil, and when this point is reached, the steam is cut off. The result of this is, where the mixture is used, that at the top of the boiler *f f* a thick and solid coat of scum is formed, and only a very small quantity of matter is precipitated to the bottom of the boiler. In a few minutes the liquor will have become clear, and can be drawn off through a tube *m*, by turning a cock in the bottom by means of a key *m'*, when it can be ascertained if the liquor is limpid. A small quantity of thick matter usually issues from the tube first, but it soon runs clear. By this mode of proceeding we avoid all the troublesome labor of skimming, &c. The juice, after leaving the tube *m*, passes into a gutter M which communicates by a pipe *c* with another reservoir *j*, by which the filters, hereafter described, are charged with the juice.

When all the clear juice is drawn off, the scum and the remainder is drawn into a reservoir underneath; after which bags are filled with it, and the syrup is drained and pressed out of it. The clarified cane juice in the reservoir F is next to be filtered through animal charcoal in grain; and this filtration constitutes one of the most important operations of the manufacture—it purifies the juice and furnishes the means for readily obtaining sugar of the first quality. In Fig. 3381 eight of these filters are represented, *h h h*, all of the same construction; the same are shown in Fig. 3382. They are constructed to contain about one and one-seventh tons of animal charcoal. They are made of sheet-iron or wood lined with copper, of a square form, narrowing slightly towards the bottom. At the lower part there is a grating, leaving a small space between that and the bottom, through which the filtered liquid flows. On this grating is placed a thick blanket for the purpose of supporting the charcoal, which should be sufficiently large to allow the edges to be pressed against the sides; a thick layer of charcoal is then spread over this blanket firmly and evenly, after which another layer of charcoal is put on, care being taken to equalize it with a trowel as it is thrown in, and the filter is filled thus to about four and a half feet in depth; the upper surface is then carefully smoothed, and it is ready for use.

A plate is laid on the place where the cock discharges the juice or syrup into the filter, in order that it may spread horizontally over the surface without forming hollows therein. The syrup penetrates the animal charcoal, and drives the air down before it, which is discharged from a pipe that leads up from the space below the grating to the top of the filter. The syrup, after passing through the grating and having deposited all its impurities in the filter above, is drawn off through the cock in the bottom, from whence it is conducted to a reservoir, shown in Fig. 3382 by the letter *k*, from which it is elevated by a cylinder *l* into a reservoir *l'*. This cylinder or monte-jus is made and operates precisely the same as that previously described and shown in Fig. 3381.

From the reservoir *l'* of Fig. 3382 the juice is conveyed to the evaporator, which is one of the most important parts of this invention, and is constructed as follows: Fig. 3382 (C' C'' C''') being a top plan, and Fig. 3381 a side elevation thereof; it consists of a double or triple series of horizontal tubes of 8½ inches in diameter, and about 300 feet in length, each series being placed one over the other, forming two or three parallel lines; the tubes of each series are connected together at each end, so as to form one long conductor for the steam, by which they are heated. The tubes of each series are supported by two upright posts, one at each end, which are connected at the top by a cross-beam or cup brace just under this beam; there is a bracket on the inside of each post which supports a triangular shaped trough or distributor P, that extends from one to the other, the lower edge of said trough being serrated without being cut through, and standing directly over the centre of the upper tube of the series, C'; one side of this trough has a row of small vertical oblong holes in it, through which the juice received from the reservoir *l'* percolates, and guided by the lower serrated edge, drops upon the top of the upper tube, spreads itself around it, and then falls on the next, and so on to the bottom, passing over the entire surface of the tubes, which, by the heat of the steam within them, serve to evaporate some of the aqueous portions of the juice that is then received at the bottom in a receiver *t'*, and ultimately into the reservoir *u*, and the juice being heated by the tubes, and being exposed to the action of the air in a state of extreme division, is evaporated, and conducted in a proportion determined by the rate at which it escapes from the distributor above, as it falls into the receiver *t'*.

A is a pan of a common construction for boiling by steam in vacuum, with the usual fixtures attached thereto; a vacuum is formed by an apparatus hereafter named, in the boiler A, and by opening a communication between the boiler and the reservoir *u* through the connecting pipe *d'*, which extends from the bottom of said reservoir to the pan, the juice contained in the reservoir rushes into the pan. As soon as the pan is filled, which is ascertained by means of the glasses in the lid of the pan, the pipe *d'* is stopped, and the steam is introduced into the respective heaters of the boilers from the steam generator.

The steam which rises from the juice in the pan into the cup *h'*, passes through a tube *a* into a large upright cylinder B, in which any saccharine matter is separated from the steam which has been forced up with it. From the vase B the steam passes by the pipes *e'* into each series of tubes above described, (lettered C' C'' C''',) entering the upper tubes of the series and passing out of the lower ones on the opposite sides; the steam, in passing through the tube C', is condensed by the juice which runs down over the outside, the apparatus thus performing the twofold operation of evaporating the juice and forming a condenser for the steam rising from the vacuum-pan. The steam, when condensed into water, runs out of the lower tubes, as above named, into an injecting-cylinder D, where, if the condensation is not perfect, water can be injected to complete it; from the cylinder D the water of condensation, &c., is drawn off by the action of the air-pump attached to a steam-engine, indicated in the drawing by E. The pump and cylinder D, above named, may be omitted, and a ventilator placed in their stead; but the vacuum will not in that case be so complete, although the expense of the apparatus is somewhat reduced. Instead of attaching the condenser with the vacuum-pan, as above described, it may be connected with the exhaust-pipe of the steam-engine.

As the depth of juice in vacuum-pan A is reduced by evaporation down to the heaters inside, a further supply is to be admitted from *u* through the pipe *d''*, as in the first instance; and when the juice under evaporation acquires a density of 24° or 25° of Beaumé, it must be drawn out of the pan, the passage of the steam to the heaters being first cut off, and the vacuum therein destroyed.

The syrup at 25° then passes through a movable spout L, which is directed into another spout N, and thence into the reservoir I, after which the boiler is charged with juice from *u*, and the process again proceeds as before. During the operation of emptying and refilling the pan, the time is so short as not to require the stopping of the flow of the cane-juice over the outside of the tubes C' C'' C'''.

From the reservoir I the syrup is raised by means of a hand-pump J into a spout which is represented at *i*, Fig. 3382, for feeding the filters before described. The syrup runs from the spout *i* into either of the filters *h* through stop-cocks attached thereto for that purpose, and passing down through the filters, it is soon after drawn off through the cock and received into the gutter *i'*, whence it is conducted into the reservoir *k'*, Fig. 3382; and when there is a sufficient quantity therein to fill the pan A, the other processes are stopped, and the pan A is filled with the syrup from the reservoir *k'*, by means of a pipe *u'*, which connects them by a proceeding similar to that for filling the pan from the reservoir *u*. The evaporation of this syrup of 25° is then proceeded with until it is sufficiently boiled, which is ascertained by the testing-rod of common form. When the syrup is in a proper state of condensation, the pan is to be emptied by means of the movable spout L, through the spout N, into one or the other of the heating pans shown by letter F.

The pans F have double bottoms, and are supplied with steam from the generators between the two bottoms, by which they are heated, until the temperature of the syrup contained therein reaches 70° Beaumé, at which point crystallization almost immediately commences; and when it is quite determined, the mixture of crystals and syrup must be stirred with a wooden spatula, care being taken to distribute the crystal formed on the bottom and sides equally; the matter is then, while in a liquid state, ready to pour into the moulds.

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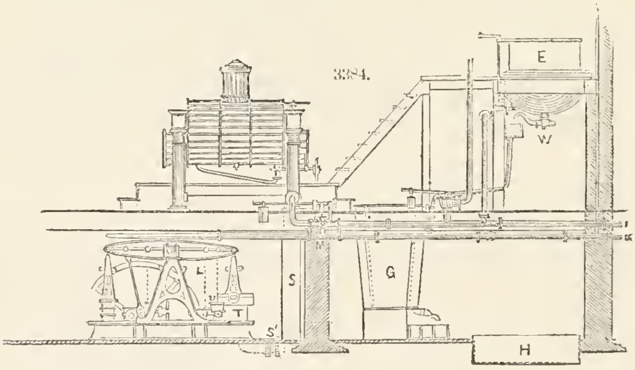


In the process of filtration, herein before named, as soon as it is found that from the use of the filter the syrup of 25° comes from it less pure than at first, it is stopped and turned into another filter; the clarified juice is then admitted into the filter from spout *j*; this drives the syrup still contained in the filter down, and takes its place. When the degree of the flowing syrup is found to be reduced to 15°, the juice flowing from the cock is directed into the gutter *j*, which conducts it into the reservoir *k*, from whence it takes its course as before indicated.

When the animal charcoal is sufficiently exhausted by the filtration of the clarified juice, water is let on to the filter, and assumes the place of the clarified juice in the same way as the juice did the syrup; by this means the greater part of the juice is recovered, the flow being stopped when the degree of the liquid is too weak to be of value.

The coal is then taken out of the filter and conveyed to the revivifier, and the filter is again refilled with fresh black.

Dérosne claims the employment of a series of horizontal tubes, placed one above another, in the manner described, having a current of steam passing through them, and the cane-juice flowing over the exterior surface, by which the steam is condensed and the juice is somewhat concentrated; thus serving the double purpose of condenser and evaporator as before described, said condenser being attached either to the vacuum-pan or to the exhaust-pipe of the steam-engine.

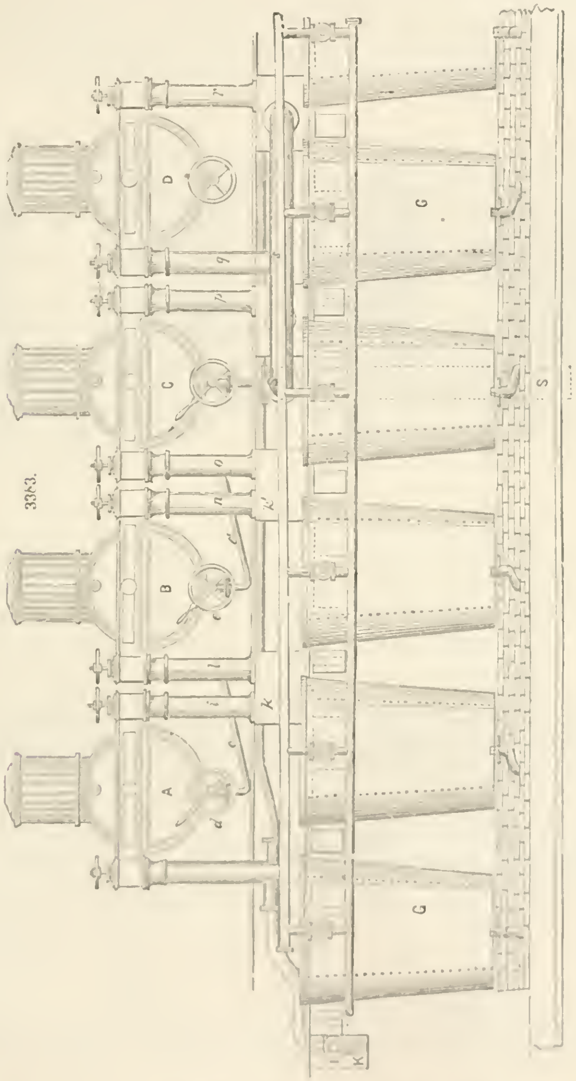
Rillieux's apparatus.—Norbert Rillieux, of New Orleans, invented an apparatus for boiling sugar in vacuo, in which he uses the latent heat arising from one pan to boil the juice or syrup in succession in another vacuum-pan of similar construction. To heat the first pan he uses the escape steam of the steam-engine which works the grinding-mill; the second, third, or fourth pan is heated from the vapors arising from the second and third pans.

An air-pump produces the necessary vacuum.

Mr. Rillieux obtained letters patent for his invention in 1843, and for improvement in the same in 1846. The following description and figures will give a correct idea of the apparatus and its mode of working.

Rillieux's boiling apparatus is composed of three or four pans.

The four-pan apparatus.—The cane-juice, after having passed the clarifiers and filters, flows into a vat, from which it is pumped in the first pan A, through a pipe *a*, Fig. 3385, which leads to the back part of that pan, on which pipe there is a stop-cock, which is opened or closed by means of a handle *b* placed in front of the apparatus, where the man who manages the apparatus is placed; and, in turning



3383.

that handle more or less, he can regulate the feeding of that pan, in front of which is a pipe *c*, Figs. 3383 and 3385, leading the cane juice to the back part of the second pan B; on that pipe and under the first pan is a stop-cock, worked by the hand *d*, by which the feeding of the second pan B is regulated; and in the front, on this second pan and below, is another stop-cock, worked by the hand *e*; from that stop-cock a pipe *c'* leads to the back of pan C, to convey the cane juice, now at the density of 15° Beaumé, into said pan; and from this pan a pipe leads to a pump which draws the sirup now arrived at 28°, from the pan *c*, and forces it up to the clarifiers E E. In those clarifiers the sirup is heated up to the boiling point and scummed; from thence it passes through the bone black filters G G, whence it goes to a vat H, Fig. 3384, below, to supply the fourth or strike pan D.

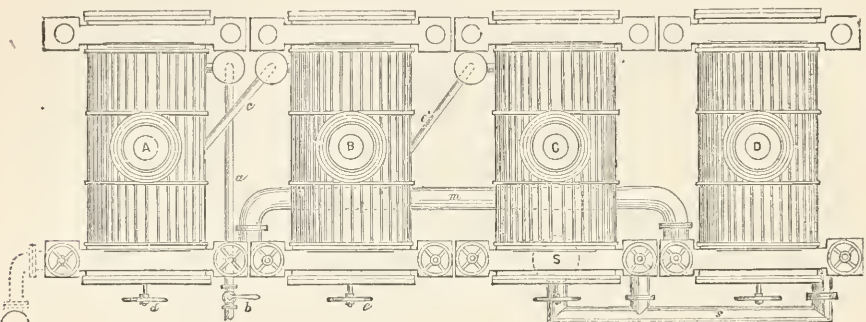
Now let us follow the steam:

The exhaust steam from the boilers goes through the pipe I, Figs. 3383 and 3384, to the first pan A. Below that is another, K, which brings the direct steam from the boiler and feeds the clarifiers F F and the pumping engine L. At M, Fig. 3384, is a valve which connects the two steam-pipes together, and through which any quantity of direct steam wanted, besides the exhaust steam, can be let into the exhaust steam-pipe I for boiling the juice.

The vapors arising from the cane-juice of the pan A are carried down through a pipe *h*, Figs. 3385 and 3386, and column *i*, in a cast-iron box, o^2, steam-chest *k*. A part of this steam passes up through the column *l* to feed the second pan B, and passes through the horizontal pipe *m*, Fig. 3385, and up the column *q* to feed the strike-pan D.

The vapor arising from the second pan B passes through column *n* and steam-chest *k'*, and up through the column *o*, to boil the pan C. The vapor from C D passes through the columns *p* 2 through the horizontal pipe *s*, and brings the vapor to the condenser *s*, where it is condensed by means of a jet of water; the vacuum being maintained through the means of an ordinary air-pump T. S is a pipe which connects the pumping engine with the condenser, the third and fourth pan.

3385.



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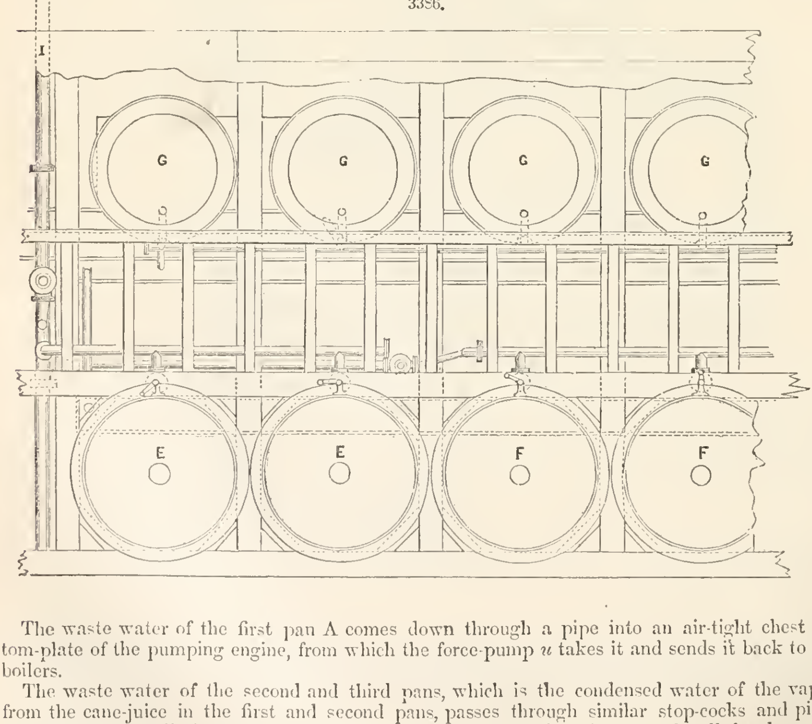


The waste water of the first pan A comes down through a pipe into an air-tight chest in the bottom-plate of the pumping engine, from which the force-pump *u* takes it and sends it back to the steam-boilers.

The waste water of the second and third pans, which is the condensed water of the vapor arising from the cane-juice in the first and second pans, passes through similar stop-cocks and pipes, which carry it to the small air-pump U, which forces it up to a vat, where it serves for all the cleansings of the establishment.

Three-pan apparatus.—When the three-pan apparatus is used, the cane-juice is pumped into the first pan A; from thence to the third C; the second, marked B, is omitted; whence it is drawn off by the pump to the clarifiers, and the juice follows the same course as in the four-pan apparatus, above described.

The exhaust steam and the direct steam are let in the first pan by means of the valve M, above mentioned, and the vapor arising from this pan feeds the pan C, and the third pan D, and the vapor of the second C, and third D, goes as in the other apparatus already described to the condenser. The waste water of the second C, and third D, follows the same course as already described in the four-pan apparatus, to the small air-pump. As the main part of the boiling in the apparatus is effected by the exhaust steam of the mill-engine, the mill must be kept grinding at a uniform speed, and with a continually regular supply of cane; and as the power of the engine is regulated by the difference of pressure between the steam in the boilers and the steam in the exhaust-pipe, and, as that difference is regulated by the weight on the valve M, it follows that, in loading that valve M more or less, the different pressure of steam, or what is called the effective pressure of the steam, is adjusted in such a way that the mill will furnish as much cane-juice as the apparatus boils—in such a way that the clarifiers, filters, and filtered juice-vat are always kept full. The liquid flows from the mill up to the clarifiers and down to the filters, with the same speed as it comes from the mill, the cane-juice passing out of the aforesaid vat as fast as it comes in, to supply the first pan, and from thence to the second pan, (or third, as the case may be,) when it is brought to the density of 29° Beaumé. A small pump is attached to the engine to take it out of that pan fast enough to keep the syrup at a certain height in it.

The syrup is pumped into one of the clarifiers E as high as the jacket reaches; when that clarifier is filled to that point the rest of the syrup is turned into the other, which is heated by letting in the steam before it is full; when the first clarifier has reached the boiling point, the steam is shut off, the scum removed, and the liquid emptied by the cock W into a trough, and thence down to the filters.

The only operation which the attendants of the pans have to observe is to keep the juice or syrup at the proper level in the first and second pans, and to feed them as well as the third pan in such a way that the syrup be maintained at 29° Beaumé in the second pan, (or third, as the case may be,) by opening or closing the feeding-cocks when the syrup runs too thick or too thin, or when the juice is too high or too low, and also to regulate the pressure of the steam by the valve M. It will be observed that there are two sets of clarifiers E F—one set to boil the syrup, and the other set to defecate the juice as it comes from the mill.

When the stop-cocks are regulated they require a constant watching by the person employed at the pans; but they remain sometimes hours without being moved, or the handles require to be moved more than one-eighth of an inch to one or the other side to keep the cane-juice at the proper height, and the syrup at its proper density. The cane-juice, when it leaves the mill, passes in a constant stream to the clarifier E, from thence to the filters and pans, and returns again to the clarifier F, at syrup of 29° density, and from there it goes through the bone-black filters G G to the vat H, which again supplies the strike-pan, and then, at last, the boiling is done by strikes, as the sugar-boiler calls it.

The juice goes from the first into the second in the three-pan apparatus, and from the first to the second, and from the second to the third in the four-pan apparatus; because, in the latter apparatus there is more vacuum in the second than in the first, and more in the third than in the second; and it is that excess of vacuum which draws the cane-juice from one pan into the other.

The waste water of the juice-clarifier F F comes through pipe X in the steam-chamber of the first pan; on which pipe there is a three-way cock, which, when properly turned, sends it directly back to the waste-water pipe *t* of the first pan. The waste water of the two other clarifiers E E comes directly to the waste-water pipe *t* of said pan. When the second pan is boiling, the three-way cock is turned to bring said waste water from the cane-juice clarifier to the steam-chamber of the first pan; and all the steam arising from said waste water upwards mixes itself with the exhaust steam, and helps the boiling of said pan; the water flows to the lower row of pipes through the other end of the pan, and mixes itself with the waste water of said pan, and goes down through the waste-water pipe *t*, mixed with the waste water of the clarifier E E to the closed chest in the bed plate of the pumping engine, from whence the whole is pumped back to the boilers in such a way that all the steam condensed in the jacket of the cane-juice and syrup clarifier, and that which has been condensed in the pipe of the first pan, is returned to the boilers. Now, as all the exhaust steam of the mill and pumping engine is used for the boiling of the first pan, it follows that all the steam raised in the boilers, except the small portions which escape from the leak of stuffing boxes or safety-valves, is entirely condensed and rendered available for heating the cane juice and syrup in the clarifier, and the whole of the waste water heated to the boiling point is sent back to the boiler.

In Rillieux's apparatus the use of the latent heat is carried out more perfectly and fully, perhaps, than in any other system known.

The first pan of his apparatus is heated by steam not exceeding a pressure of four to eight lbs. per square inch, and the latent heat of the vapor from this pan is used to evaporate the syrup in the next of the series of pans, and so on. We have seen from the description of this apparatus that he uses an air pump to form the vacuum, which is worked in connection with the various other pumps by a separate steam-engine, which is placed under the apparatus.

Merrick & Town, of Philadelphia, assignees of N. Rillieux's patent, carried the plans of the highly intelligent inventor into execution, and developed in its results its admirable adaptation to the purpose for which it was intended.

The principle of the successive use of latent heat has been long known and applied for distilling and evaporating, but it has never been applied in connection with vacuum, by which connection only the rapid boiling required for the evaporation of saccharine can be obtained.

This is, therefore, an American invention, which will form a new era in the sugar-growing interest of the United States.

Mr. Th. Packwood uses three steam boilers of ordinary size: the fire-grate extends only under two of them; the third boiler is heated by a return flue, and this is the only fire employed about the whole sugar-house, generating enough steam to work the grinding-mill, to heat the defecators, supply the necessary quantity of steam to the boiling apparatus, to work the engine for the air, juice, syrup, and water pumps; making 12,000 lbs. of sugar in 24 hours.

The apparatus is solid and requires very small space, and has a pleasant appearance.

The sugar made with this apparatus is of a beautiful light straw-color, of fine large crystal, and free from unpleasant odor, and commanding a good price and ready sale.

The price of a Rillieux apparatus varies according to the size; a three-pan apparatus sufficiently large to take off a crop of 440 hogsheads of first sugar, including clarifiers, bone-black filters, vat for filtered cane-juice and syrup, three boiling-pans, pumping engine, cast-iron and copper pipes, and all expenses of setting up, is $11,000.*

A. Stillman patented an improvement in evaporating saccharine juices in 1843.

The invention consists in employing the surplus or waste heat from the "train" in generating steam for grinding cane, pumping, or any other purpose for which it may be required.

To supply the deficiency of evaporating power occasioned by diminishing the train of kettles, he substitutes in their place any number of *steam evaporators or clarifiers*, into which is introduced *the "exhaust" or waste steam* from the steam-engine. This waste steam, to be made effective, must be introduced into the clarifiers or evaporators under a pressure greater than that of the atmosphere, and the effect will be in proportion to the pressure.

The objects of this arrangement are, a saving of fuel and improvement in the quality of the product, and the improvement in the latter respect will be proportionate to that amount of the process of clarifying and evaporating which is transferred from the ordinary kettles in contact with the fire, to those making use of the waste steam.

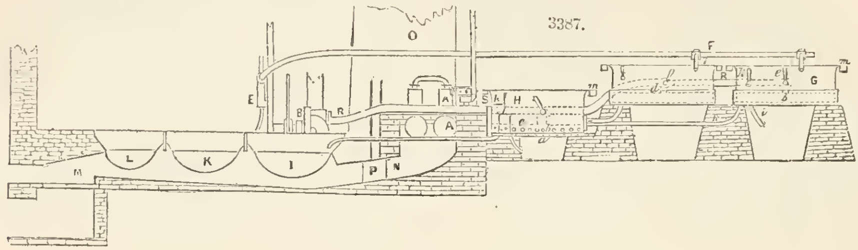


Fig. 3387 is a section of the sugar-works in which are shown the application of the improvement, and respecting only a general arrangement. A A are the steam-boilers so placed as to receive under them the waste heat from the train; B, the steam-engine; E, pump for bringing the liquor from the reservoir to the clarifiers through the pipe F. This pump is not an essential fixture, as the mill is more frequently elevated to a height sufficiently for the liquor to run directly to the clarifiers. G G, the clarifiers; H, the evaporator, which is of the same form and construction as the clarifiers; I K L, a train of "coppers" or evaporators, such as are in common use; M, fireplace for the train; N, the flue, through which the flame passes from the "train" under the steam-boilers to the chimney; O P is also a flue to the chimney, so that the flame from the "train" may be turned off from the steam-boilers at will; R, exhaust steam-pipe from the engine; this pipe communicates with the pipes in the clarifiers or evaporators; S, the escape-valve, by which a pressure is maintained in the exhaust-pipe.

The clarifiers are rectangular boxes of sheet-iron, (boiler-plate,) the bottoms of which are double, so as to form a steam-chamber *a*; around the top they have a channel-way *m*, which forms the "skimming-spout;" the skimmings, which it receives, are carried off by a pipe. In addition to the heating surface obtained by the double bottom, there is above it one or more tiers of copper pipes. The method of introducing them is as follows: on two opposite sides of the clarifiers is a cast-iron box riveted, which forms the side chamber *b b*, and extends the whole length of the clarifier; this chamber is closed by a movable plate which is fastened by bolts; these two opposite chambers are connected by the cross-pipes *c*; the pipes are received into the chambers through "packing-joints," so as to prevent any communication between the steam in the chamber and the liquor within the clarifier. To the top of one of the side chambers there is a cylindrical valve-chamber attached, which receives the steam from the exhaust-pipe on either side; from the lower side of this valve-chamber is a steam passage communicating with the chamber *b*; this steam passage is opened or closed by means of a sliding-valve *d*.

When the engine is in operation, the waste steam passing through the exhaust-pipe R is admitted through into the side chamber *b*, and from thence into the pipes *c c*, and also through apertures into the bottom chamber *a*. The liquor in the clarifier is then exposed to the heating surfaces of the pipes *c c*, and also of the "false" or "double bottom."

Steam-pipes passing through the liquor have been before employed, but not in combination with the double bottom. The advantage of this combination is this: by using the pipes alone, that portion of the liquor beneath them would be in a great measure unaffected, whilst the double bottom above would not give the necessary heating surface; so that the combination is necessary to a perfect operation.

h and *i* are two valves; one for discharging the clarified or concentrated liquor, and the other for discharging the sediment formed in clarifying. Their construction is as follows: the valve is the ordinary "puppet valve," with a hinge on the upper side for attaching the rods; the seat is fitted between the two bottoms of the clarifier and riveted to both; the pipes for carrying the liquor and sediment are

* See De Bow's Commercial Review, p. 293, vol. 5.

attached by flanches and bolts to the bottom of the seats. The valves will close by their own weight, and the weight of the liquor above them will keep them tight; the valves are raised by cords connecting them to levers on the shaft R, which shaft is worked by a handle on the outside of the clarifier The valves are so placed that the levers stand in opposite directions upon the same shaft, so that both valves can never be opened at the same time.

S the escape-valve, made like an ordinary safety-valve, and attached to the exhaust-pipe of the engine. Its particular construction, however, is not essential, its purpose being to obtain all the useful effect of the waste steam by confining it in the exhaust-pipe and clarifiers at any required pressure. Suppose, for instance, that the engine is in operation, and the exhaust-pipe terminating in the clarifiers, but in some part of the exhaust-pipe there is an opening into the air of a size equal to that of the pipe, the steam, of course, would escape through the opening against the pressure of the atmosphere only; its effect in the clarifiers would then be very slight; but when that opening is closed by means of a loaded valve, by increasing the weight on the valve, we may so confine the waste steam as to effect the entire absorption of its heat in the clarifiers or evaporators.

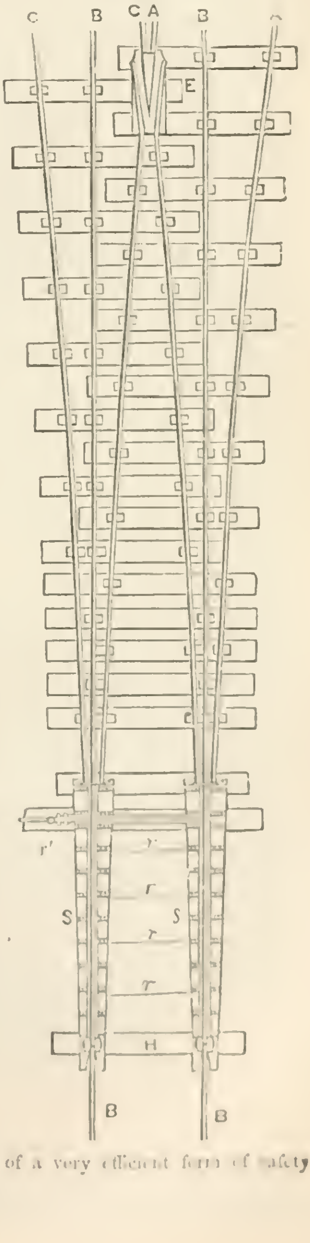
The operation of this apparatus is as follows: The flues N and P being closed by dampers, a fire is made under the steam-boilers in the usual manner. As soon as a sufficiency of steam is generated the engine and cane-mill are put in operation. The pump E is then put in operation, and the liquor carried to the clarifiers G G, through the pipe F; the steam is then admitted from the exhaust-pipe into the clarifiers; and the liquor having gone through the usual process of clarifying, is discharged by means of the valves *h h* into the evaporators H, and through that into the train of coppers I K L, where the evaporation is to be completed. These coppers or kettles being filled with the clarified liquor, the furnace is closed, and the fire started under the trains of coppers on the furnace M, by which fire, besides effecting the concentration of the liquor in the kettles, the steam is generated in the boilers and the operation continued.

The steam-clarifiers may be used indiscriminately in clarifying or evaporating, as the case may require.

If the train of coppers be very much diminished, more of the evaporation, of course, must be carried on in the steam evaporator.

SWITCH. A contrivance of a variable rail by means of which the cars on a railroad are passed from one line of rail to another.

3388.



3389.

Fig. 3388 shows the method of operating. S S are called the switch-bars, movable about the point H, at which point they form part of the line of rail of the straight track B B B B. These bars are secured together by iron rods *r r r*; a rod *r'* is connected to the short arm of a lever *l*, seen in elevation in Fig. 3389: by throwing this lever to the right or left the switch bars are moved so that they form either part of the straight and right-hand track B A, B A, or part of the straight and left-hand track B C, B C. Where the rails cross at E is the fixed casting called a *frog*, the use of which to pass the flange of the wheel through the curved rail is too obvious to require explanation. This is the double switch connecting a main line with a turn-out or track on either side, and wherever the rails cross each other a frog is inserted, bolted to the cross ties. See FROG.

Innumerable forms of switch bar and frog have been devised for accomplishing the same purpose, and several patents have been taken out for switches called "safety switches," the object of which is to prevent the cars passing off the track when through negligence the variable rail is left in a wrong position. Mr. Nichols, of Philadelphia, is the patentee of a very efficient form of safety switch, as is also Mr. Tyler, of Worcester, Mass.

TELEGRAPH, *History of the.* Soon after the discovery of the Leyden jar, in 1747, it was observed that the shock, passed through twelve thousand feet of wire, affected persons placed at either extremity, apparently at the same instant of time. The idea of the instantaneous passage of electricity was probably thus first received, and it was forced, by new observations, on the attention of all succeeding electricians.

In 1794, Reizen proposed a telegraph, employing the spark, with seventy-six wires, or thirty-six complete circuits, one for each letter and number. In 1798, Betancourt constructed a telegraph, also employing the spark, which is stated to have been in successful operation, between Madrid and Aranjuez, for twenty-six miles. This was the achievement of the close of the last century. The difficulty of insulating free electricity made it impossible that any great results should be obtained from its use.

The first year of the present century produced the voltaic or galvanic battery. In 1809, Sœmmering improved this discovery by inventing a telegraph of thirty-five wires, which indicated the letters by the decomposition of water, which took place under the eye of the observer, from little pins of gold. He also caused the liberation of the gases to raise a cup attached to a lever, and thereby drop a weight on a little platform, connected with chime machinery, so as to ring a bell. In 1816, Dr. J. R. Coxe, of Philadelphia, proposed a similar decomposing apparatus, and confidently predicted the ultimate success of the telegraph. In the same year, Ronalds, in England, returned to the use of free electricity, inventing an elaborate telegraph, which was put into operation over eight miles of wire.

The first registering telegraph seems to have been constructed by Mr. Harrison Gray Dyar, of Long Island, in 1826, who used the decomposing power of the spark, acting upon a fillet of paper, moistened and stained with litmus, and moved by hand or clock-work. The passage of each spark from a conductor to the paper produced a discoloration, and, by different combinations of marks thus made, any signal could be transmitted and registered. This was a very important step in the history of the telegraph, and appears to be the origin of the system of telegraphic alphabets so generally used in later inventions.

In the telegraphs already referred to, it had been necessary to interpose the indicating apparatus in the course of the circuit; that is, to interrupt the circuit for a short space. This was obviated by the discovery of the deflection of the compass needle by Œrsted, in 1819, and the discovery of the electro-magnet by Ampère, in 1820. According to the first of these discoveries, a magnetic needle tends to place itself at right angles to a wire in its neighborhood, through which a galvanic current passes. According to the second, a piece of soft iron, placed in the axis or centre of a coil of wire, becomes a magnet during the passage of a galvanic current through the coil.

In 1820 and 1822, Ampère proposed and fully described the use of the deflection of a number of needles to constitute a telegraph similar to that of Wheatstone, now in operation, with a less number of circuits, in England. From this time the subject became one of frequent suggestion among philosophers. The deflective telegraph was, however, finally introduced into practice by Schilling, in Russia, at the end of 1832, by Gauss and Weber at Gottingen, in 1833, and finally, on a large scale, by Wheatstone, in England, and Steinheil, at Munich, in 1837, or soon after. The credit of the first *construction* of the galvanic telegraph belongs thus to Schilling, Steinheil, and Wheatstone, by the latter of whom, with some of his English coadjutors, many of the practical difficulties in the modes of transmitting the current were overcome.

The telegraph of Steinheil, which was in operation between Munich and Bogenhausen in the summer of 1837, seems to be the first *electro-magnetic* telegraph on record which employed a registering apparatus. The deflection of his needles moved little levers, carrying pen-points, which marked dots or short lines on a fillet of paper moved by clock-work, as had been done with common electricity previously by Dyar, and as was subsequently brought into use in this country by Professor Morse.

The deflective telegraph was still imperfect, each deflection of the needle requiring a very appreciable time to be accomplished. The use of the electro-magnet was the next step taken in advance. It was not until the experiments, in 1830, of Professor Joseph Henry, now secretary of the Smithsonian Institute, upon powerful electro-magnets, and the effect of long conductors, that this form of telegraph became possible; and in his first paper on the result of these experiments, he at once applied the new facts to the idea of the construction of the telegraph.

In 1844, the registering telegraph of Professor S. F. B. Morse, employing the electro-magnet, was introduced upon a line between Baltimore and Washington, the caveat to his patent bearing the date of October, 1837. The first suggestion of this form of telegraph is claimed to have been made by Professor Morse in 1832, and also, in its general character, by Dr. C. T. Jackson. This telegraph, together with the House telegraph, and the Bain decomposing telegraph, constitute the three systems now, for the most part, in operation in this country.

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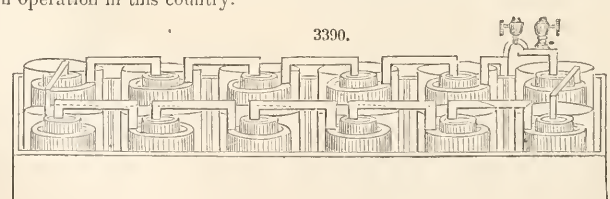

Description of the telegraph.—Fig. 3390 represents a series of twelve pairs of Grove's battery, such as is generally used in connection with the telegraph. When a plate of platina and a plate of zinc are placed in an acid solution, a current tends to flow from the platina to the zinc, through any conductor

which may be so disposed as to connect the two. In the figure, the galvanic series is represented, consisting of twelve single pairs, the zinc of each of which is connected with the platina of the next. It may be considered that a current is produced by each of these pairs, which has, however, to flow in the same direction, and fall in with all the others. Hence their intensity is multiplied twelve times. It is by this means that the resistance to the passage of the current through very long conductors is overcome. The number of pairs in the telegraph is always proportioned to the distance which the current is to traverse, fifty or more being used on a line of two hundred miles.

Each pair of the battery consists of a pint glass tumbler, a cylinder of zinc, a small porous cylindrical earthenware cell within the zinc, and a platinum strip suspended within the cell from an arm belonging to the zinc of the next pair. A solution of diluted sulphuric acid is used with the zinc, outside the porous cell, and the cell itself is filled with nitric acid. The two acids are used on account of an increase of power depending on a chemical reaction. The zinc cylinder is amalgamated with mercury, to prevent its being acted upon by the acid when the battery is not in use. A solution of sulphate of soda is sometimes added to the sulphuric acid, to assist in accomplishing the same object. This is the most powerful form of battery known.

A battery, using copper and zinc plates in flat glass cells, has been lately employed on the lines of the chemical telegraph in this country. The interval between the plates is filled with white sand. The sand is moistened to the consistency of a paste with diluted sulphuric acid. This battery proves very constant, and, though less powerful, is much more easily managed than the Grove battery.

Two screw-cups will be seen rising above the battery in Fig. 3390, one of which is the positive pole or extremity of the series, the other the negative. To these the wires are attached which convey the current. These wires, as first used in the telegraph, were of copper, which is a better conductor of galvanism than iron; but the liability to accident, from their want of strength, was so great, that iron wires were substituted by Steinheil, in Germany, of a size sufficient to make up by their quantity for the poorness of their quality as conductors.

The wires are usually supported on posts, from which they are insulated by glass supports or knobs. They have been sometimes carried through the ground, insulated within a metallic tube.

Fig. 3391 represents the signal-key in its simple form. It is placed, when in use, in the course of the conductors or telegraphic circuit, proceeding from the battery. When the hand depresses the key, it comes in contact with the knob and metallic strip below, making connection between the two screw-cups, and completing the battery circuit. While the key is depressed, a continuous current passes; but if it be depressed, and allowed to spring immediately up, only an instantaneous wave or impulse is communicated. The use of the signal-key, in connection with the telegraph, was described by Ampère, in 1820.

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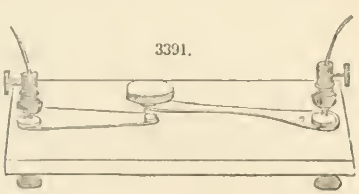

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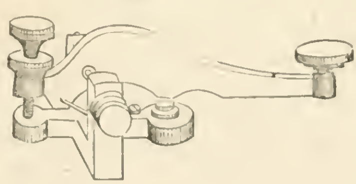
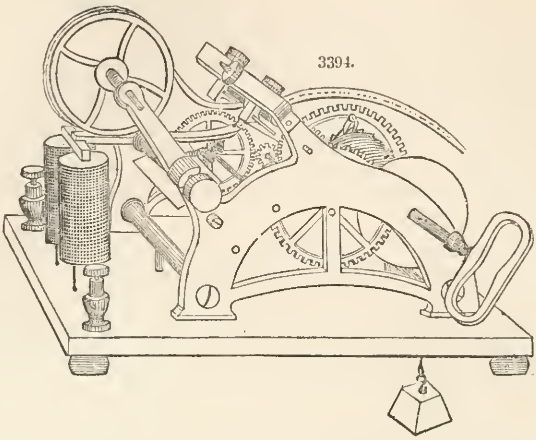


The signal-key, in its more perfect construction, is represented in Fig. 3392. It consists of a lever, mounted on a horizontal axis, with a knob of ivory for the hand at the extremity of the long arm, which is at the right in the figure. This lever is thrown up by a spring, so as to avoid contact with the button on the frame below, except when the lever is depressed for the purpose of completing the circuit. A regulating screw is seen at the extremity of the short arm of the lever, which graduates precisely the amount of motion of which it is at any time capable.

3393.

The registering part of Morse's telegraph is shown in Fig. 3393. Two screw cups are seen on the board, intended for the insertion of the wires from the distant battery. Next the screw cups is seen a U shaped electro magnet, with coils of wire upon it, the ends of which, passing down through the board, are connected with the screw cups. Over the poles of the magnet is a little armature, or bar of soft iron, attached to the short arm of a lever, whose long arm carries a point or style, nearly in contact with the grooved roller above. The action which takes place, on depressing the signal key at the distant station, is, in the simplest terms, as follows: A wave of electricity is transmitted over the wire of the telegraph, arrives at the electro magnet, and circulates through the coil of wire surrounding it. The U shaped soft iron becomes at once a magnet, (see Magnetism,) and attracts the little armature down to it. The long arm of the lever is thrown up and marks the strip of paper passing between it and the roller. When the distant operator lets the signal key fly back, and the current ceases, the iron of the electro-magnet losing all its magnetism, and the armature, with the lever, is carried back by the action of a little spring, being a *dot* impressed upon the strip of paper. Should the distant operator hold down the key, a continuous current will pass, and a *line* is marked on the paper which moves under the roller.

3394.



The complete registering instrument, shown in Fig. 3394, is a large spool, on which the strip of paper is wound, and clock-work, with rollers, give the strip a steady motion onwards under the style upon the lever of the electro-magnet. A bell may also be added, which is struck by its hammer on the first motion of the lever, to draw attention. There is a stop-motion sometimes used, by which the clock-work is brought to rest in a few seconds after the lever ceases to act, and which is released again by the first motion of the lever.

The annexed is the combination of dots and lines on the fillet of paper used by Professor Morse to indicate the different letters and numbers.

Between each letter of a word a short space is allowed, between words a longer space, and between sentences a still longer one. Many short-hand signals are also employed.

Where a long circuit is used, the resistance to conduction, measured by the amount of electricity which passes, is very great. The diminution of the current is most sensible when tested through the first few miles of wire, the amount which subsequently passes appearing nearly constant for a long distance. It is not, however, sufficient, in its electro-magnetic effects, to work one of Morse's registers directly. The current, which has traversed a great length of wire, can only move the lever of the electro-magnet sufficiently to bring a platina point in contact with a little platina disk placed opposite to it, so as to complete the circuit of a local battery, which works the register with energy. This is the principle of *combination of circuits*, and constitutes the important invention of the *receiving magnet* and *relay* or *local battery*, as they are familiarly known in connection with Morse's telegraph.

MORSE'S TELEGRAPHIC ALPHABET.

a · —	*o* · ·	
b — · · ·	*p* · · · · ·	
c · · ·	*q* · · — ·	NUMERALS.
d — · ·	*r* · · ·	1 · — — ·
e ·	*s* · · ·	2 · · — · ·
f · — ·	*t* —	3 · · · — ·
g — — ·	*u* · · —	4 · · · · —
h · · · ·	*v* · · · —	5 — — —
i · ·	*w* · — —	6 · · · · · ·
j — · — ·	*x* · — · ·	7 — — · ·
k — · —	*y* · · · ·	8 — · · · ·
l ——	*z* · · · ·	9 — · · —
m — —	*&* · · · ·	0 ———
n — ·		

The effect of the combination of circuits is to enable a weak or exhausted current to bring into action, and substitute for itself, a fresh and powerful one. This is an essential condition to obtaining useful mechanical results from electricity itself, where a long circuit of conductors is used, and accordingly it received the attention of early experimenters with the telegraph. This principle seems to have been first successfully applied by Professor Joseph Henry, of Princeton College, in the latter part of 1836. He was thus enabled to ring large bells at a distance, by means of a combined telegraphic and local circuit. In the early part of 1837, Wheatstone, in England, used a combining instrument, which consisted of a magnetic needle, so arranged as to dip an arch of wire into two mercury cups, when deflected by a feeble current, thus completing the circuit of a local battery, which struck a signal-bell. Davy patented in England, in 1838, a system of combined circuits, for four different purposes connected with his telegraph. He brought into action a local circuit, 1st, to discolor or dye, by electro-decomposition, the calico on which he registered his signs; 2d, to actuate an electro-magnet regulating the motion of the calico; 3d, to direct the long or telegraphic circuit to either of two branches, by means of a receiving instrument placed at their point of meeting, and operated upon from a distance; 4th, he provided for a complete system of relays of long circuits. His instrument resembled Wheatstone's, only the contact was made by two surfaces of metal, without the use of mercury.

The receiving magnet used by Professor Morse is a very slight modification of his register, the platina point for completing the local circuit being substituted for the marking point. The magnet is surrounded with helices of fine wire, which multiply the effects of the feeble current, and the whole instrument is constructed with delicacy. By Morse's patent of 1840, this is applied to the combination of long circuits, or the *relay* of currents; and by his patent of 1846, it is applied to operating the register by a local or office circuit. The electro-magnet, armature, and lever, constituting the chief part of both these instruments, is simply the electro-magnet of Professor Henry, described in 1831.

In a line of telegraph of several hundred or thousand miles, any number of receiving magnets may be interspersed, as they do not interrupt the circuit. Each one of these may work a local register, and thus the same message may be recorded at a multitude of places, practically at the same moment of time. If the receiving magnet is to effect a relay of currents, the motion of its lever brings into action a powerful battery on the spot, which works the next receiving magnet in succession, and so on.

The use of the receiving magnet, however, for the purpose of *relay* of the galvanic force, may be dispensed with by simply increasing the number of pairs, and distributing them in groups along the line. Thus Mr. Sears C. Walker, of the Coast Survey, writes, "We have made abundant experiments on the line from Philadelphia to Louisville, a distance in the air of *nine* hundred miles, and in circuit of *eighteen* hundred miles. The performance of this long line was better than that of any of the shorter lines has hitherto been. I learn, from an authentic source, that the same success attends the work from Philadelphia to St. Louis, *a distance in circuit of one-twelfth of the earth's circumference.* The number of Grove's pint cups used is about one for every twenty miles. It is natural to conclude, from this experiment, that, if a telegraph line round the earth were practicable, *twelve hundred* Grove's pint cups, in equidistant groups of fifties, would suffice for the galvanic power for the whole line. The daily expense of acids, for maintaining this whole line, would be about five mills per day for each cup, or six dollars per day for the whole line." This distribution of the galvanic agency is frequently adopted in the mode of placing one half of the necessary number of pairs at each extremity of the line.

The conductors hitherto spoken of have been exclusively the telegraph wires. It has now, however, become a universal custom to use the earth as one-half of the circuit, and thus to employ but one wire. This is accomplished by carrying a wire down at each extremity of the line, and connecting it with a metallic plate buried in the earth. The advantage consists not only in the economy of employing a single wire to each circuit, but the loss from conduction by using the earth is vastly less. The use of the ground circuit for the telegraph seems to be due to Professor Steinheil, of Munich.

In case of interruption of the telegraph wire, much ingenuity has been shown by the association of a through line and a test line, which latter communicates with a number of intermediate stations, and by means of which the place of interruption can be readily ascertained, and the injury repaired. An interruption is shown by the increased strength, the weakness, or the suspension of the current, which each station has the means of examining, and from which the direction and nature of the accident can be inferred.

A great source of irregularity in the action of the telegraph, in this country, has been atmospheric electricity. The air being in different electrical states in different places, or thunder-storms taking place in the course of the line, the insulated telegraph wires frequently become the medium of transfer of atmospheric electricity. The safety of the operators, and even the regular action of the electro-magnet, requires the use of conductors at the stations, which are nearly in contact with the wires, and which communicate with the earth, so as to carry off any excessive charge of electricity which might destroy the instrument, or even endanger life. Much irregularity in the action of the telegraph still exists from this cause.

These facts of general application to the electric telegraph have been considered here, as many of them were first developed and applied in this country, in connection with Morse's register. This instrument, and the system connected with it, will always deserve credit for its early service in adapting the telegraph to our climate and natural resources.

Lightning Protector. By L. POUGET, Maisonneuve. This is a beautiful and most important discovery as an auxiliary in the perfection and full development of the electric telegraph. It is designed to drain off the atmospheric electricity, which in certain conditions of the atmosphere accumulates in the wire, seriously interrupting the transmission of signals by deranging the magnets, and often even melting and destroying them. The beauty of the invention is in its simplicity: it consists in the discovery that *absolute alcohol*, after having been subjected to proper chemical treatment, becomes a good conductor of the high tension electricity of the atmosphere, while it is a non-conductor of the current generated by the galvanic battery.

The apparatus consists simply of a glass tube, two inches in diameter by five in length, filled with the prepared liquid, and a brass cap hermetically sealed to each end. The telegraph wire is made to pass through the tube, and is surrounded by, and is in direct contact with the liquid. On one side of the tube is introduced a wire connecting with the ground, which terminates in the liquid, but does not come in metallic contact with the former wire. Its operation is as follows:

The accumulations of high tension electricity from the atmosphere pass along the wire until they enter the tube, where they leave the wire, pass through the liquid to the ground wire, and thence to the great reservoir of electricity, in the earth. Thus the line wire is relieved of the disruptive discharges, which otherwise would pass through and interrupt the proper action of the magnets, and the battery current is left free from disturbance, and goes on to its destination, performing its mission with fidelity.

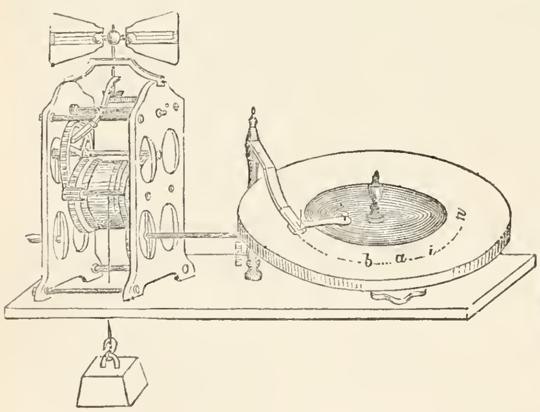
Bain's Telegraph. The telegraph of Bain, represented in fig. [illegible], is constructed on the principle of the decomposition of a saline solution, through which a galvanic current passes, and is the most simple now in use. The indication of the current takes place here without motion. The circular tablet, on which the writing is obtained, is moved by clock-work, at a uniform rate, under the wire, which constitutes the telegraphic pen. But the pen itself never stirs. It bears silently on the tablet, and as the eye observes the point of contact, now a blank space, and now a deep blue line, appears upon the retreating surface. This is the record of the intermitting current, sent over the wires from a distance.

In Fig. 3395 the clock-work which moves the tablet is seen on the left. Its motion is regulated by a fly-wheel above, the vanes of which can be inclined so as to present greater or less resistance to the air. A lever or break bears upon the axle of the fly-wheel, by moving which lever the clock-work may be stopped, or allowed to go on. The circular disk, or tablet of brass, carried by the clock-work, is seen on the right of the figure, inclined towards the observer. In the centre of the disk, occupying the shaded portion, a spiral groove is cut, in which the guide to the pen travels. This guide is seen attached at right angles to the penholder, which extends over the disk. The pen-wire is seen held by a little clamp, descending so as to touch the tablet. This wire, of course, traces a spiral upon the outer ring of the disk's surface, exactly corresponding, in the distance of its lines, to the spiral groove within, which serves as a guide. By this beautiful contrivance, the writing is dispósed in a close spiral, occupying but very little space.

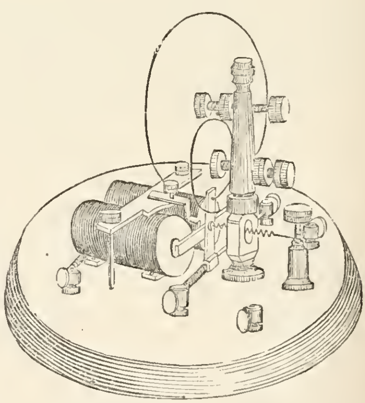
The outer part of the surface of the disk, upon which the letters are represented in the figure, is covered with a ring of moistened and chemically prepared paper. This may be renewed or removed at pleasure. The penholder is connected with the positive wire of the telegraph, and the tablet with the negative. The circuit of conductors is completed by the moistened paper which intervenes, and which the current accordingly traverses. This paper is moistened with a solution of the yellow prussiate of potash, acidulated with nitric or sulphuric acid. The pen-wire consists of iron. When the current passes, this pen-wire is attacked by the solution, and the portion of iron dissolved unites with the prussiate of potash to form the color known as Prussian blue, which permanently stains or dyes the paper.

A modification in the mode of marking has been introduced in this telegraph by Mr. Rogers, of Baltimore. He substitutes a pen carrying an ink which is decomposed by the current when in contact with the brass disk, without any intervening paper. A superficial stain is produced on the metallic surface, which is easily obliterated by friction.

3395.



3396.



In Bain's telegraph, no receiving magnet is necessary. The current traversing the long wires is sufficient to leave its trace upon the paper. There would be a disadvantage, however, in the use of this telegraph, with a simple circuit, where it is desirable to register the same communication at a number of different places, as the interposition of the paper, moistened with a saline solution, somewhat obstructs the current. The receiving magnet and register used by Morse present a metallic conductor for the current throughout, and they can, therefore, be multiplied without serious loss. To compensate this disadvantage, a system of branch circuits at way-stations has been devised, in connection with the Bain telegraph, by which communications can be received at various places at the same time. Morse's instrument requires the time taken by the motion of the armature to make each mark. The decomposition in Bain's instrument is instantaneous. This is an advantage where mechanical means are used to complete and break the circuit with great rapidity for the purpose of rapid communication.

An ingenious instrument to effect this object has been recently contrived. One of the circular metallic disks of the register has its surface coated with wax or other composition. The lines and dots which constitute the writing to be transmitted, are scratched through this so as to expose the metal, by the operator, previous to completing the telegraphic circuit. This writing is effected, and disposed in spirals around the disk, by simply putting a little signal-key in place of the pen-wire, and allowing the disk to revolve. The guide to the penholder, of course, carries the signal-key over the same spiral which the pen-wire would describe on the disk. The signal-key has a sharp or cutting point, which removes the wax from the disk whenever the key is depressed. The usual motion for signalizing the letters, therefore, prepares the impression of the writing, which is afterwards to be connected with the telegraph, and transmitted with speed. This transmission is effected by restoring again the pen-wire to its holder, and allowing it to follow over the track just made by the signal-key. The battery being connected, the wire completes the circuit whenever it touches the exposed metal, and breaks the circuit when it rests upon the wax. The disks at both the transmitting and receiving ends are made finally to revolve rapidly, and the message is said to be thus communicated at the rate of one thousand or more letters per minute.

The alphabet used by Bain is the same in principle as that employed by Dyar, Steinheil, and also by Morse, consisting of combinations of dots and lines.

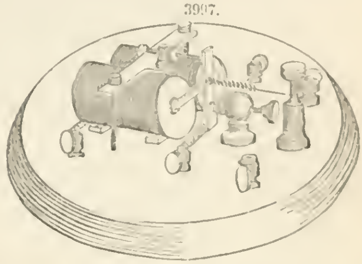
The *call*, commonly used on the Bain lines, is represented in Fig. 3396. It consists of a U-shaped receiving magnet, placed horizontally on the board, with two helices of wire surrounding the legs. An armature, supported on an upright bar, so as to form a cross, is seen in the figure before the poles of the magnet. This is held back by a delicate spiral spring, graduated by a screw, which is also seen to the left. Above are two circular plates of glass. The upright bar, armed with two little knobs, to perform the part of a hammer, rises between these plates. When the armature is drawn to the magnet, it strikes one of them, and on being drawn back it strikes the other. As they are of different tone, the repetition of this signal at once draws attention to the register. The duty of the operator is then to set the clock-work in motion, and receive the message communicated. This instrument can be used also as a receiving magnet, by placing a platinum point on the upright bar or pendulum, and a little platinum disk immediately in front of it, so connected that the interval between the point and disk shall constitute the break in a local circuit, an additional pair of screw-cups for the attachment of which may be seen upon the base-board. When the armature approaches the electro-magnet, it closes the local circuit, and when it recedes it breaks it. This is essentially the receiving instrument of Morse and others.

This call is similar in purpose or principle to those used by Sœmmering in 1811, Schilling in 1831, and Henry, Steinheil and Wheatstone in 1836 and 1837.

Bain's telegraph has been introduced very extensively into this country, especially in connection with the network of lines constructed throughout the South and West by the enterprise of O'Reilly.

The receiving magnet in its improved form, Fig. 3397, used for the purpose of combining or connecting circuits, is closely allied in its construction to the call, and may therefore be described here, though already referred to in connection with Morse's telegraph. The armature is mounted on an upright bar, and is seen forming part of the cross just in front of the poles of the horizontal electro-magnet, surrounded with helices of fine wire. The long or telegraphic circuit is connected with these helices by means of two of the screw-cups on the board. When the current flows, the armature is attracted to the magnet, and the upright bar is brought in contact with the end of the horizontal screw, seen at the top of the instrument. This completes a local circuit, or branch circuit from the main battery, the conductors of which are connected with the instrument by means of two other screw-cups, seen on the left of the board. The points of contact of the upright bar and screw are protected from oxidation by the use of platinum.

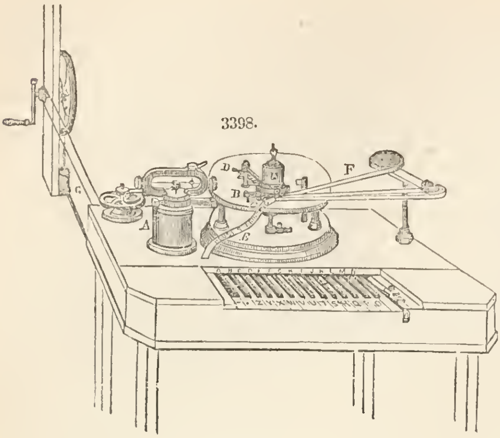
3397.



TELEGRAPHIC COMPOSITOR. The experience of Bain and others, in transmitting signals by electricity, has demonstrated that the amount of time requisite to send a message to a distant place, is not dependent upon the speed with which the electricity travels, but upon the time in which the human hand can perform the proper manipulations. This, in actual practice, as experience with the various methods in use has proved, has never reached an average of more than eighty letters per minute. In the mean time the researches in electricity have shown, that when the wave or pulsation is given to the current by the finger, it flies to its destination with the swiftness of thought, though its path may be thousands of miles in length, and leading over precipitous mountains and through barren deserts.

The telegraphic compositor was invented by J. P. Humaston, of New Haven, Connecticut, and was patented September 8, 1857. Its object is to increase the rapidity of manipulation so that it shall bear some fair proportion to the capacity of electricity to record the signals. This is effected by an instrument termed a *compositor*, which cuts the dots and lines of the telegraphic letters in a strip of paper of about three-eighths of an inch in width. The message thus prepared is passed through the transmitting instrument, which may be run at any speed requisite to keep pace with the record of the signals. This speed with the magnetic instruments, is not more than about three hundred letters per minute; this is owing to the fact that they require machinery whose moving parts have weight and inertia. With the electro-chemical mode, Mr. Bain, in 1846, transmitted as many as one thousand letters per minute between London and Manchester, England; this was done by preparing the message strip by hand, and then passing it rapidly between the poles of contact in the electro-chemical instrument.

The compositor consists of a key-board and twelve small steel cutters, which lie side by side; the keys are connected with the cutters in such a manner, that when any key is depressed, the cutters are carried forward, and through the paper in the proper combination to form the letter which it represents. This is done as rapidly as the touch can be made, and a single touch forms the letter with mathematical certainty and accuracy. The compositor is to the telegraph wire what the font of type is to the printing press, and any number of compositors may be used to prepare the messages which the capacity of the wire will enable it to transmit. Thus far, its use has proved that one well insulated wire will transmit, per day of 12 hours, 10,800 messages of ten words each. To do this with any system depending upon the manipulation or touch of the finger direct, would require the use of at least ten wires and twenty instruments. With the rapid extension and future development of the telegraph, this improvement furnishes the means of reducing the tariff for telegraphing to a point low enough to bring it within the means of every human being possessing sufficient intelligence to commit his thoughts to writing. It may be used as an auxiliary to the magnetic telegraph, and is readily adapted to any system of telegraphic alphabet. Its usefulness however is greatly enhanced in connection with the electro-chemical instrument, which records its signs by the simple pulsations of the electric current.



3398.

House's Printing Telegraph. This beautiful invention may be considered as one of the wonders of the age. Using but a single wire, it is yet able to select and print in order the letters of the common alphabet, with a greater rapidity than the hieroglyphic marks of Professor Morse, representing the same letters can be produced.

This instrument is complicated, though all its parts are simple. We shall try to describe it so that the mode of its operation may be understood. A perspective view of the instrument is shown in Fig. 3398, comprising both the transmitting and receiving apparatus. The principle by which the different letters are signalized over the wire, is the transmission of a given number of electrical impulses for each letter, by the rapid opening and closing of the circuit. This is accomplished by means of the twenty-six letter-keys, and the two keys for the dot and dash, seen in the figure. Under the key-board is a horizontal cylinder, which is kept in revolution by turning the crank and wheel, seen at the left of the figure. At one end of this cylinder is a circuit-wheel or break-piece, having fourteen projections and fourteen spaces, on which a spring, connected with the telegraphic circuit, bears. Consequently the battery circuit is completed fourteen times and broken fourteen times with each revolution of the cylinder. Under each key a projection or stop is placed upon the cylinder, in such a position that when the key is depressed and comes in contact with it, the cylinder shall have performed such part of a revolution as to have made and broken the circuit the number of times which represents the letter corresponding to the key. The motion of the cylinder is communicated by means of slight friction, and it is accordingly arrested by depressing the key. This is the transmitting or "composing" apparatus.

The receiving or printing apparatus is seen behind the key-board in the figure. There is one such at each extremity of the line, to receive messages transmitted from the other extremity. But both are left constantly in the circuit, so that the operator signalizes or prints the message which he sends both at the distant end of the line and immediately before his eyes. The printing instrument which we are examining is, therefore, a fac-simile of the one which receives the communication at a distance from the operator at the key-board in the figure.

The printing apparatus consists of an upright rod-electro-magnet, inclosed in the metallic cylinder A of a little engine, operated by condensed air, and moving an escapement at B; of a type-wheel at C of a printing eccentric and lever, the end of which is seen at D; of a black coloring-band at E, and the strip of printing paper at F F.

The electro-magnet consists of a compound rod of several short pieces of iron strung upon a rod of brass. This rod is inclosed in a tube of brass, attached to which, within, are several short tubes of iron, corresponding to and reacting with the pieces belonging to the axial magnet. This whole system of tubular and axial magnets is inclosed in a single helix of fine wire, connected with the telegraphic circuit. The tube is fixed, but the compound rod is movable, and attracted downwards by several co-operating reactions when the current passes. This rod is suspended by a cross-wire, which may be seen stretched across the top of the cylinder A, and acts as a spring, drawing the rod back after the current has ceased to act. A very rapid vibration of the rod is thus obtained, corresponding to the opening and closing of the circuit effected at the transmitting end of the line.

Connected with the wheel is a condensing pump at G, which keeps up a supply of condensed air. At the upper part of the electro-magnetic rod is a collar-valve, which changes the direction of the current of condensed air with each vibration of the rod, though these vibrations are only 1-64th of an inch. The air is thus admitted to opposite sides of the cylinder of a little atmospheric engine, which, by means of its reciprocating motion, permits the action of an escapement, tooth by tooth, and the corresponding revolution of the type-wheel, which is impelled by a spring kept wound up by the manual power employed at the crank and wheel.

The result is that the type-wheel, which has twenty-eight teeth, revolves just as far as the cylinder attached to the circuit-wheel, at the distant extremity of the line, has been permitted to revolve by depressing one of the keys. Each break, as well as each completion of the circuit, thus corresponds to a letter. It only requires that the instruments at both ends of the line should be set to the same letter, and then the cylinder at one extremity and the type-wheel at the other, regulated by the pulsations of the current, will always revolve at the same rate; and if the cylinder is stopped at any one point representing a letter, the type-wheel is stopped at the same point, and presents the type which it carries on its periphery to the strip of paper in front of it.

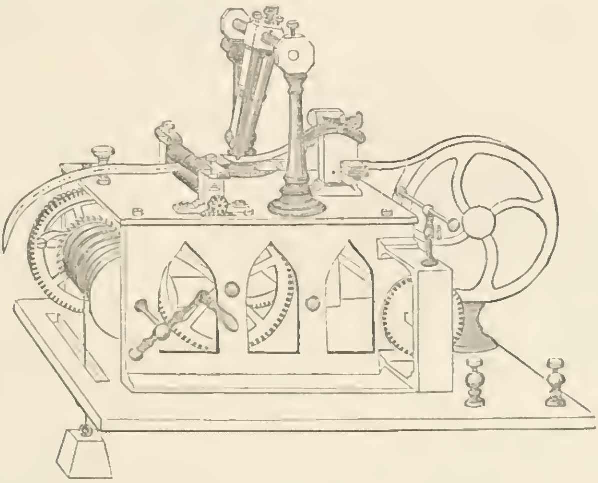
When the type-wheel stops, an eccentric, actuated also by the local power at the crank and wheel, brings the black band and paper forcibly against the type, and leaves the impression of the letter. The paper is then carried on just the distance of a letter, and is ready for another impression. Roman letters are thus printed over a long line at the rate of from one hundred and fifty to more than two hundred a minute.

In the figure the letter A will be observed at a little window above the type-wheel. This letter is on a letter-wheel, connected with the type-wheel below, so that the letters may be presented to the sight at the same time as printed; or the printing eccentric may be detached, and only the visible letters read.

The action of the electricity in this telegraph is merely to produce correspondence of motion in machinery at different ends of the line, in the same manner that uniformity of rate has been secured in clocks at different places, regulated by the electro-telegraphic current. All the mechanical results of House's telegraph are produced by local mechanical power. For this purpose, clock-work, having a regular rate, would be preferable to manual power.

Horn's igniting telegraph.—The register invented by G. H. Horn employs a principle never before applied to the telegraph, namely, the heating or igniting effect of electricity. When an electrical current flows through a fine platinum wire it ignites it, or brings it to a red heat. If this wire is bent, as at A, in the figure below, so as to be in contact, for a short distance, with a moving fillet of paper, it will burn a hole through the paper when the current passes. This can be done with great rapidity, so as to represent probably a hundred linear letters per minute.

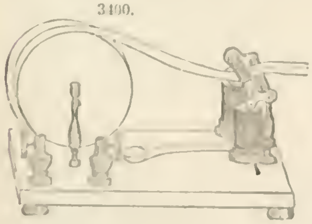
3399.



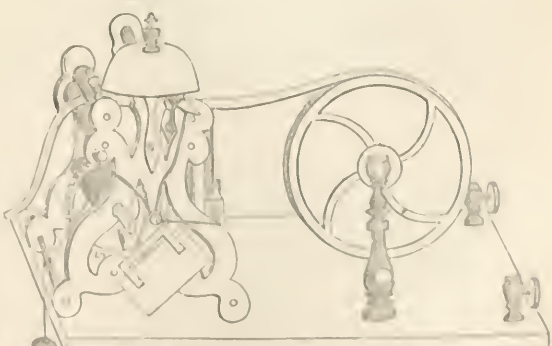
This instrument is shown in Fig. 3399, the greater part of which consists of the clock-work, spool, &c., required for moving the paper. Above the clock-work are two pillars, supporting an axis, upon which is the adjustable wire-holder, the lower extremity of which is seen touching the fillet of paper. By means of the connections and insulations of the pillars, axis, and wire-holder, the platinum wire, which passes over a little slip of porcelain at the end of the wire-holder, becomes part of the circuit, with which the two screw-cups on the right of the base-board are connected. When the wire needs adjustment, the wire-holder can be turned up on its axis. The bed supporting the fillet of paper is also adjustable, so as to regulate the contact between the wire and the paper.

This register requires a quantity current to produce the effect of ignition, and therefore needs a receiving instrument and local battery, to be operated by the telegraphic circuit.

3400.



3401.



Axial Telegraph. The axial telegraph is founded on the tendency of a bar of iron to be drawn into a coil of wire, through which a galvanic current is made to pass. This influence is increased where two coils of wire are used, surrounding the legs of a U-shaped piece of soft iron. the power of this reaction is so great, that it has been successfully applied by Prof. Charles G. Page, of Washington, to the propulsion of machinery on a large scale.

The axial telegraph is represented in a simple form in Fig. 3400. The U-shaped iron rests upon a spring, seen on the board. A style attached to the iron, projects up between the coils so as to be nearly in contact with the roller, under which the strip of paper is made to pass. A little rod or armature of iron, placed across the top of the coils, causes the soft iron to move in obedience also to electro-magnetic attraction, somewhat increasing the power, but introducing a new and unnecessary principle into the reaction. The axial telegraph in its complete form. is represented in Fig. 3401, where the spool and clock-work for the movement of the paper are added.

The axial motion is due to the *deflective* power of a coil, as in the telegraphs of Amphere, Steinheil, and Wheatstone, and not to electro-magnetic attraction. This instrument requires, on a long line, the intervention of a receiving instrument and short circuit.

Telegraph, Hughes. The Hughes instrument consists of a train of clock work, keys for closing the circuit, an electro-magnet, and a vibrating spring to govern the type wheel, which revolves by aid of the train of wheels. The clock work consists of four cog wheels, turned by a weight, which turns a shaft with a wheel, upon which are engraved the letters of the alphabet. This wheel is inked by a small roller. Below the type wheel a small press moves the paper to be printed upon against the letters. This press moves only when the armature of the magnet acts by a current of electricity being sent along the line.

The magnet of the Hughes instrument is a peculiarly simple and effective arrangement, by which electricity is made to work at its highest development. Electricity only holds the armature whilst in contact. As soon as it is set free by the distant operator closing the circuit, it falls against a detent which brings a small cam in play, and restores the armature to its resting place in contact with the electro-magnet. This operation is performed every letter that is printed, the magnet never acting until a letter is sent, and then only once to each letter.

The principle of making all the instruments keep exact time with one another, so that they always present a certain letter opposite the press at the same instant, and also to revolve rapidly, has been accomplished by the union of a well known law in acoustics to mechanics: thus a certain number of vibrations per second produces a certain musical tone; if these two instruments have each a vibrating spring of the same tone, the two instruments must always revolve in exact time with each other.

These type wheels, revolving by means of clock work, carry around with them a circuit closer, which travels over twenty-eight pins corresponding to the letters upon type wheels; if any of these pins are touched by corresponding keys, the circuit is closed at the moment the closer passes that point. The armature immediately falls off, opens the detent which locks the press to the wheel work; this moves up the press, and when the letter is printed unlocks itself until again locked by the action of the armature.

The fact of the possibility of writing both ways simultaneously on one wire has been fully demonstrated. This is accomplished by the arrangement of the battery, so that it does not affect the magnet at the office sending, but the instant that a distant office puts on battery the magnet acts; thus each magnet acts only from the distant battery, and is not affected by its own writing, whilst it receives perfectly what is sent to it. Another great feature in this machine is the freedom of disturbance from atmospheric causes. This is caused by the line being always open except at the instant of the letter being sent; then if in same direction, can only assist the current from the battery.

Another new feature is its power of cutting off all offices except those to which it is desired to communicate. This is accomplished by a flange on the type wheel—this flange having a space cut out opposite a certain letter—each office having the flange cut out at different letters from each other. A bolt is made to slide through this space, and moved through by the action of the instrument. If this bolt is sent through at the moment the space is opposite, it permits the instrument to run; if not, it goes against the flange and locks the wheel.

The success of telegraphs for overland communications soon turned the attention to its practicability as a submarine conductor. As early as in August 1843, Prof. S. F. B. Morse, in a letter to the Secretary of the Treasury of the United States, speaking of an experiment which he made the previous year, of passing an electric current through a submerged conductor, says: the inference from this law is that a telegraphic communication may with certainty be established across the Atlantic. In the autumn of 1842, he submerged an insulated wire from the Battery to Governor's Island, and had just begun to operate, having received but two or three characters, when the wire was raised and broken by being drawn up with the anchor of a vessel. He also succeeded in transmitting a current across a stream or canal, by means of parallel lines along the banks.

In the fall of 1850, a wire of about the size of an ordinary knitting needle encased in a coating of gutta percha, was laid from Calais to Dover; communications were transmitted for a time through this wire, but soon a portion became broken, and another cable was laid composed of four copper wires, each insulated with gutta percha, and afterwards bound together with hemp steeped in a solution of tar and tallow.

In May, 1852, Holyhead and Howth, a distance of 65 miles across the Irish Channel, were connected by a single wire encased in gutta percha. Scotland and Ireland were connected by a cable of thirty miles long consisting of six wires.

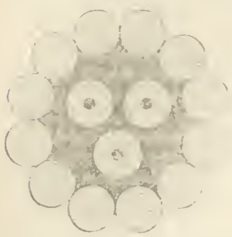
The following June a cable was laid from Orfordness, in England, to the Hague in Holland, a distance of 115 miles. This task was accomplished in thirty-four hours, and only 4½ miles of cable were required in the paying out over the actual length from point to point, making hardly 120 miles altogether Another cable connects Dover with Ostend, making the third between England and the continent.

In the summer of 1854 a telegraphic union was effected between Corsica and Sardinia. This work was attended with much difficulty in consequence of the breaking of a part of the wire. The submerging of a cable between Corsica and the island of Sardinia was successfully accomplished shortly after·

but the attempt which was subsequently made to connect the island of Sardinia and Algeria, and thus establish immediate communication between the continents of Europe and Africa, was unsuccessful, and has not since been attempted.

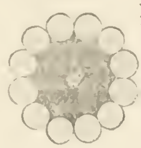
The New York, Newfoundland and London Telegraph Company made an attempt in August of 1855, to unite the islands of Newfoundland and Cape Breton, but the vessels employed in the work were caught in a gale, the cable was obliged to be cut, and the undertaking abandoned for that time. The cable, as may be seen from the accompanying engravings, which show the exact size, had three conductors, and was protected in the same manner, by iron wire, as those already described.

3402.



In 1856 the company succeeded in making the desired connection between the opposite shores of Newfoundland and Cape Breton. This time they rejected the three wire cable and procured a much lighter one, with a single wire, consisting of seven strands. The object of this arrangement, instead of a single wire of the same thickness, is to provide against the possibility of any break of continuity taking place in the metal. This strand will stretch twenty per cent. of its own length, and is covered with three layers of the purest gutta percha, separately applied. The cable weighs somewhat less than a ton to the mile, and is one of the lightest and strongest of its thickness yet manufactured.

3403.



A few weeks after the allied army entered the Crimea a single wire cable was laid across the Black Sea, a distance of 374 miles, between Varna and Balaklava, and it was through this that the English and French governments were apprised every day of the movements of the belligerent forces on either side. This is the longest submarine cable which has yet been laid.

In the fall of 1857, an attempt was made to lay a cable between Valentia Bay, Ireland, and St. Johns, Newfoundland, a distance of 1650 miles. The attempt was unsuccessful, the cable having parted after some 300 and odd miles had been laid. It will be again undertaken this year, and it is to be hoped with better success.

From the following engravings it will be seen that the transatlantic submarine cable is somewhat differently made from any previously manufactured. The core, or conductor, is composed like that of the

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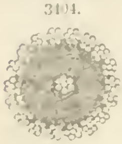
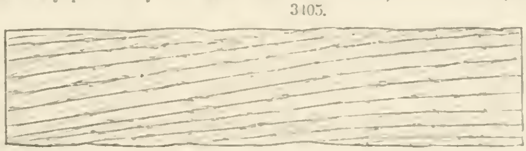


3405.



gulf cable, of seven copper wires wound together in the same manner. The cable will be 2,500 miles in length, the surplus over the actual distance to be traversed being considered necessary in case of emergency to make up for the inequalities in the bed of the ocean, and the variations that may be caused by the winds and the currents. The protecting wires are made into strands, each composed of seven of the best charcoal iron wires. The aggregate length of the smaller wires required in the manufacture of one mile of the cable is one hundred and twenty-six miles, and the whole cable will require three hundred and fifteen thousand miles of this wire.

The flexibility of this cable is so great that it can be made as manageable as a small rope, and it is capable of being tied around the arm without injury. Its weight is but 1,800 pounds to the mile, and its strength such that it will bear in water over six miles of its own length if suspended vertically.

Table of Submarine Cables already laid down.

	Miles.		Miles.
From Dover to Calais,	21	Between Corsica and the Island of Sardinia,	6
From Howth to Holyhead,	65	Across the Gulf of St. Lawrence, from Cape Breton to Newfoundland,	74
Between Ireland and Scotland,	20	Across the straits of Northumberland, between Cape Tormentine and Prince Edward's Island,	10½
From England to Holland,	115		
From Dover to Ostend,	60		
From Balaklava to Varna, Black Sea,	374		
Between Sardinia on the main land, and Corsica,	60		
Total miles now laid,			805½

The application of the telegraph to comparative astronomical observations is a splendid result of the operations of the American Coast Survey. The transit of a star over the meridian of two places, connected by telegraph, was notified from one to the other by a touch of the signal-key, and the time at each was observed. The longitude could be thus obtained, with some precautions, with an ease and accuracy not before possible. A second step was then taken, by connecting the chronometer, which was the standard of time, directly with the telegraph. Thus the seconds wheel was made, by Dr. Locke, to raise a little platinum hammer, by which the circuit of the telegraph was broken once a second. By another invention, the pendulum swept through a little globule of mercury when at its centre of oscillation, thus completing the circuit once a second. The fillet of paper of the telegraph, as it unwound from its spool, at the extreme, and also at the intermediate stations of the line, was thus graduated accurately into seconds, represented by a line with a short break, or a break with a short line. A signal key was also included in the circuit, by which the observer could complete or break the circuit momentarily so as to mark upon the same fillet the transit of the star over the wire of the telescope. A permanent and incomparably accurate record was thus made of the observation, and the instant of its time. It is estimated that the facilities of astronomical observation are increased sixty-fold by this invention. In fact, it constitutes an era in modern astronomy. Though the work of the last one or two years, it has already received the tribute of the most distinguished foreign observers.

TELESCOPE. An optical instrument for viewing distant objects.

For several reasons a distant object is seen less distinctly than a similar near one. The angle which an object subtends diminishes as the distance increases; the density of the light which renders it visible also diminishes with the distance, but in a much faster ratio; and a considerable portion of light is always lost in its passage through the atmosphere.

It is found by experience that to be discernible at all in ordinary daylight, a detached object must subtend at the eye an angle of not less that 30″, and that the least angle under which contiguous objects can be satisfactorily distinguished is about one minute. By the aid of a telescope a magnified image of the object is obtained; and within certain limits the object is not only apparently enlarged, but rendered brighter than it appears to the unassisted eye.

The invention of the telescope, to which practical astronomy is indebted for its most important discoveries, has been ascribed to various persons. Sir David Brewster (*Encyc. Brit.*, art. "Optics") says "We have no doubt that this invaluable instrument was invented by Roger Bacon or Baptista Porta, in the form of an experiment; though it had not, perhaps, in their hands assumed the maturity of an instrument made for sale, and applied to useful purposes, both terrestrial and celestial. If a telescope is an instrument by means of which things at a distance can be seen better than by the naked eye, then Baptista Porta's concave lens was a real telescope; but if we give the name to a tube having a convex object-glass at one end, and a convex or concave lens at the other, placed at the distance of the sum or difference of their focal lengths, then we have no distinct evidence that such an instrument was used before the beginning of the 17th century." Descartes ascribes the invention to James Metius, a citizen of Alkmaer in Holland; Huygens to John Lippersey, or Zacharias Jansen; Borellus also to Jansen. Professor Moll, who has discussed these rival claims, after examining the official papers preserved in the archives at the Hague, comes to the conclusion that Metius (whose proper name was Jacob Adriaansy,) on the 17th of October, 1608, was in possession of the art of making telescopes, but that from some unexplained reason he concealed his invention, and thus gave up every claim to the honor he would have derived from it; that on the 21st of October in the same year, 1608, John or Hans Lippersey, a spectacle-maker of Middleburg, was actually in possession of the invention; and that there is little reason to believe that either Hans or Zacharias Zanz (or Jansen, father and son) were inventors of the telescope, though one of them invented a compound microscope about 1590. (*Journal of the Royal Institution*, vol. i.)

The telescope soon made its way into other countries. In April or May, 1609, the illustrious Galileo, having heard a rumor of the invention, set about considering the means whereby distant objects could be seen distinctly, and was soon in possession of a telescope which magnified three times. In subsequent trials he succeeded in increasing the magnifying power; and before the beginning of 1610 he had observed the satellites of Jupiter. In England, Harriot also, in 1609, began to use the telescope for examining the disk of the moon, and before he had heard of the discoveries of Galileo. (*Priestley's History of Discoveries relating to Vision, Light, and Colors.*)

Telescopes are of two kinds, *refracting* and *reflecting* telescopes: the former depending on the use of properly figured lenses, through which the rays of light pass; and the latter on the use of specula, or polished metallic mirrors, which reflect the rays; an inverted image of the object being formed in both cases in the focus of the lens or mirror.

Refracting telescopes were those which were first constructed. They were of the most simple character, consisting merely of an object-glass of one lens, and an eye-glass of one lens, but of a shorter focus. But in this construction the prismatic colors produced by the difference of the refrangibility of the luminous rays tinged the images of all objects seen through the telescope, and the image was likewise distorted by the aberration of the extreme rays. It was soon found that the latter defect could be sufficiently corrected by employing more lenses than one in the eye-piece; but it was long before a remedy was found for the chromatic dispersion; and artists, despairing of success, generally turned their attention to the improvement of instruments of the reflecting class. The difficulty, however, was at length overcome through the persevering efforts of John Dolland, (see Achromatism;) and the *achromatic refracting telescope* may now be regarded as an instrument all but perfect.

The general aim in the construction of a telescope is to form, by means of lenses or mirrors, as large, bright, and distinct an image of a distant object as possible, and then to view the image with a magnifying glass in any convenient manner. We shall first describe those of the refracting glass.

Galilean telescope.—This is the most ancient form of the telescope, and is that which was used by Galileo. It consists of a converging object-glass A B, Fig. 3402, and a concave diverging eye-glass C D On passing through the object-glass A B the rays of light coming from the different points of a distant object in parallel pencils are rendered convergent, and proceed towards the principal focus, where they would form an inverted image; but before they arrive at this point they fall upon the concave lens C D, by which they are again rendered parallel, or at least their convergence is corrected so as to give distinct vision of the object to the eye at E. The lens C D is therefore placed between the object-glass and the image, and at a distance from the image equal to its principal focal distance. The magnifying power is equal to the principal focal distance of the object-glass. See Lens.

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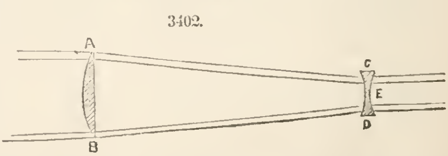
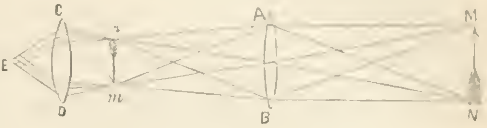


In this telescope the object is seen erect, and the length of the tube is only the difference between the focal lengths of the two lenses. These properties render it preferable to any other telescope for many ordinary purposes; as, for example, an *opera-glass.* When used for this purpose the magnifying power is hardly ever greater than 4; and it is often as low as 2.

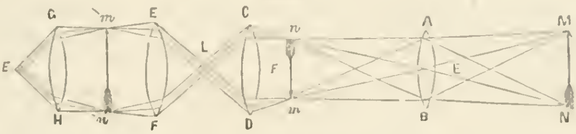
Astronomical telescope.—This is composed of a converging object glass A B, Fig. 3103, and of a converging eye-glass C D. Rays of light proceeding from any point M of a distant object M N, and falling on the different points of the object-glass, are refracted into a point *m* in the principal focus. In like manner, those proceeding from the point N are refracted into the point *n*; and thus an inverted image *m n* is formed at the focus of the object-glass. The eye-glass is placed so that its focus shall coincide with the place of the image; consequently rays diverging from any point of the image, and falling on the lens C D, are refracted into a parallel direction before they enter the eye at E, and are thereby rendered fit to produce distinct vision. The length of the telescope is equal to the sum of the focal distances of the two lenses; and the magnifying power is equal to the focal distance of the object-glass divided by the focal distance of the eye-glass. This telescope was first described by Kepler in his *Dioptrice,* 1611; but it does not appear to have been executed until about twenty or thirty years later.

3103.



Terrestrial telescope.—This differs from the astronomical telescope only in having two additional lenses E F, G H, Fig. 3104, placed in the tube of the eye-glass for the purpose of restoring the inverted image to its erect position, and thereby accommodating the telescope to terrestrial objects. The focal lengths of these additional lenses are usually the same as that of the eye-glass. The two pencils of rays proceeding from the points M and N cross each other in the anterior focus of the second lens E F, and falling parallel on E F form in its principal focus an inverted image of *m n*, and consequently an erect image of the object M N. This image *m' n'* is seen by the eye at E through the lens G H, as the rays diverging from *m'* and *n'* in the focus of G H enter the eye in parallel pencils. When the three first lenses are equal, the magnifying power is the same as that of the astronomical telescope, whose object and eye glasses are the same as A B and C D.

3104.

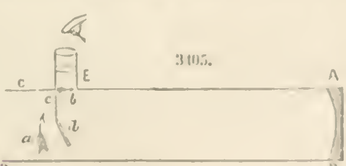


The performance of refracting telescopes depends most essentially on the goodness of the object-glass, for if the first image is bright and distinct, and perfectly achromatic, there is little difficulty in constructing eye-pieces to magnify it, without causing it to undergo any sensible alteration.

Reflecting telescopes.—In reflecting telescopes the speculum, or mirror, performs the same office that the object-glass does in those of the refracting kind, and is therefore called the *object-mirror.* The instrument is constructed in various forms; but these differ from one another chiefly in reference to the contrivances which have been adopted for bringing the focal image into a convenient situation for being viewed by the eye-piece. The principal forms are the Newtonian, the Gregorian, the Cassegrainian, and the Herschelian.

Newtonian telescope.—Let A B C D, Fig. 3105, represent a section of the tube of the telescope; A B the object mirror, which would form at its focus the image *a* of any distant object. Now if a person attempted to view the image in its place at *a* by placing himself directly before the mirror, he would necessarily intercept the rays of light from the object passing down the tube to the mirror, and consequently there would be no image to view. Sir Isaac Newton overcame this difficulty by introducing a small diagonal plane speculum *d* between A B and *a*, which intercepting itself but a small portion of

3105.



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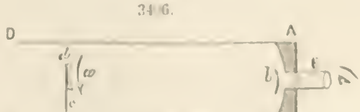


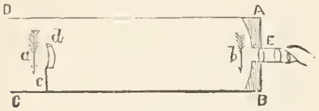
light, reflects towards the side of the tube the rays converging from A B, and causes the image which would have been formed at *a* to be formed at *b*, where it can be conveniently viewed by the eye-piece E attached to the side of the tube. The small mirror is of an oval form, and is fixed on a slender arm *c* connected with a slide, by means of which it may be made to approach or recede from the large speculum A B, according as the image approaches to or recedes from it. In this telescope the magnifying power is equal to the focal length of the object mirror A B divided by that of the eye-glass.

Gregorian telescope.—In this construction the object-mirror A B, Fig. 3406, is perforated in the middle, and the rays of light from a distant object being reflected from the surface of A B cross each other in the focus, where they form an inverted image *a*, and are then intercepted by a small concave mirror *d*, which causes them again to converge to a focus at *b*, near the perforation of the object-mirror, where they form a reinverted or direct image, which is viewed by an eye-piece E screwed into the tube behind A B. The curvature of the small speculum should be elliptical, having the foci at *a* and *b*; but it is generally made spherical. In this case the great speculum should be slightly hyperbolic, to counteract the aberration of the small mirror.

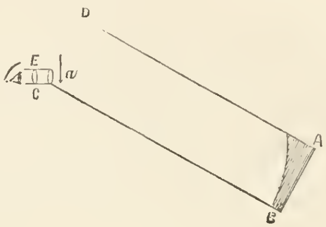
Cassegrainian telescope.—The great speculum of this instrument is perforated like the Gregorian; but the rays converging from the surface of the mirror A B, Fig. 3407, towards the focus *a*, are intercepted before they reach that point by a small convex mirror *d*, not sufficiently convex to make the rays divergent, but of such a curvature as to prevent them from coming to a focus till they are thrown back to *b*, near the aperture in A B, where they form an inverted image which is viewed by the eye-piece E. This construction has the advantage of requiring a shorter tube than the Gregorian; but the inversion of the image is not corrected, and for this reason probably it has not been much used.

In the two last constructions the small mirror *d* is adjusted by means of a rod turning on a shoulder near the eye end of the tube, and connected by a screw with the apparatus which carries the arm *c*, to which the mirror is attached.

3407.



3408.



Herschelian telescope.—This construction differs from the others in having no second mirror. The large speculum A B, Fig. 3408, is placed at the bottom of the tube in an inclined position, so as to bring the focal image *a* near the edge of the tube, where it is viewed directly by the eye-piece F without interfering with the light entering the telescope from the object observed. The magnifying power is the same as in the Newtonian.

The reflecting telescope was invented by James Gregory, and is described by him in his *Optica Promota*, 1663; but the first telescope of the kind was executed by Newton. Reflecting telescopes have been made on a very large scale. The celebrated instrument of Sir William Herschel, erected at Slough in 1789, was 40 feet in length. Its great speculum had a diameter of 49½ inches; its thickness was about 3½ inches, and its weight when cast was 2118 lbs. Its focal length was 40 feet, and it admitted of a power of 6450 being applied to it. The essential advantage of large telescopes of this kind consists in the immense quantity of light which they collect, whereby the observer is enabled to perceive faint nebulæ and stars which are altogether invisible in ordinary instruments.

Reflecting telescopes are used only for observing *phenomena*, and are not like refracting telescopes, attached to circular instruments for the purpose of measuring angles with greater precision. In order to derive full benefit from them they must be used in the open air; and must either be mounted equatorially, (see EQUATORIAL;) or else in such a manner as to be capable of a smooth motion both in a vertical and horizontal direction. Telescopes of this kind being generally used with a high magnifying power, and consequently having a small field of view, are always accompanied with a smaller telescope or *finder* fixed to the tube, so that the axes of the two instruments are exactly parallel.

Eye-pieces of telescopes.—When the image formed by the object-glass or mirror is viewed with a single lens or eye-glass, whether concave or convex, it is only in the centre of the field that distinct vision is obtained, all towards the margin being hazy and distorted. To remedy this defect, Boscovich and Huygens separately proposed the construction of an eye-piece formed of two lenses, placed at a distance from each other equal to half their focal distances. Boscovich recommended two similar lenses; Huygens, that the focal length of the one should be twice that of the other; and as this construction is found to answer best in practice, it is that which is most commonly used.

The two lenses are usually plano-convex, with the convex faces towards the object-glass; the larger lens, called the field glass, is innermost, or nearest the object-glass; and a diaphragm cutting off the marginal rays is usually placed between them near the focus of the eye-lens, where the image is formed. This eye-piece is usually called the *negative* eye-piece, from its having the image seen by the eye behind the field glass; and is that which is commonly supplied with telescopes intended only for the purpose of *seeing* objects without reference to measurement.

Another modification of the two-lens eye-piece was proposed by Ramsden, and is called the *positive* eye-piece, because the image observed is before both lenses. The lenses are plano-convex, and nearly of the same focal length; but their distance from each other is less than the focal distance of the lens nearest the eye, two lenses thus placed acting as a compound simple lens. This eye-piece is the most convenient when micrometer wires are placed in the focus, because it can be taken out without injuring the wires; and it has also this advantage, that the measure of an object given by one eye-piece is not altered when it is changed for another of a different magnifying power.

In both the eye-pieces now described, the image is seen inverted; and though this is of no importance in astronomical observations, it is inconvenient when the telescope is used for looking at terrestrial objects. By placing an additional pair of lenses in the tube of the eye-piece, the image is repeated and reinverted, and, consequently, seen erect. By this means, as explained above, the terrestrial telescope is obtained.

The name of *diagonal eye-piece* has been given to eye-pieces furnished with a diagonal reflecting mirror, the object of which is to give a more convenient direction to the rays emerging from the eye-piece when the telescope is pointed high.

Telescopes are generally supplied with eye-pieces of different powers, which are all fitted to enter the same tube; and the focal adjustment is commonly effected by a rack and pinion motion acting on the tube which carries the eye-piece.

TEMPERING, HARDENING, AND SOFTENING METALS *used in the mechanical and useful arts.*—When the malleable metals are hammered, or rolled, they generally increase in hardness, in elasticity, and in density or specific gravity, which effects are produced simply from the closer approximation of their particles; and in this respect steel may be perhaps considered to excel, as the process called hammer-hardening, which simply means hammering without heat, is frequently employed as the sole means of hardening some kinds of steel springs, and for which it answers remarkably well.

After a certain degree of compression, the malleable metals assume their closest and most condensed states; and it then becomes necessary to discontinue the compression or elongation, as it would cause the disunion or cracking of the sheet or wire, or else the metal must be softened by the process of annealing.

The metals, lead, tin, and zinc, are by some considered to be perceptibly softened by immersion in boiling water; but such of the metals as will bear it are generally heated to redness, the cohesion of the mass is for the time reduced, and the metal becomes as soft as at first, and the working and annealing may be thus alternately pursued, until the sheet metal, or the wire, reaches its limit of tenuity.

The generality of the metals and alloys suffer no very observable change, whether or not they are suddenly quenched in water from the red-heat. Pure hammered iron, like the rest, appears after annealing to be equally soft, whether suddenly or slowly cooled; some of the impure kinds of malleable iron harden by immersion, but only to an extent that is rather hurtful than useful, and which may be considered as an accidental quality.

Steel however receives by sudden cooling that extreme degree of hardness combined with tenacity, which places it so incalculably beyond every other material for the manufacture of cutting tools; especially as it likewise admits of a regular gradation from extreme hardness to its softest state, when subsequently reheated or *tempered.* Steel therefore assumes a place in the economy of manufactures unapproachable by any other material; consequently we may safely say that without it, it would be impossible to produce nearly all our finished works in metal and other hard substances; for although some of the metallic alloys are remarkable for hardness, and were used for various implements of peaceful industry, and also those of war, before the invention of steel, yet in point of absolute and enduring hardness, and equally so in respect to elasticity and tenacity, they fall exceedingly short of hardened steel.

Hammer-hardening renders the steel more fibrous and less crystalline, and reduces it in bulk; on the other hand, fire-hardening makes steel more crystalline, and frequently of greater bulk; but the elastic nature of hammer-hardened steel will not take so wide nor so efficient a range as that which is fire-hardened.

If we attempt to seek the remarkable difference between pure iron and steel in their chemical analyses, it appears to result from a minute portion of carbon; and cast-iron, which possesses a much larger share, presents, as we should expect, somewhat similar phenomena.

Iron semi-steelified	contains one	150th	of carbon.
Soft cast-steel capable of welding	"	120th	"
Cast-steel for common purposes	"	100th	"
Cast-steel requiring more hardness	"	90th	"
Steel capable of standing a few blows, but quite unfit for drawing	"	50th	"
First approach to a steely granulated fracture	"	30th to 40th	"
White cast-iron	"	25th	"
Mottled cast-iron	"	20th	"
Carbonated cast-iron	"	15th	"
Super-carbonated crude iron	"	12th	"

Moreover, as the hard and soft condition of steel may be reversed backwards and forwards without any rapid chemical change in its substance, it has been pronounced to result from internal arrangement or crystallization, which may be in a degree illustrated and explained by similar changes observed in glass.

A wine glass, or other object recently blown, and plunged whilst red-hot into cold water, cracks in a thousand places, and even cooled in warm air is very brittle, and will scarcely endure the slightest violence or sudden change of temperature; and visitors to the glass-house are often shown that a wine glass or other article of irregular form, breaks in cooling in the open air from its unequal contraction at different parts. But the objects would have become useful, and less disposed to fracture, if they had been allowed to arrange their particles gradually, during their very slow passage through the long annealing oven or *leer* of the glass house, the end at which they enter being at the red-heat, and the opposite extremity almost cold.

To perfect the annealing, it is not unusual with lamp-glasses, tubes for steam-gauges, and similar pieces exposed to sudden transitions of heat and cold, to place them in a vessel of cold water, which is slowly raised to the boiling temperature, kept for some hours at that heat, and then allowed to cool very slowly: the effect thus produced is far from chimerical. For such pieces of flint glass intended for cutting as are found to be insufficiently annealed, the boiling is sometimes preferred to a second passage through the leer: lamp-glasses are also much *less* exposed to fracture when they have been once used, as the heat if not too suddenly applied or checked, completes the annealing.

Steel in like manner when suddenly cooled is disposed to crack in pieces, which is a constant source of anxiety; the danger increases with the thickness in the same way as with glass, and the more especially when the works are unequally thick and thin.

Another ground of analogy between glass and steel, appears to exist in the pieces of unannealed glass used for exhibiting the phenomena, formerly called double refraction, but now polarization of light; an effect distinctly traced to its peculiar crystalline structure.

In glass it is supposed to arise from the cooling of the external crust more rapidly than the internal mass; the outer crust is therefore in a state of tension, or restraint, from an attempt to squeeze the inner mass into a smaller space than it seems to require; and from the hasty arrangement of the unannealed glass, the natural positions of its crystals are in a measure disturbed or dislocated.

It has been shown experimentally, that a rearrangement of the particles of glass occurs in the process of annealing, as of two pieces of the same tube each 40 inches long, the one sent through the leer, contracted one-sixteenth of an inch more than the other, which was cooled as usual in the open air. Tubes for philosophical purposes are not annealed, as their inner surfaces are apt to become soiled with the sulphur of the fuel; they are in consequence very brittle and liable to accident.

In the philosophical toy, the Prince Rupert's drop, this disruption is curiously evident to the sight, as the inner substance is cracked and divided into a multitude of detached parts, held together by the smooth external coat. The unannealed glass, when cautiously heated and slowly cooled, ceases to present the polarizing effect, and the steel similarly treated ceases to be hard, and may we not therefore indulge in the speculation, that in both cases a peculiar crystalline structure is consequent upon the unannealed or hardened state?

In the process of hardening steel, water is by no means essential, as the sole object is to extract its heat rapidly; and the following are examples, commencing with the condition of extreme hardness, and ending with the reverse condition.

A thin heated blade placed between the cold hammer and anvil, or other good conductors of heat, becomes perfectly hard. Thicker pieces of steel, cooled by exposure to the air upon the anvil, become rather hard, but readily admit of being filed. They become softer when placed on the cold cinders, or other bad conductors of heat. Still more soft when placed in hot cinders, or within the fire itself, and cooled by their gradual extinction. When the steel is incased in close boxes with charcoal powder, and it is raised to a red-heat and allowed to cool in the fire or furnace, it assumes its softest state; unless lastly, we proceed to its partial decomposition. This is done by inclosing the steel with iron turnings or filings, the scales from the smith's anvil, lime, or other matters that will abstract the carbon from its surface; by this mode it is superficially decarbonized, or reduced to the condition of pure soft iron, in the manner practised by Mr. Jacob Perkins, in his most ingenious and effective combination of processes, employed for producing, in unlimited numbers, absolutely identical impressions of bank notes and checks, for the prevention of forgery.

A nearly similar variety of conditions might be referred to as existing in cast-iron in its ordinary state, governed by the magnitude, quality, and management of the castings; independently of which, by one particular method, some cast-iron may be rendered externally as hard as the hardest steel: such are called *chilled-iron castings;* and, as the opposite extreme, by a method of annealing combined with partial decomposition, *malleable-iron castings* may be obtained, so that cast-iron nails may be clenched.

Again, the purest iron, and most varieties of cast-iron, may, by another proceeding, be superficially converted into steel, and then hardened, the operation being appropriately named *case-hardening.*

It may perhaps be truly said, that upon no one subject connected with mechanical art does there exist such a contrariety of opinion, not unmixed with prejudice, as upon that of hardening and tempering steel; which makes it often difficult to reconcile the practices followed by different individuals in order to arrive at exactly similar ends. The real difficulty of the subject occurs in part from the mysteriousness of the change; and from the absence of defined measures, by which either the steps of the process itself, or the value of the results when obtained, may be satisfactorily measured; as each is determined almost alone by the unassisted senses of sight and touch, instead of by those physical means by which numerous other matters may be strictly tested and measured, nearly without reference to the judgment of the individual, which in its very nature is less to be relied upon.

The excellence of cutting-tools, for instance, is pronounced upon their relative degrees of endurance, but many accidental circumstances here interfere to vitiate the strict comparison: and in respect to the measure of simple hardness, nearly the only test is the resistance the objects offer to the file, a mode in two ways defective, as the files differ among themselves in hardness; and they only serve to indicate in an imperfect manner to the touch of the individual, a general notion without any distinct measure, so that when the opinion of half a dozen persons may be taken, upon as many pieces of steel differing but slightly in hardness, the want of uniformity in their decisions will show the vague nature of the proof.

Under these circumstances, instead of recommending any particular methods, we have determined to advance a variety of practical examples derived from various sources, which will serve in most cases to confirm, but in some to confute one another; leaving to every individual to follow those examples which may be the most nearly parallel with his own wants. There are, however, some few points upon which it may be said that all are agreed; namely,

The temperature suitable to forging and hardening steel differs in some degree with its quality and its mode of manufacture· the heat that is required diminishes with the increase of carbon:

In every case *the lowest available temperature* should be employed in each process, the hammering should be applied in *the most equal manner throughout*, and for cutting tools it should be continued until they are nearly cold:

Coke or charcoal is much better as a fuel than fresh coal, the sulphur of which is highly injurious:

The scale should be removed from the face of the work to expose it the more uniformly to the effect of the cooling medium:

Hardening a second time without the intervention of hammering is attended with increased risk; and the less frequently steel passes through the fire the better.

In hardening and tempering steel there are three things to be considered; namely, the means of heating the objects to redness, the means of cooling the same, and the means of applying the heat for tempering or letting them down. I will speak of these separately, before giving examples of their application.

The smallest works are heated with the flame of the blowpipe and are occasionally supported upon charcoal. (See SOLDERING.)

For objects that are too large to be heated by the blowpipe, and too small to be conveniently warmed in the naked fire, various protective means are employed. Thus an iron tube or sheet iron box inserted in the midst of the ignited fuel is a safe and cleanly way; it resembles the mufile employed in chemical works. The work is then managed with long forceps made of steel or iron wire, bent in the form of the letter U, and flattened or hollowed at the ends. A crucible or an iron pot about four to six inches deep, filled with lead and heated to redness, is likewise excellent, but more particularly for long and thin tools, such as gravers for artists, and other slight instruments; several of these may be inserted at once, although towards the last they should be moved about to equalize the heat; the weight of the lead makes it desirable to use a bridle or trevet for the support of the crucible. Some workmen place on the fire a pan of charcoal dust, and heat it to redness.

Great numbers of tools, both of medium and large size, are heated in the ordinary forge fire, which should consist of cinders rather than fresh coals: coke and also charcoal are used, but far less generally; recourse is also had to hollow fires; but the bellows should be very sparingly used, except in blowing up the fire before the introduction of the work, *which should be allowed ample time to get hot*, or, as it is called, to "*soak*."

It is a common and excellent practice among some workmen to use coke both in forging and hardening steel goods. They frequently prepare it for themselves, either upon the forge-hearth or in a heap in the open yard.

Which method soever may be resorted to for heating the work, the greatest care should be given to communicate to all the parts requiring to be hardened a *uniform* temperature, and which is only to be arrived at by cautiously moving the work to and fro to expose all parts alike to the fire; the difficulty of accomplishing this of course increases with long objects, for which fires of proportionate length are required.

It is far better to err on the side of deficiency than of excess of heat; the point is rather critical, and not alike in all varieties of steel. Until the quality of the steel is familiarly known, it is a safe precaution to commence rather too low than otherwise, as then the extent of the mischief will be the necessity for a repetition of the process at a higher degree of heat; but the steel if burned or overheated will be covered with scales, and what is far worse, its quality will be permanently injured; a good hammering will, in a degree, restore it; but this in finished works is generally impracticable.

It is argued by some, that by heating pieces of steel to different degrees, before plunging them into the water, the one piece attains full hardness, the next the temper of a tool fit for metal, another of a tool fit for wood, a fourth that of a spring, and so on. That this view is not altogether without foundation, appears in the fact that if the end of a piece of steel be made entirely hard, the transition is not quite immediate from the hard to the soft part; in making points, such as are used in a dividing-engine, it is customary to harden the end of a longer piece of steel than is required, and form the point upon the grindstone, exactly at that part where the temper suits, without the steel being let down at all. In hardening by this method, however, without tempering, the scale of proper hardness is confined within such extremely narrow limits, as to be nearly useless; thus, it frequently happens that in a number of tools heated as nearly alike as the workman could judge, some few will be found too soft for any use, although they were all intended to receive the ordinary hardness, so as to require letting down, as usual with those tools exposed to violent strains or blows, such as screw-taps, cold chisels, and hatchets, although many tools for metal, used with quiet and uniform pressure, are left of the full hardness for greater durability.

With the *excess* of heat, beyond *the lowest that will suffice*, the brittleness rather than the useful hardness of tools is increased; and when *no excess* of heat is employed beyond that *absolutely requisite* for hardening in the usual manner, the steel does not appear to be injured, and the colors on its brightened surface that occur in tempering are an excellent, and in general, sufficiently trustworthy index of the inferior degrees of hardness proper for various uses.

Less than a certain heat fails to produce hardness, and in the opinion of some workmen has quite the opposite effect, and they consequently resort to it as the means of rapid annealing, not, however, by plunging the steel into the water and allowing it to remain until cold, but dipping it quickly, holding it in the steam for a few moments, dipping it again, and so on, reducing it to the cold state in a hasty but intermittent manner.

There is another opinion prevalent among workmen, that steel which is "*piney*," or as if composed of a bundle of hard wires, is rendered uniform in its substance if it is first hardened and then annealed.

. Secondly, the choice of the cooling medium has reference mainly to the relative powers of conducting heat they severally possess: the following have been at different times resorted to with various degrees of success: currents of cold air; immersion in water in various states, in oil or wax, and in freezing mixtures; mercury, and that metallic surfaces have been also used. Mr Perkins recommended, as the result of his experiments, plain water at a temperature of 40° Fahrenheit. On the whole, however, there appears to be an opinion that mercury gives the greatest degree of hardness; then cold salt and water, or water mixed with various "astringent and acidifying matters;" plain water follows; and lastly, oily mixtures.

I find but one person who has commonly used the mercury; many presume upon the good conducting power of the metal, and the nonformation of steam, which causes a separation betwixt the steel and water when the latter is employed as the cooling medium. I have failed to learn the *reason* of the advantage of salt and water, unless the fluid have, as well as a greater density, a superior conducting power. The file-makers medicate the water in other ways, but this is one of the questionable mysteries which is never divulged; although it is supposed that a small quantity of white arsenic is generally added to water saturated with salt. One thing however may be noticed, that articles hardened in salt and water are apt to rust, unless they are laid for a time in lime-water, or some neutralizing agent.

With plain water an opinion very largely exists in favor of that which has been used over and over again even for years, provided it is not greasy: and when the steel is very harsh, the chill is taken off plain water to lessen the risk of cracking it; oily mixtures impart to *thin* articles, such as springs, a sufficient and milder degree of hardness, with less danger of cracking, than from water; and in some cases a medium course is pursued by covering the water with a thick film of oil, which is said to be adopted occasionally with scythes, reaping-hooks, and thin edge-tools.

From experiments upon all these means, we are induced fully to acquiesce in Mr. Perkins' recommendation of plain cold water for general purposes; except in the case of thin elastic works, for which oil, or oily compositions are certainly more proper.

A so-called natural spring is made by a vessel with a true and a false bottom, the latter perforated with small holes; it is filled with water, and a copious supply is admitted beneath the partition; it ascends through the holes, and pursues the same current as the heated portions, which also escape at the top. This was invented by the late Jacob Perkins, and was used by him in hardening the rollers for transferring the impressions to the steel-plates for bank notes.

Sometimes when neighboring parts of works are required to be respectively hard and soft, metal tubes or collars are fitted tight upon the work, to protect the parts to be kept soft from the direct action of the water, at any rate for so long a period as they retain the temperature suitable to hardening.

The process of hardening is generally one of anxiety, as the sudden transition from heat to cold often causes the works to become greatly distorted if not cracked. The last accident is much the most likely to occur with thick massive pieces, which are as it were hardened in layers, as although the external crust or shell may be perfectly hard, there is almost a certainty that towards the centre the parts are gradually less hard; and when broken the inner portions will sometimes admit of being readily filed.

When in the fire the steel becomes altogether expanded, and in the water its outer crust is suddenly arrested, but with a tendency to contract from the loss of heat, which cannot so rapidly occur at the central part; it may be therefore presumed that the inner bulk continues to contract after the outer crust is fixed, and which tends to tear the two asunder, the more especially if there be any defective part in the steel itself. An external flake of greater or less extent not unfrequently shells off in hardening; and it often happens that works remain unbroken for hours after removed from the water, but eventually give way and crack with a loud report, from the rigid unequal tension produced by the violence of the process of hardening.

The contiguity of thick and thin parts is also highly dangerous, as they can neither receive, nor yield up heat, in the same times; the mischief is sometimes lessened by binding pieces of metal around the thin parts with wire, to save them from the action of the cooling medium. Sharp angular notches are also fertile sources of mischief, and, where practicable, they should be rejected in favor of curved lines.

As regards both cracks and distortions, it may perhaps be generally said, that their avoidance depends principally upon *manipulation, or the successful management of every step:* first the original manufacture of the steel, its being forged and wrought, so that it may be equally condensed on all sides with the hammer, otherwise when the cohesion of the mass is lessened from its becoming red-hot, it recovers in part from any unequal state of density in which it may have been placed.

While red-hot, it is also in its weakest condition; it is therefore prone to injury either from incautious handling with the tongs, or from meeting the sudden cooling action irregularly, and therefore it is generally best to plunge works vertically, as all parts are then exposed to equal circumstances, and less disturbance is risked than when the objects are immersed obliquely or sideways into the water; although for swords, and objects of similar form, it is found the best to dip them exactly as in making a vertical downward cut with a sabre, which for this weapon is its strongest direction.

Occasionally objects are clamped between stubborn pieces of metal, as soft iron or copper, during their passage through the fire and water. Such plans can be seldom adopted and are rarely followed, the success of the process being mostly allowed to depend exclusively upon good general management.

In recent experiments in making the magnets for dipping-needles, which are about ten inches long, one-fourth of an inch wide, and the two-hundredth part of an inch thick, this precaution entirely failed; and the needles assumed all sorts of distortions when released from between the stiff bars within which they were hardened. The plan was eventually abandoned, and the magnets were heated in the ordinary way within an iron tube, and were set straight with the hammer after being let down to a deep orange or brown color. Steel however is in the best condition for the formation of good permanent magnets when perfectly hard.

In all cases the thick unequal scale left from the forge should be ground off before hardening, in order to expose a clean metallic surface, otherwise the cooling medium cannot produce its due and equal effect throughout the instrument. The edges also should be left thick, that they may not be burned in the fire; thus it will frequently happen that the extreme end or edge of a tool is inferior in quality to the part within, and that the instrument is much better after it has been a few times ground:

"He that will a good Edge win
Must Forge thick and Grind thin."

Thirdly, the heat for tempering or letting down. Between the extreme conditions of hard and soft steel there are many intermediate grades, the common index for which is the oxidation of the brightened surface, and it is quite sufficient for practice. These tints, and their respective approximate temperatures, are thus tabulated:

1. Very pale straw yellow	430°	Tools for metal.
2. A shade of darker yellow	440	
3. Darker straw yellow	470	Tools for wood, and screw-taps, &c.
4. Still darker straw yellow	490	
5. A brown yellow	500	Hatchets, chipping-chisels, and other percussive tools, saws, &c.
6. A yellow, tinged slightly with purple	520	
7. Light purple	530	
8. Dark purple	550	Springs.
9. Dark blue	570	
10. Paler blue	590	Too soft for the above purposes.
11. Still paler blue	610	
12. Still paler blue, with a tinge of green	630	

The first tint arrives at about 430° F., but it is only seen by comparison with a piece of steel not heated: the tempering colors differ slightly with the various qualities of steel.

The knife-edges, for Captain Kater's experimental pendulum, were very carefully hardened and tempered in a bath heated to 430°; being then found too soft they were rehardened, and tempered, at only the heat of boiling water, after which they were considered admirably suited to their purpose.

The heat for tempering being moderate, it is often supplied by the part of the tool not requiring to be hardened, and which is not therefore cooled in the water. The workman first hastily tries with a file whether the work is hard, he then partially brightens it at a few parts with a piece of grindstone or an emery stick, that he may be enabled to watch for the required color; which attained, the work is usually cooled in any convenient manner, lest the body of the tool should continue to supply heat. But when, on the contrary, the color does not otherwise appear, partial recurrence is had to the mode in which the work was heated, as the flame of the candle, or the surface of the clear fire applied, if possible, a little below the part where the color is to be observed, that it may not be soiled by the smoke.

A very convenient and general manner of tempering small objects, is to heat to redness a few inches of the end of a flat bar of iron about two feet long; it is laid across the anvil, or fixed by its cold extremity in the vice; and the work is placed on that part of its surface which is found by trial to be of the suitable temperature, by gradually sliding the work towards the heated extremity. In this manner many tools may be tempered at once, those at the hot part being pushed off into a vessel of water or oil, as they severally show the required color, but it requires dexterity and quickness in thus managing many pieces.

Vessels containing oil or fusible alloys carefully heated to the required temperatures have also been used, and I shall have to describe a method called "*blazing off*," resorted to for many articles, such as springs and saws, by heating them over the naked fire until the oil, wax, or composition in which they have been hardened ignites; this can only occur when they respectively reach their boiling temperatures and are evaporated in the gaseous form.

The period of letting down the works is also commonly chosen for correcting, by means of the hammer, those distortions which so commonly occur in hardening; this is done upon the anvil, either with the thin pane of an ordinary hammer, or else with a *hack-hammer*, a tool terminating at each end in an obtuse chisel-edge, which requires continual repair on the grindstone.

The blows are given on the hollow side of the work, and at right angles to the length of the curve; they elongate the concave side, and gradually restore it to a plane surface, when the blows are distributed consistently with the positions of the erroneous parts. The hack hammer unavoidably injures the surface of the work, but the blows should not be violent, as they are then also more prone to break the work, the liability to which is materially lessened when it is kept at or near the tempering heat, and the edge of the hack hammer is slightly rounded.

Watchmakers' drills of the smallest kinds, are heated in the blue part of the flame of the candle; larger drills are heated with the blowpipe flame, applied very obliquely, and a little below the point; when very thin they may be whisked in the air to cool them, but they are more generally thrust into the tallow of the candle or the oil of the lamp; they are tempered either by their own heat, or by immersion in the flame below the point of the tool.

For tools between those suited to the action of the blowpipe, and those proper for the open fire, there are many which require either the iron tube, or the bath of lead or charcoal; but the greater number of works are hardened in the ordinary smith's fire, without such defences.

Tools of moderate size, such as the majority of turning tools, carpenters' chisels and gouges, and so forth, are generally heated in the open fire; they require to be continually drawn backwards and forwards through the fire, to equalize the temperature applied: they are plunged vertically into the water, and then moved about sideways to expose them to the cooler portions of the fluid. If needful, they are only dipped to a certain depth, the remainder being left soft.

Some persons use a shallow vessel filled only to the height of the portion to be hardened, and plunge the tools to the bottom; but the strict line of demarcation is sometimes dangerous, as the tools are apt to become cracked at the part, and therefore a small vertical movement is also generally given, that the transition from the hard to the soft part may occupy more length.

Razors and penknives are too frequently hardened without the removal of the scale arising from the forging; *this practice which is not done with the best works, cannot be too much deprecated.* The blades are heated in a coke or charcoal fire, and dipped into the water obliquely. In tempering razors, they are laid on their backs upon a clear fire, about half-a-dozen together, and they are removed one at a time, when the edges, which are as yet thick, come down to a pale straw-color; should the backs accidentally get heated beyond the straw-color, the blades are cooled in water, but not otherwise. Penknife blades are tempered, a dozen or two at a time, on a plate of iron or copper, about twelve inches long, three or four wide, and about a quarter of an inch thick; the blades are arranged close together on their backs, and lean at an angle against each other. As they come down to the temper, they are picked out with small pliers and thrown into water, if necessary; other blades are then thrust forward from the cooler parts of the plate to take their place.

Hatchets, adzes, cold chisels, and numbers of similar tools, in which the total bulk is considerable compared with the part to be hardened, are only partially dipped; they are afterwards let down by the heat of the remainder of the tool, and when the color indicative of the temper is attained, they are entirely quenched. With the view of removing the loose scales, or the oxidation acquired in the fire, some workmen rub the objects hastily in dry salt before plunging them in the water, in order to give them a cleaner and whiter face.

In hardening large dies, anvils, and other pieces of considerable size, by direct immersion, the rapid formation of steam at the sides of the metal prevents the free access of the water for the removal of the heat with the required expedition; in these cases, a copious stream of water from a reservoir above is allowed to fall on the surface to be hardened. This contrivance is frequently called a "float," and although the derivation of the name is not very clear, the practice is excellent, as it supplies an abundance of cold water; and which, as it falls directly on the centre of the anvil, is sure to render that part hard. It is, however, rather dangerous to stand near such works at the time, as when the anvil face is not perfectly welded, it sometimes in part flies off with great violence and a loud report.

Occasionally the object is partly immersed in a tank beneath the fall of water, by means of a crane and slings; it is ultimately tempered with its own heat, and dropped in the water to become entirely cold.

Oil, or various mixtures of oil, tallow, wax, and resin, are used for many thin and elastic objects, such as needles, fish-hooks, steel pens and springs, which require a milder degree of hardness than is given by water.

For example, steel pens are heated in large quantities in iron trays within a furnace, and are then hardened in an oily mixture; generally they are likewise tempered in oil, or a composition the boiling point of which is the same as the temperature suited to letting them down. This mode is particularly expeditious, as the temper cannot fall below the assigned degree. The dry heat of an oven is also used, and both the oil and oven may be made to serve for tempers harder than that given by boiling oil; but more care and observation are required for these lower temperatures.

Saws and springs are generally hardened in various compositions of oil, suet, wax, and other ingredients. The composition used by an experienced saw-maker is two pounds of suet and a quarter of a pound of bees-wax to every gallon of whale-oil; these are boiled together, and will serve for thin works and most kinds of steel. The addition of black resin, to the extent of about one pound to the gallon, makes it serve for thicker pieces and for those it refused to harden before; but the resin should be added with judgment, or the works will become too hard and brittle. The composition is useless when it has been constantly employed for about a month: the period depends, however, on the extent to which it is used, and the trough should be thoroughly cleaned out before new mixture is placed in it.

The following recipe is recommended by an experienced workman: "Twenty gallons of spermaceti oil; twenty pounds of beef suet rendered; one gallon of neats-foot oil; one pound of pitch; three pounds of black resin. These two last articles must be previously melted together, and then added to the other ingredients; when the whole must be heated in a proper iron vessel, with a close cover fitted to it, until the moisture is entirely evaporated, and the composition will take fire on a flaming body being presented to its surface, but which must be instantly extinguished again by putting on the cover of the vessel."

The above ingredients lose their hardening property after a few weeks' constant use. The saws are heated in long furnaces, and then immersed horizontally and edgeways in a long trough containing the composition; two troughs are commonly used, the one until it gets too warm, then the other for a period, and so on alternately. Part of the composition is wiped off the saws with a piece of leather, when they are removed from the trough, and they are heated one by one over a clear coke fire, until the grease inflames; this is called "*blazing off*." When the saws are wanted to be rather hard, but little of the grease is burned off; when milder, a larger portion; and for a spring temper, the whole is allowed to burn away. When the work is thick, or irregularly thick and thin, as in some springs, a second and third dose is burned off, to insure equality of temper at all parts alike.

Gun-lock springs are sometimes literally *fried in oil* for a considerable time over a fire in an iron tray; the thick parts are then sure to be sufficiently reduced, and the thin parts do not become the more softened from the continuance of the blazing heat.

Springs and saws appear to lose their elasticity, after hardening and tempering, from the reduction and friction they undergo in grinding and polishing. Towards the conclusion of the manufacture, the elasticity of the saw is restored principally by hammering, and partly by heating it over a clear coke fire to a straw-color: the tint is removed by very diluted muriatic acid, after which the saws are well washed in plain water and dried.

Watch-springs are hammered out of round steel wire, of suitable diameter, until they fill the gage for width, which at the same time insures equality of thickness; the holes are punched in their extremities, and they are trimmed on the edge with a smooth file; the springs are then tied up with binding-wire, in a loose *open coil*, and heated over a charcoal fire upon a perforated revolving-plate, they are hardened in oil, and blazed off.

The spring is now distended in a long metal frame, similar to that used for a saw-blade, and ground and polished with emery and oil, between lead blocks; by this time its elasticity appears quite lost, and it may be bent in any direction; its elasticity is, however, entirely restored by a subsequent hammering on a very bright anvil, which "*puts the nature into the spring.*"

The coloring is done over a flat plate of iron, or hood, under which a little spirit lamp is kept burning; the spring is continually drawn backwards and forwards, about two or three inches at a time, until it assumes the orange or deep-blue tint throughout, according to the taste of the purchaser; by many the coloring is considered to be a matter of ornamant, and not essential. The last process is to coil the spring into the spiral form, that it may enter the barrel in which it is to be contained; this is done by a tool with a small axis and winch-handle, and does not require heat.

The balance-springs of marine chronometers, which are in the form of a screw, are wound into the square thread of a screw of the appropriate diameter and coarseness; the two ends of the spring are retained by side-screws, and the whole is carefully enveloped in platinum foil, and tightly bound with wire. The mass is next heated in a piece of gun-barrel closed at the one end, and plunged into oil, which hardens the spring almost without discoloring it, owing to the exclusion of the air by the close platinum covering, which is now removed, and the spring is let down to the blue, before removal from the screwed block.

The balance or hair springs of common watches are frequently left soft; those of the best watches are hardened in the coil upon a plain cylinder, and are then curled into the spiral form between the edge of a blunt knife and the thumb, the same as in curling up a narrow riband of paper, or the filaments of an ostrich feather.

Mr. Dent says that 3200 balance-springs weigh only one ounce; but springs also include the heaviest examples of hardened steel works uncombined with iron: for example, of Mr. Adams' patent bow-springs for all kinds of vehicles, some intended for railway use, measure 3½ feet long, and weigh 50 pounds each piece; two of these are used in combination: other single springs are 6 feet long, and weigh 70 pounds.

In hardening them they are heated by being drawn backwards and forwards through an ordinary forge-fire built hollow, and they are immersed in a trough of plain water: in tempering them they are heated until the black-red is just visible at night; by daylight the heat is denoted by its making a piece of wood sparkle when rubbed on the spring, which is then allowed to cool in the air. The metal is 9-16ths of an inch thick, and Mr. Adams considers 5-8ths the limit to which steel will harden properly—that is, sufficiently alike to serve as a spring: he tests their elasticity far beyond their intended range.

Great diversity of opinion exists respecting the cause of elasticity in springs: by some it is referred to different states of electricity; by others the elasticity is considered to reside in the thin, blue, oxidized surface, the removal of which is thought to destroy the elasticity, much in the same manner that the elasticity of a cane is greatly lost by stripping off its siliceous rind. The elasticity of a thick spring is certainly much impaired by grinding off a small quantity of its exterior metal, which is harder than the inner portion; and perhaps thin springs sustain in the polishing a proportional loss, which is to them equally fatal.

It has been found experimentally that the bare removal of the blue tint from a pendulum spring, by its immersion in weak acid, caused the chronometer to lose nearly one minute each hour; a second and equal immersion scarcely caused any further loss. It is also stated as a well-known fact that such springs get stronger, in a minute degree, during the first two or three years they are in use, from some atmospheric change; when the springs are coated with gold by the electrotype process, no such change is observable, and the covering, although perfect, may be so thin as not to compensate for the loss of the blue oxidized surface.

One of the most serious evils in hardening steel, especially in thick blocks, or those which are unequally thick and thin, is their liability to crack, from the sudden transition; and in reference to hardening razors, a case in point, Mr. Stodart mentions it as the observation and practice of one of his workmen, "that the charcoal fire should be made up with shavings of leather;" and upon being asked what good he supposed the leather could do, this workman replied, "that he could take upon him to say that he never had a razor crack in the hardening since he had used this method, though it was a frequent occurrence before."

When brittle substances crack in cooling, it always happens from the outside contracting and becoming too small to contain the interior parts. But it is known that hard steel occupies more space than when soft; and it may easily be inferred that the nearer the steel approaches to the state of iron, the less will be this increase of dimensions. If, then, we suppose a razor or any other piece of steel to be heated in an open fire with a current of air passing through it, the external part will, by the loss of carbon, become less steely than before; and when the whole piece comes to be hardened, the inside will be too large for the external part, which will probably crack. But if the piece of steel be wrapped up in the cementing mixture, or if the fire itself contain animal coal, and is put together so as to operate in the manner of that mixture, the external part, instead of being degraded by the heat, will be more carbonated than the internal part, in consequence of which it will be so far from splitting or bursting during its cooling, that it will be acted upon in a contrary direction, tending to render it more dense and solid.

The cracking which so often occurs on the immersion of steel articles in water, does not appear to arise so much from any decarbonization of the surface merely, as from the sudden condensation and contraction of a superficial portion of the metal, while the mass inside remains swelled with heat, and probably expands for a moment on the outside coming in contact with the water.

The file makers, to save their works from *clinking*, or cracking partly through in hardening, draw the files through yeast, beer grounds, or any sticky material, and then through a mixture of common salt and animal hoof roasted and pounded. This is corroborative of the above, as in the like manner it supplies a little carbon to the outside, and also renders the steel somewhat harder and less disposed to crack; the composition also renders the more important service of protecting the fine points of the teeth from being injured by the fire.

An analogous method is now practised in hardening patent axletrees which are of wrought-iron, with two pieces of steel welded into the lower side where they rest upon the wheels and sustain the load The work is heated in an open forge-fire, quite in the ordinary way, and when it is removed a mixture, principally the prussiate of potash, is laid upon the steel; the axletree is then immediately immersed in water, and additional water is allowed to fall upon it from a cistern. The steel is considered to become very materially harder for the treatment, and the iron around the same is also partially hardened.

These are, in fact, applications of the case-hardening process, which is usually applied to wrought-iron for giving it a steely exterior, as the name very properly implies. Occasionally steel which hardens but imperfectly, either from an original defect in the material, or from its having become deteriorated by bad treatment, or too frequent passage through the fire, is submitted to the case-hardening process in the ordinary way, by inclosing the objects in iron boxes, as will be explained. This in part restores the carbon which has been lost, and the steel admits of being hardened; but this practice is not to be generally recommended, although it is well employed for the purposes of transfer engraving, explained at Engraving on Steel, a method introduced by Mr. Jacob Perkins, and which took its origin in the curious transfer processes of the calico-works, wherein, however, copper is the material principally used.

Various methods have been likewise attempted to prevent the distortions to which work is liable in the operation of hardening, but without any very advantageous results: for instance, it has been recommended to harden small cylindrical wires by rolling them when heated between cold metallic surfaces to retain them perfectly straight. This might probably answer, but unfortunately cylindrical steel wires supply but a very insignificant portion of our wants.

Another mode tried by Dr. Wollaston was to inclose the piece of steel in a tube filled with Newton's fusible alloy, the whole to be heated to redness and plunged in cold water; the object was released by immersion in boiling water, which melted the alloy, and the piece came out perfectly unaltered in form, and quite hard. This mode is too circuitous for common practice, and the reason why it is to be always successful is not very apparent.

Mr. Perkins resorted to a very simple practice with the view of lessening the distortion of his engraved steel plates, by boiling the water in which they were to be hardened to drive off the air, and plunging them vertically; and as the plates were required to be tempered to a straw color, instead of allowing them to remain in the water until entirely cold, he removed them whilst the inside was still hot, and placed them on the top of a clear fire until the tallow with which they were rubbed smoked; the plate was then returned to the water for a few moments, and so on alternately until they were quite cold, the surface never being allowed to exceed the tempering heat.

From various observations, it appears on the whole to be the best in thick works thus to combine the hardening and tempering processes, instead of allowing the objects to become entirely cold, and then to reheat them for tempering. To ascertain the time when the plate should be first removed from the water, Mr. Perkins heated a piece of steel to the straw color, and dipped it into water to learn the sound it made; and when the hardened plate caused the *same* sound, it was considered to be cooled to the right degree, and was immediately withdrawn.

Locomotive wheels with hardened-steel tires may be viewed as the most ponderons example of hardening, as the tires of the eight-foot wheels weigh about 10 cwt., and consist of about one-third steel, and there seems no reason why this diameter might not be greatly exceeded.

The materials for the tires are first swaged separately, and then welded together under the heavy hammer at the steel-works, after which they are bent to the circle, welded, and turned to certain gages. The tire is now heated to redness in a circular furnace; during the time it is getting hot the iron wheel, previously turned to the right diameter, is bolted down upon a face-plate; the tire expands with the heat, and when at a cherry-red it is dropped over the wheel, for which it was previously too small, and is also hastily bolted down to the surface-plate, the whole load is quickly immersed by a swing-crane into a tank of water about five feet deep, and hauled up and down until nearly cold; the steel tires are not afterwards tempered.

Hardening and softening cast-iron.—The similitude of chemical constitution between steel, which usually contains about one per cent. of carbon, and cast-iron, that has from three to six or seven per cent., naturally leads to the expectation of some correspondence in their characters, and which is found to exist. Thus some kinds of cast-iron will harden almost like steel, but they generally require a higher temperature; and the majority of cast-iron, also like steel, assumes different degrees of hardness, according to the rapidity with which the pieces are allowed to cool.

The casting left undisturbed in the mould, is softer than a similar one exposed to the air soon after it has been poured. Large castings cannot cool very hastily, and are seldom so hard as the small pieces, some of which are hardened like steel by the moisture combined with the moulding sand, and cannot be filed until they have been annealed after the manner of steel, which renders them soft and easy to be worked.

Chilled iron castings present as difficult a problem as the hardening and tempering of steel; the fact is simply this, that iron castings, made in iron moulds under particular circumstances, become on their outer surfaces perfectly hard, and resist the file almost like hardened steel; the effect is, however, superficial, as the chilled exterior shows a distinct line of demarcation when the objects are broken.

Ploughshares are sometimes cast on this principle; the under sides and points are hard from the chilling process, and these, from resisting abrasion more than the softer parts, maintain a comparatively thin edge.

The production of chilled castings is always a matter of some uncertainty, and depends upon the united effect of several causes: the quality of the iron, the thickness of the casting, the temperature of the iron at the time of pouring, and the condition or temperature of the iron mould, which has a greater effect in "striking in" when the mould is *heated* than if quite cold: a very thin stratum of earthy matter will almost entirely obviate the chilling effect. A cold mould does not generally chill so readily as one heated nearly to the extent called "black hot;" but the reverse conditions occur with some cast-iron

There is this remarkable difference between cast-iron thus hardened, and steel hardened by plunging whilst hot into water: that whereas the latter is softened again by a dull-red heat, the chilled castings, on the contrary, are turned out of the moulds as soon as the metal is set, and are allowed to cool in the air; yet although the whole is at a bright-red heat, no softening of the chilled part takes place. This material has been employed for punches for red-hot iron; the punches were fixed in cast-iron sockets, from which they only projected sufficiently to perforate the wheel-tires in the formation of which they were used, and from retaining their hardness they were more efficient than those punches made of steel.

Chilled castings are also commonly employed for axletree-boxes, and naves of wheels, which are finished by grinding only; also for cylinders for rolling metal, for the heavy hammers and anvils or stithies for iron-works, the stamp-heads for pounding metallic ores, &c. Cannon-balls, as well as plough-shares, are examples of chilled castings; with the destructive engine the chilling is unimportant, and occurs alone from the method essential to giving the balls the required perfection of form and size.

Malleable iron castings are at the opposite extreme of the scale, and are rendered externally *soft* by the abstraction of their carbon, whereby they are nearly reduced to the condition of pure malleable iron, but without the fibre which is due to the hammering and rolling employed at the forge.

The malleable-iron castings are made from the rich Pennsylvania iron, and are at first as brittle as glass or hardened steel; they are inclosed in iron boxes of suitable size, and surrounded with pounded iron-stone, or some of the metallic oxides, as the scales from the iron forge, or with common lime, and various other absorbents of carbon, used either together or separately. The cases, which are sometimes as large as barrels, are luted, rolled into the ovens or furnaces, and submitted to a good heat for about five days, and are then allowed to cool very gradually within the furnaces.

The time and other circumstances determine the depth of the effect; thin pieces become malleable entirely through, they are then readily bent, and may be slightly forged; cast-iron nails and tacks thus treated admit of being clinched, thicker pieces retain a central portion of cast-iron, but in a softened state, and not brittle as at first; on sawing them through, the skin or coat of soft iron is perfectly distinct from the remainder.

The mode is particularly useful for thin articles that can be more economically and correctly cast than wrought at the forge, as bridle-bits, snuffers, parts of locks, culinary and other vessels, pokers and tongs, many of which are subsequently case-hardened and polished, as will be explained, but malleable cast-iron should never be used for cutting-tools.

Case-hardening wrought and cast iron.—The property of hardening is not possessed by pure malleable iron; but we have now to explain a rapid and partial process of cementation, by which wrought-iron is first converted exteriorly into steel, and is subsequently hardened to that particular depth; leaving the central parts in their original condition of soft fibrous iron. The process is very consistently called *case-hardening*, and is of great importance in the mechanical arts, as the pieces combine the economy, strength, and internal flexibility of iron, with a thin casing of steel; which, although admirable as an armor of defence from wear or deterioration as regards the surface, is unfit for the formation of cutting edges or tools, owing to the entire absence of hammering, subsequent to the cementation with the carbon. Cast-iron obtains in like manner a coating of steel, which surrounds the peculiar shape the metal may have assumed in the iron-foundry and workshop.

The principal agents used for case-hardening are animal matters, as the hoofs, horns, bones, and skins of animals; these are nearly alike in chemical constitution, and they are mostly charred and coarsely pounded; some persons also mix a little common salt with some of the above; the works should be surrounded on all sides with a layer from half an inch to one inch thick.

The methods pursued by different individuals do not greatly differ; for example, the gunsmith inserts the iron-work of the gun-lock in a sheet-iron case in the midst of bone-dust, (often not burned,) the lid of the box is tied on with iron-wire, and the joint is luted with clay; it is then heated to redness as quickly as possible and retained at that heat from half an hour to an hour, and the contents are quickly immersed in cold water. The objects sought are a steely exterior, and a clean surface covered with the pretty mottled tints, apparently caused by oxidation from the partial admission of air.

Some of the malleable iron castings, such as snuffers, are case-hardened to admit of a better polish; it is usually done with burnt bone-dust, and at a dull red heat; they remain in the fire about two or three hours, and should be immersed in oil, as it does not render them quite so brittle as when plunged into water. It must be remembered they are sometimes changed throughout their substance into an inferior kind of steel, by a process that should in such instances be called cementation, and not *case-hardening*, consequently they will not endure violence.

The mechanician and engineer use horns, hoofs, bone-dust, and leather, and allow the period to extend from two to eight hours, most generally four or five; sometimes, for its greater penetration, the process is repeated a second time with new carbonaceous materials. Some open the box and immerse the work in water direct from the furnace; others, with the view to preserve a better surface, allow the box to cool without being opened, and harden the pieces with the open fire as a subsequent operation; the carbon once added, the work may be annealed and hardened much the same as ordinary steel.

When the case-hardening is required to terminate at any particular part, as a shoulder, the object is left with a band or projection, the work is allowed to cool without being immersed in water, the band is turned off, and the work when hardened in the open fire is only effected so far as the original cemented surface remains. This ingenious method was introduced by Mr Roberts, who considers the success of the case-hardening process to depend on the gentle application of the heat, and that, by proper management not to overheat the work, it may be made to penetrate three-eighths of an inch in four or five hours.

A new substance for the case-hardening process, but containing the same elements as those more commonly employed, has of late years been added, namely, the prussiate of potash, (a salt consisting of two atoms of carbon and one of nitrogen,) which is made from a variety of animal matters.

It is a new application without any change of principle; the time occupied in this steelifying process is sometimes only minutes, instead of hours and days; as, for example, when iron is heated in the open fire to a dull red, and the prussiate is either sprinkled upon it or rubbed on in the lump, it is returned to the fire for a few minutes and immersed in water; but the process is then exceedingly superficial, and it may if needful be limited to any particular part upon which alone the prussiate is applied. The effect by many is thought to be partial or in spots, as if the salt refused to act uniformly, in the same manner that water only moistens a greasy surface in places.

The prussiate of potash has been used for case-hardening the bearings of wrought-iron shafts, but this seems scarcely worth the doing. It has been also employed with the view of giving an additional and extreme, although superficial hardness to steel, as in axletrees, Perkins's engraved steel-plates, &c.; but we have only heard of one individual who has encased work with this salt—it was for case-hardening the iron rollers and side-plates of glaziers' vices employed for milling window-lead.

In the general way, the conversion of the iron into steel by case-hardening is quite superficial, and does not exceed the sixteenth of an inch; if made to extend to one-quarter or three-eighths of an inch in depth, to say the least, it would be generally useless, as the object is to obtain durability of surface, with strength of interior, and this would disproportionately encroach on the strong iron within. The steel obtained in this adventitious manner is not equal in strength to that converted and hammered in the usual way, and if sent in so deeply, the provision for wear would far exceed that which is required.

Let us compare the case-hardening process with the usual conversion of steel. The latter requires a period of about seven days, and a very pure carbon, namely, wood charcoal, of which a minute portion only is absorbed; and it being a simple body, when the access of air is prevented by the proper security of the troughs, the bulk of the charcoal remains unconsumed, and is reserved for future use, as it has undergone no change. The hasty and partial process of cementation is produced in a period commonly less than as many hours with the animal charcoal, or than as many minutes with the prussiate of potash; but all these are compound bodies, (which contain cyanogen, a body consisting of carbon and nitrogen,) and are never used a second time, but on the contrary the process is often repeated with another dose. It would be, therefore, an interesting inquiry for the chemist, as to whether the cyanogen is absorbed after the same manner as carbon in ordinary steel, (and which in Mackintosh's patent process was driven through the crucible in the form of carbonic acid gas, and is stated to be absorbed at the rate of one-thirtieth of an inch in depth, each hour;) or whether the nitrogen assists in any way in hastening the admission of the carbon, by some as yet untraced affinity or decomposition.

This hasty supposition will apply less easily to cast-iron, which contains from three to seven times as much carbon as steel, and although not always hardened by simple immersion, is constantly under the influence of the case-hardening process; unless we adopt the supposition, that the carbon in cast-iron which is mixed with the metal in the shape of cinder in the blast-furnace, when all is in a fluid state, is in a less refined union than that instilled in a more aeriform condition in the acts of cementation and case-hardening. (See Tools.)

THERMOMETER. An instrument for measuring variations of heat or temperature. The principle upon which thermometers are constructed is the change of volume which takes place in bodies when their temperature undergoes an alteration. Generally speaking, all bodies expand when heated and contract when cooled, and in such a manner that, under the same circumstances of temperature, they return to the same dimensions; so that the change of volume becomes the exponent of the temperature which produces it. But as it is necessary not merely that expansion and contraction take place, but that they be capable of being conveniently observed and measured, only a small number of bodies are adapted for thermometrical purposes. Solid bodies, for example, undergo so small a change of volume with moderate variations of temperature, that they are in general only used for measuring very high temperatures, as the heat of furnaces, of melting metals, &c. Instruments for such purposes are called pyrometers. (See Pyrometer.) The gaseous fluids, on the other hand, are extremely susceptible of the impressions of heat and cold; and as their changes of volume are great even with moderate accessions of heat, they are only adapted for indicating very minute variations, or for forming *differential* thermometers. Liquids hold an intermediate place; and by reason of their moderate but sensible expansion through the ranges of temperature within which observations have to be made for by far the greater number of purposes, are commonly used for the construction of thermometers. Various liquids have been proposed, as oils, ether, spirits of wine, and mercury; but scarcely any other than the two last are now ever used, and mercury by far the most generally.

The properties which render mercury preferable to all other liquids (unless for particular purposes) are these: 1. It supports, before it boils and is reduced to vapor, more heat than any other fluid, excepting certain oils, and endures a greater cold than would congeal most other liquids, excepting certain spirituous liquors. 2. It takes the temperature of the medium in which it is placed more quickly than any other fluid. Count Rumford found that mercury was heated from the freezing to the boiling point of water in 58 seconds, while water took 133 seconds, and air 617 seconds, the heat applied being the same in all the three cases. 3. The variations of its volume within limits which include the temperatures most frequently required to be observed, are found to be perfectly regular, and proportional to the variations of temperature. The spirit thermometer is now little used excepting for observations of very low temperatures, or as a self-registering instrument for meteorological observations.

Construction of the mercurial thermometer.—In order to render small changes of volume sensible, a glass bulb, having a slender hollow tube attached to it, is filled with mercury, so that expansion or contraction can only take place by the rise or fall of the liquid in the tube. The diameter of the tube may be of any convenient size; but the smaller it is the larger will be the scale of the variations; and capillary tubes are usually employed. It is essential that the diameter of the bore be of a uniform width throughout; a quality which is tested by drawing up into the tube a short column of mercury, and measuring its length at the different parts with a pair of compasses. Not more than a sixth part of the tubes which come from the glass-house are found to be fit for the purpose.

Having selected a tube, the workman begins by blowing a hollow ball A, Fig. 3409, upon one extremity of it, by means of an air-bag of caoutchouc, (in order to avoid the introduction of watery vapor by blowing from the mouth.) The length which the thermometer is to have is then marked, and above this point the tube is expanded into a second bulb B, rather larger than the first. When the tube has acquired its natural temperature one of the bulbs is warmed, in order to expel the air from it, and the open end of the tube is plunged into distilled and well-boiled mercury. During the cooling the mercury rises into the second bulb B, whence it is made to pass into A by placing this undermost, and expelling the air from it by heat, after which the mercury descends from the effect of cooling. When the bulb A has been completely filled, and also a part of B, the tube is suspended horizontally over a charcoal fire, so as to be equally heated throughout, and the inclosed mercury boiled, in order to expel every remaining particle of air or humidity. The open end is then touched with sealing-wax, and the tube withdrawn from the fire, and placed in an upright position until it is cooled, when the bulb A and the portion of the tube under B will be filled with mercury. A portion of mercury is then expelled by heat, so that the column may stand at the proper height in the tube. The tube is then carefully softened with the blowpipe, and hermetically sealed under the bulb B, which is thus cut off.

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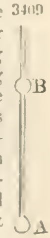


Graduation of the scale.—The instrument prepared in the manner now described is admirably adapted for rendering evident the expansions and contractions of the inclosed fluid, and it only remains to adopt a scale to it in order to have a complete thermometer. The graduation of the scale is in some measure arbitrary; nevertheless, in order that different thermometers may be comparable with each other, it is necessary that two points at least be taken on the scale corresponding to fixed and determinate temperatures, the distance between which will determine the graduation. The two points which are now universally chosen for this purpose are those which correspond to the temperatures of freezing and boiling water. With respect to the first of these there is no difficulty; it is only necessary to surround the bulb with ice, and to mark on the stem the point at which the mercury stands when the ice begins to melt. The boiling point is not so readily determined. As the temperature at which water boils varies to a small extent with the barometric pressure, it is necessary, in order to have instruments comparable with each other, either that the boiling point on the scale be determined when the barometer stands at a certain height which is arbitrarily assumed for the standard, or else to apply a correction when the actual height of the barometer is above or below the assumed standard. De Luc made a number of experiments on this subject, and gave a formula for the correction, which was adapted to Fahrenheit's scale and English inches by Horsley. (*Phil. Trans.*, vol. lxiv.) A committee of the Royal Society who undertook to investigate the best method of adjusting the fixed points, and whose report is contained in vol. lxvii. of the *Transactions*, laid down a set of rules which have been generally followed by English instrument-makers. They recommended the adoption of 29·8 inches for the standard barometric pressure, and gave a table of the corrections for all ordinary pressures above or below this standard. Their table is very nearly represented by the following simple rule, which will be quite sufficient for the guidance of the artist in all ordinary cases:

Supposing the thermometer placed in an atmosphere of steam immediately over the surface of boiling water, then for every tenth of an inch by which the barometer is above or below 29·8, the correction for the boiling point of the scale of the thermometer is one-thousandth part of the interval between the freezing and boiling points. The corrected must be placed lower than the observed boiling point by this quantity when the pressure exceeds 29·8 inches, and higher when the pressure is less than the standard.

Several other minute circumstances must be attended to in the construction of delicate instruments. As the temperature of boiling water is different at the top and near the bottom of the vessel in which it boils, the thermometer should not be plunged into the water itself, but into the vapor which rises above it, in a close vessel with an aperture for the escape of the steam. The vessel should be of metal, because water boils at a different temperature in vessels of different substances, as metal and glass. Distilled water, or clear soft water, should be used; if mixed with saline ingredients, the temperature at which it boils would be affected, and the instrument rendered inaccurate.

The interval between the two fixed points on the stem may be divided into any number of degrees at pleasure, and the graduation continued above and below as far as may be thought requisite: the numeration may also be begun at any point whatever on the scale; but there are only three methods of division so generally adopted as to require particular notice. The first is Fahrenheit's, which is used in England, Holland, and North America; the second, Reaumur's, which was formerly in general use in France, and is still followed in Spain and some parts of Germany; and the third that of Celsius, or the centigrade scale, now used in France, Germany, and Sweden.

Fahrenheit's scale.—In this scale the interval between the freezing and boiling points of water is divided into 180 equal parts or degrees, which number was chosen by Fahrenheit, (or probably Roemer,) from some theoretical considerations respecting the expansion of mercury; it being computed that the thermometer, when plunged into melting snow, contained 11,156 parts of mercury, which, at the temperature of boiling water, were expanded into 11,336 parts, being an increase of 180 parts. The zero point of the scale is placed at 32° below the freezing point of water. It has been frequently stated that this point was selected as indicating the temperature of a freezing mixture of snow and salt; but it appears from Boerhaave that it was adopted from a still more precarious supposition, namely, the greatest cold observed in Iceland, which was probably assumed to be the lowest natural temperature. The freezing point is thus marked 32°, and consequently the boiling point at 32 + 180 = 212. It must be admitted that this scale, though it possesses some advantages in the lowness of the zero point and the smallness of the divisions, is not well adapted to philosophical purposes.

Reaumur's scale.—Reaumur, in 1730, proposed the adoption of the temperature of melting ice as the zero of the scale, and to divide the distance between this and the boiling point of water into 80°, having observed that between those temperatures spirits of wine (which he used for the thermometric fluid) expanded from 1000 parts to 1080. This division soon became general in France and other countries, and a great number of valuable observations have been recorded in terms of it; but it is now seldom used in works of science.

Centigrade scale.—In 1742 Celsius, professor at Upsal, in Sweden, proposed to divide the space between the freezing and boiling points of water into 100 equal parts, the zero point being placed (as in Reaumer's) at freezing. This division being in harmony with our decimal arithmetic, is better adapted than the two former to scientific purposes. It has been adopted by all the French writers since the Revolution, and is the best known in most parts of the north and middle of Europe.

It has been sometimes objected to this scale, (and the objection applies equally to Reaumer's,) that on account of the comparatively high point at which the zero is placed, meteorological observations are embarrassed with the algebraic signs of *plus* and *minus.* The inconvenience (if any) is a very trifling one, and is much more than compensated by the facilities for calculation which the scale affords.

Conversion of degrees of one scale into degrees of another.—From the manner in which the three scales are graduated, it is easy to deduce formulæ expressing any temperature given according to one scale in terms of either of the others. The interval which in Fahrenheit's scale is divided into 180 parts is divided into only 100 parts in the centigrade scale, and into 80 in Reaumer's. Hence one degree of Fahrenheit's is equal to 5-9ths of a degree of the centigrade, and to 4-9ths of a degree of Reaumer. But some attention is required on account of the difference of the zero points. For the sake of perspicuity, it is convenient to adapt the expressions to three distinct cases. Let F denote degrees of Fahrenheit's scale, C degrees of the centigrade, and R degrees of Reaumer; then,

Case 1. For all temperatures above the freezing point,

$$F - 32 = \tfrac{9}{5} C = \tfrac{9}{4} R.$$

Case 2. For all temperatures between the freezing point and the zero of Fahrenheit's scale,

$$32 - F = -\tfrac{9}{5} C = -\tfrac{9}{4} R.$$

Case 3. For all temperatures below the zero of Fahrenheit,

$$-32 - F = -\tfrac{9}{5} C = -\tfrac{9}{4} R.$$

By substituting numbers in these formulæ for F, C, or R, as the case may require, the corresponding values on the other scales is immediately obtained; but if many reductions are required to be made, it is more convenient to have comparative tables, by which the correspondence of the scales is seen at a glance. Such tables are given in most treatises on chemistry.

Theory of the graduation.—It will be evident from what has now been said that, whatever scale be adopted, the division is founded on the assumed principle that equal increments of heat produce equal expansions. This assumption may be put to the test of experiment by the mixture of fluids at different temperatures. For example, if a pound of water at 212° Fahr. be mixed with another pound of water at 32°, and the requisite precautions be used, then the temperature of the mixture will be 122°, which is the arithmetical mean between the two temperatures; and if the assumed principle be correct, a thermometer plunged into the mixture will stand at 122°. This is found to be the case with the mercurial, but not with the spirit thermometer; and, in general, thermometers formed of different fluids, when exposed to the same temperatures, do not give the same indications throughout the whole extent of the scale. An important question hence arises: what substance ought to be adopted as the standard to which, in comparing observations, all others should be reduced? It is, perhaps, not possible to determine this question with absolute certainty; but the experiments of the French chemists Dulong and Petit on the dilatation of various substances, render it probable that air and the other permanent gases (which all expand equally) afford the most accurate indications of the true variations of temperature. As compared with the air thermometer, the expansion of mercury is proportional to the increase of temperature from — 36° to + 100° of the centigrade scale. From this point to 360° (the boiling point of mercury) mercury expands more rapidly than air, and consequently the mercurial thermometer stands higher than the air thermometer in the same temperature. When the former indicates 200° and 300°, the latter indicates 197° and 292·7° respectively; and it seems to be a general law that all fluids with the same increase of heat expand more rapidly as the temperature approaches their boiling point. The more rapid expansion of the mercury at high temperatures is, however, in some measure corrected by the expansion of the bulb.

Change of the zero point.—There is a circumstance connected with the mercurial thermometer which requires to be attended to when very exact determinations of temperature are to be made. Bellani, in Italy, and Flaugergues in France, observed that when thermometers which have been constructed for several years are placed in melting ice, the mercury stands in general higher than the zero point of the scale; and this circumstance, which renders the scale inaccurate, has been usually ascribed to the slowness with which the glass of the bulb acquires its permanent arrangement, after having been heated to a high degree in boiling the mercury. Despretz (*Traité de Physique*) observes, that in very nice experiments it is always necessary to verify the zero point; for he found that when thermometers have been kept during a certain time in a low temperature, the zero point rises, but falls when they have been kept in a high temperature; and this remark applies equally to old thermometers and to those which have been recently constructed.

Register thermometers.—In meteorological observations it is of great importance to ascertain the limits of the range of the thermometer in a given period of time, during a day or night, for example, while the observer is absent. Numerous contrivances have accordingly been proposed for this purpose, but the two following are those most frequently used.

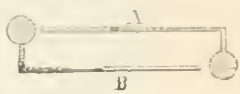
Six's register thermometer.—This instrument was invented by Mr. Six, of Colchester, England, and is described in the *Phil. Trans.*, vol. lxxii. It is a spirit thermometer, having a long cylindrical bulb A, Fig. 3410, with the tube bent in the form of a siphon, and terminating in a small cavity B. A part of the tube, from *a* to *b*, is filled with mercury; but the bulb A, and the remaining portion of the tube and a small part of the cavity B, with highly rectified alcohol. The use of the mercury in the middle of the tube is to give motion to two indices, *c* and *d*, which consist each of a glass tube in which a small bit of iron wire is inclosed, the ends being capped with enamel. The indices are of such a size that they move freely within the barometric tube, and allow the spirit to pass; but a slender spring is attached to each, which presses against the side of the tube, and is just strong enough to prevent the index from falling down when it has been raised to any point and the mercury recedes. The action of the instrument will be readily apprehended from the figure. An increase of heat expands the alcohol in the bulb A, depresses the mercury at *a*, and consequently raises it in the other branch of the siphon at *b*. The mercury while rising drives the index *d* before it; and when the temperature diminishes, the mercury recedes from the index, which is retained in its place by the action of the spring, and consequently marks the highest point at which the mercury has stood. In like manner, when the spirit in the bulb A is contracted by a diminution of heat, the mercury is pressed towards A by the elastic force of a portion of air purposely left in the cavity B, and drives before it the index *c*, which is prevented from falling back by the spring, and consequently remains at the highest point at which the mercury has stood in that branch of the siphon. When the observation has been made, the indices are brought back to the surface of the mercury by means of a magnet, which acts on the inclosed iron wire and overcomes the force of the spring. A scale is applied to each limb of the siphon, and graduated by comparison with a standard thermometer.

3110.

This instrument has all the defects which belong to the spirit thermometer, and the indications are besides in some degree deranged by the expansion and contraction of the inclosed column of mercury; probably, also, by the friction of the indices. Nevertheless, it is the best instrument we possess for determining the temperature of the sea at great depths.

Rutherford's thermometer.—Another register thermometer, simpler in its construction, and less expensive than the former, and consequently more generally used, is the *day and night thermometer* proposed by Dr. Rutherford in the *Edinburgh Transactions*, vol. iii. It consists simply of two thermometers; a mercurial thermometer A, Fig. 3411, and a spirit thermometer B, attached horizontally to the same frame, and each provided with its own scale. The index of A is a bit of steel, which is pushed before the mercury; but, in consequence of its horizontal position, remains in its place when the mercury recedes, and consequently indicates the highest degree of the scale to which the mercury has risen. The index of B is of glass, with a small knob at each end. This lies in the spirit, which freely passes it when the thermometer rises; but when the spirit recedes, the cohesive attraction between the fluid and the glass overcomes the friction arising from the weight of the index, and the index is consequently carried back with the spirit towards the bulb. As there is no force to move it in the opposite direction, it remains at the point nearest the bulb to which it has been brought, and thus indicates the lowest temperature which has occurred. By inclining the instrument the indices are brought to the surfaces of their respective fluids, and prepared for a new observation.

3111.



History of the thermometer.—The invention of the thermometer dates from about the beginning of the 17th century, but it is not certainly known when or by whom it was first brought into use. By the Dutch authors it is ascribed to Cornelius Drebbel, a peasant of Alkmaar, and by the Italians to Sanctorio. Libri (*Annales de Chimie*, Dec. 1830) maintains, on the authority of Castelli and Viviani, that the instrument was invented by Galileo prior to 1597. The thermometer of Drebbel and Sanctorio was a very imperfect instrument. It consisted of a glass tube, having a ball blown on one of its extremities, and the other end left open. A portion of air being expelled from the ball by heat, the open end was plunged into a cup containing any liquid, when, on the cooling of the ball, the liquid would rise in the tube, and the variations of its height indicate the increase or diminution of the temperature of the bulb. The instrument had no scale, and was therefore merely an indicator of changes of temperature, or a *thermoscope;* and it was defective even in this respect, inasmuch as it is affected not merely by heat and cold, but by the varying pressure of the atmosphere. The Florentine academicians first excluded the influence of atmospheric pressure by using a spirit instead of an air thermometer, and hermetically sealing the tube. The next step in improvement was the adoption of a fixed point in the scale. Boyle proposed the thawing oil of aniseeds, which he preferred to thawing ice, because it could be readily obtained at all times of the year. Halley proposed the uniform temperature of a deep pit, which he probably considered would be the mean temperature of the earth; but he also suggested the point at which spirit boils as well as the boiling point of water. Newton appears to have been the first who saw the advantage of having two fixed points in the scale; and in order that the instrument might be applicable to a wider range of temperature, he used linseed oil as the thermometric fluid. This, however, has not been found to answer, on account of its sluggish motion and adhesion to the sides of the tube. The astronomer Roemer proposed the substitution of mercury, which is now generally used; and the knowledge of the fluctuation of the boiling point of water, owing to atmospheric pressure, is due to Fahrenheit, about 1721. Since that time no improvement has been made in the principle of the instrument.

For further information on this subject the reader may be referred to De Luc, *Recherches sur les Modifications de l'Atmosphère*, Genève, 1772; Biot, *Traité de Physique*, tome 1; *Nicholson's* [illegible]; *Library of Useful Knowledge*, "Thermometer and Pyrometer;" Muncke in *Gehler's Physikalisches Wörterbuch.*

Saxton's *Deep Sea Thermometer.* In conducting the off-shore hydrography of the United States Coast Survey, the proximity of the Gulf Stream, and its important bearings on the chief highways of our commerce, have made it specially incumbent on the Coast Survey organization to develop the great physical features of this phenomenon with as much accuracy as possible. The exigency of the work of sounding along the shore has hitherto withheld the organization from any full investigation of the Gulf Stream problems, yet several results of much interest, as to its form, position, movements, and temperatures, have been already reached in more or less detail. How to observe the deep sea temperatures which are ever disturbing the rest of the ocean—how to bring up, from a depth of several miles, a trustworthy reading of the heat which prevails in those unexplored recesses, is a question which demands an answer before the Gulf Stream can be fully comprehended in its fundamental facts.

The proposed investigations were seriously obstructed by the enormous pressures in the regions to be explored, which deranged all common contrivances. The ordinary glass thermometers were repeatedly tried in the Coast Survey soundings, but as uniformly broken. Attempts were made to protect them by strong metallic cases, which were also crushed in. Mr. Saxton, the eminently ingenious and successful head of the Instrument Department in the Coast Survey Office, then devised the deep sea thermometer which bears his name, and which has been used for several years with entire success. Some accidents, not faults of the instrument, have had the effect to prevent such extensive observations as Mr. Bache had provided for, but it is to be hoped that each year will contribute to the number of our reliable observations with this elegant apparatus. We proceed to state its principle and the arrangement of its parts.

The main feature is a compound spiral of helical band or ribbon, composed of two similar plates firmly united along their surface of contact, the outer one being of silver, and the inner one of platinum. As the rates of expansion of these two metals are widely different, the variation of temperature to which the spiral is exposed, will produce a considerable movement of torsion, or rotation at the bottom of the helix, the top being fixed. This principle is familiar in Breguet's torsion thermometer, and Mr. Saxton has only applied it to a novel case, with an improved arrangement at the upper extremity of the spiral, for magnifying and reading the indication furnished. The motion of rotation given by a change of temperature, is very well fitted for reading, as by gearing it up, it gives a quite ample rotation to an index hand. Within the spiral is a hollow tube, to which at the top the spiral is screwed fast, as shown in fig. 1. Within this tube is a small rod or axle, which is connected with the bottom of the spiral, and turns freely on a supporting pivot, so as to communicate the torsion rotation to a toothed

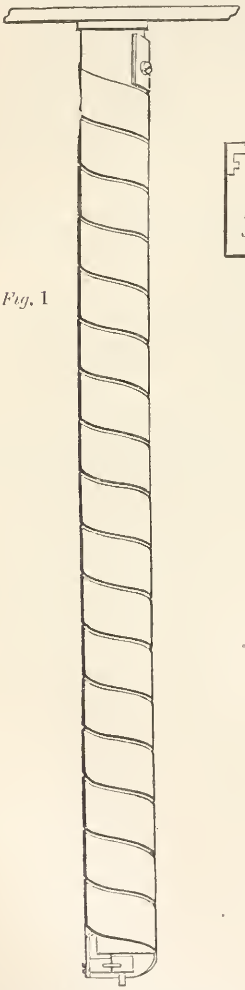


Fig. 1

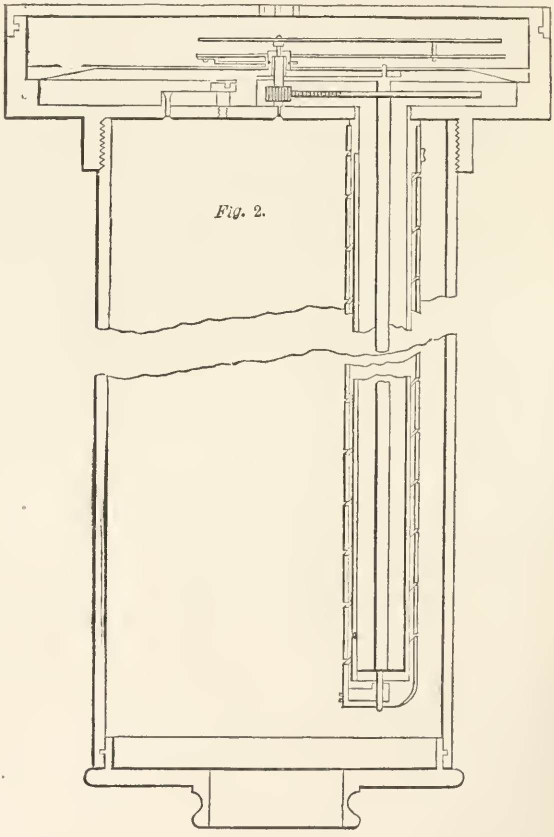


Fig. 2.

silver wheel on its top, which is shown in fig. 2; that part only being toothed which will be needed. A small pinion, which bears the index hand, takes up the motion, and is made to traverse the graduated silver rim, and carry with it a stop hand, fig. 3, which will indicate the maximum or minimum temperatures passed in the descent, according to its arrangement. Surface temperatures are read off at once, and the sounding lines give the depths.

The whole of this arrangement is inclosed in a firm metal case, as shown in fig. 4, which protects it from injury, and yet permits the water to pass freely around the spiral, causing it instantly to take the temperature of its locality. The top case is covered with a cap, pierced with small holes to permit the water to pass freely. The whole case is then mounted in a metal frame by means of two rings. The top ring turns on two side pivots, to permit the insertion of the case; but the lower ring is in halves, one of which is fixed, and the other opens out to receive the case, after which it closes, and is tightly clamped. An eye at the top receives the sounding-line, and one at the bottom any requisite sinking weights. All the delicate parts of this thermometer which could be corroded, are heavily electro-plated with gold by Mr. Mathiot in the Coast Survey Electrotype Laboratory, so that they are not liable to injury with fair treatment.

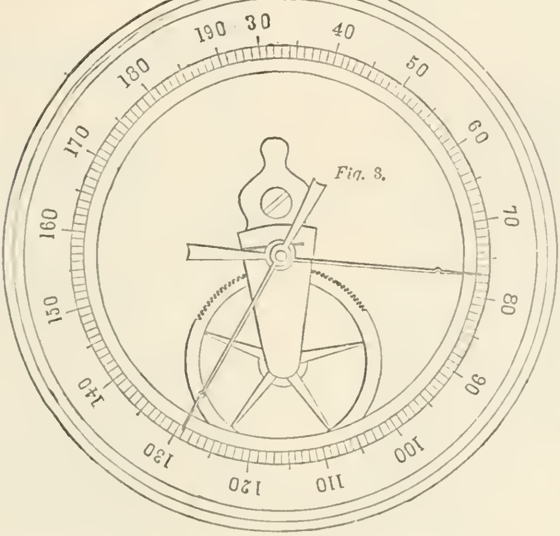


Fig. 3.

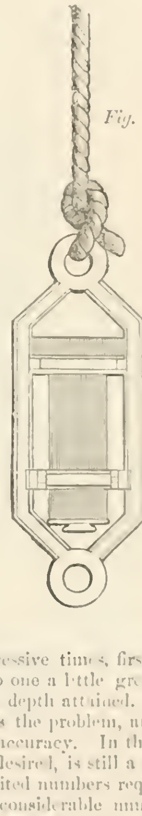


Fig. 4.

In using this instrument, it is thrown from the side of the vessel at successive times, first observing the surface temperature, and then sinking it to a small depth, and again to one a little greater, and so on, till it can be decided that the stop hand indication belongs to the greatest depth attained. The passing of a point of maximum or minimum temperature, however, complicates the problem, and makes it a matter of critical judgment to connect the temperature and depth with accuracy. In the hands of good observers, it yields excellent results, and, though not all that could be desired, is still a most excellent instrument within the range of its capacities. Its cost, made in the limited numbers required in the operation of the Coast Survey, is about sixty dollars, though a demand for considerable numbers would much reduce this amount. We trust that this or some better instrument, if possible, will hereafter be employed with increased zeal in the study, not only of Gulf Stream temperatures, but of the ocean throughout its whole expanse, and even in our lakes and the interior seas of the whole world. Surface temperatures alone are quite insufficient to give correct results, for the solar radiation produces a great effect on the superficial layers, and we must penetrate to one or two hundred feet before we enter on the grand temperature scale. A minimum temperature is usually passed in descending, at that depth where the sun's effects may be assumed to terminate, and we then enter on an increasing scale of temperatures, which, according to one of Prof. Bache's discussions, give, with the co-ordinates of depth, a curve clearly and obviously the logarithmic curve. The connection between this result, and some of the grand results of that theory of heat, which treats it as an elastic fluid, is striking and eminently suggestive, though too recondite to be more than mentioned here. There is then a vast field of research, full of interest and promise, for whose exploration this thermometer is, we believe, the most reliable instrument, and we trust it will therefore be put into increasingly active requisition.

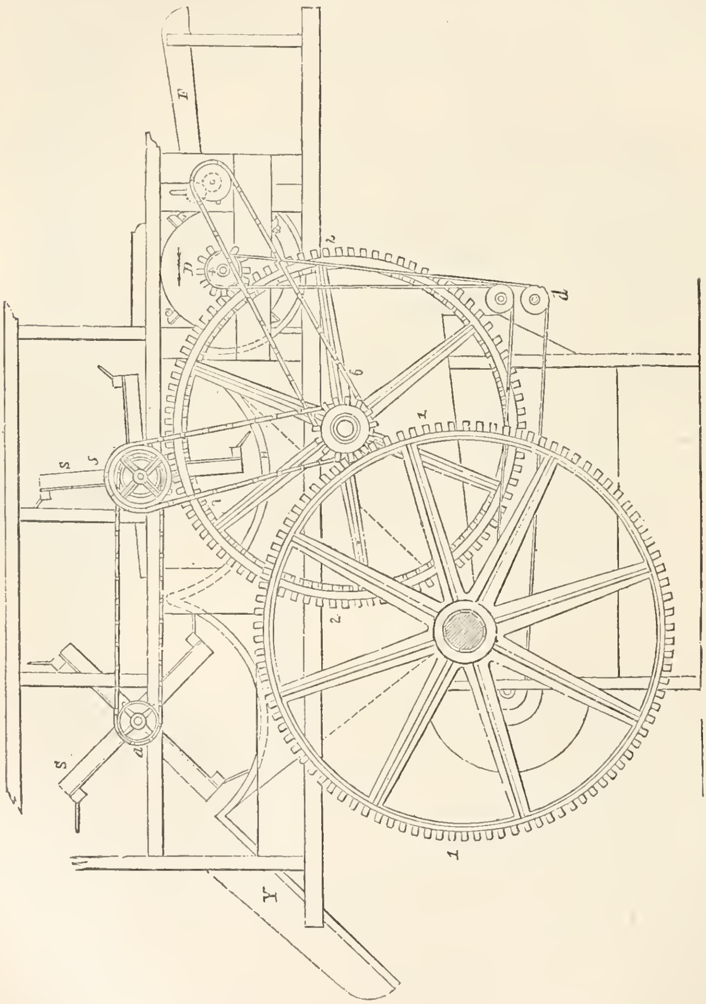
THRESHING MACHINE, WATER, *of eight horse power.* Fig. 3412 contains a side elevation of the machine, and Fig 3413 contains a plan of the same.

The same parts are denoted by the same letters in both of the drawings.

The water-wheel is of the kind denominated *overshot*, with wooden buckets. The shaft of this wheel rests on pillow-blocks bolted to the stone-work forming the sides of the wheel-pit. These pillow-blocks have sometimes covers of the regular form, but more commonly they are unprovided with covers of any sort; occasionally they are furnished with *shell-covers* for the sake of appearance, and to preserve the gudgeons from water and sand.

On the end of the water-wheel shaft, which passes into the *barn*, is keyed a spur-wheel 1, of 121 teeth; this wheel geers with the pinion 3, of sixteen teeth, upon the shaft B. On the other end of the shaft is keyed the cog-wheel 2, of 115 teeth; this last geers with the pinion 4, of 15 teeth, on the end of the shaft of a drum D, which carries on its circumference four projecting pieces called the *beaters*, their purpose being to *beat* or *thresh* the grain from the straw as this passes forward between the feed-rollers R, at the bottom of the feed-table F, upon which the unthreshen material is spread out in a layer previous to its being introduced between the feed-rollers. The feed-rollers are both fluted, and derive their motion from a pulley on the shaft B, by means of a pitch-chain 6, which passes over the pulley 8, on the spindle of the lower roller.

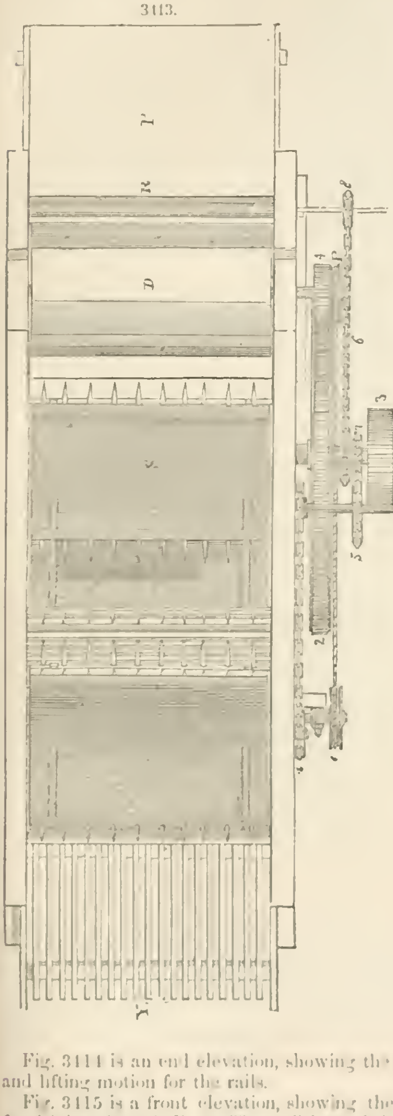
3412.



On passing the beater-drum D, the straw is taken up by the two sets of shakers S S in succession. The shakers are driven likewise from the shaft B by a pulley marked 7, and a pitch-chain which passes over a pulley marked 5, on the shaft of the first set of shakers. The second set of shakers is connected with the first by a pitch-chain, which passes over the equal pulleys *a a*, upon their shafts.

During the operation of threshing, the straw is tossed out behind the machine by the second set of shakers upon a *heck* Y, and the grain falling through the sparred segmental bottoms H H, is collected by the hopper *k k* into the fanner, situated below the machine, as shown in Fig. 3412. The fan is driven from the shaft of the beater-drum by a rope-band, which, passing from the pulley P on the beater-shaft to the guide-pulleys *b b*, embraces the fan-pulley C, of the same diameter as P, so that the fan and the beater-drum have the same speed, supposing no *slip* of the band. But the guide-pulleys *b b* are usually fixed in a frame, which can be shifted vertically, so as to increase or lessen the tension of the band at pleasure, according as the grain is heavy or light; for, when the grain is light, it will be more easily blown away with the chaff than when heavy, and for that reason a certain amount of slip of the band is allowed by lessening the tension, until the proper strength of blast is obtained.

3113.



The directions of the motions of the several parts of the machine are indicated by arrows on the elevation figures, and, indeed, are obvious from the mode of action of the machine.

THROSTLE. A spinning frame for the manufacture of cotton yarn of the lower numbers, say below 20's. Throstles are designated as the *live spindle*, used in the Middle and Southern States, the *dead spindle* used in Lowell. The Cap Spinner, or Danforth Throstle; the Ring Throstle, or Ring and Traveller. Figs. 3414, 3415, 3416 represent one of the latter class; it differs from the more common form of ring and traveller in its manner of driving the spindle. In all other throstles the motion is given to the flyer or to the spindle by a twisted band, from a central drum passing round a small pulley on the spindle.

3414.

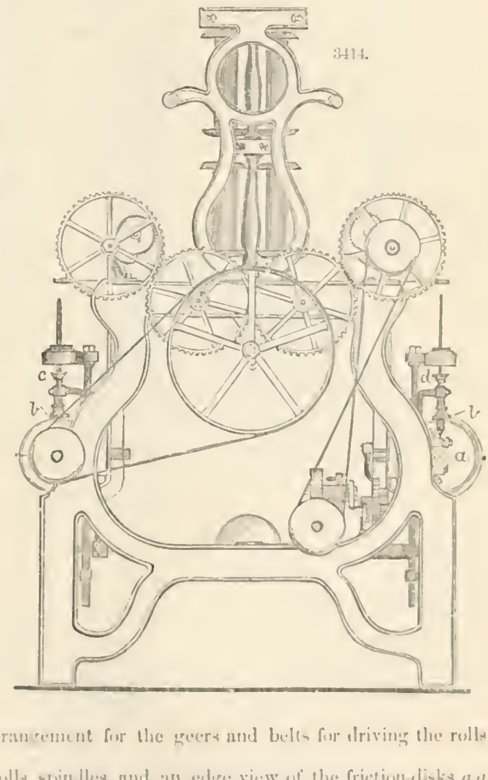


Fig. 3414 is an end elevation, showing the arrangement for the geers and belts for driving the rolls and lifting motion for the rails.

Fig. 3415 is a front elevation, showing the rolls, spindles, and an edge view of the friction-disks *a a* for driving the spindles. These disks and the whirls running upon them constitute the parts patented by McCulley. The advantages derived by this improvement are the saving of power, (which is 60 per cent.,) and the dispensing with the bands, which constantly require tightening and renewing, also a great saving in room, wear, and repair. The whirls, which are covered with leather, will last several years without need of repair.

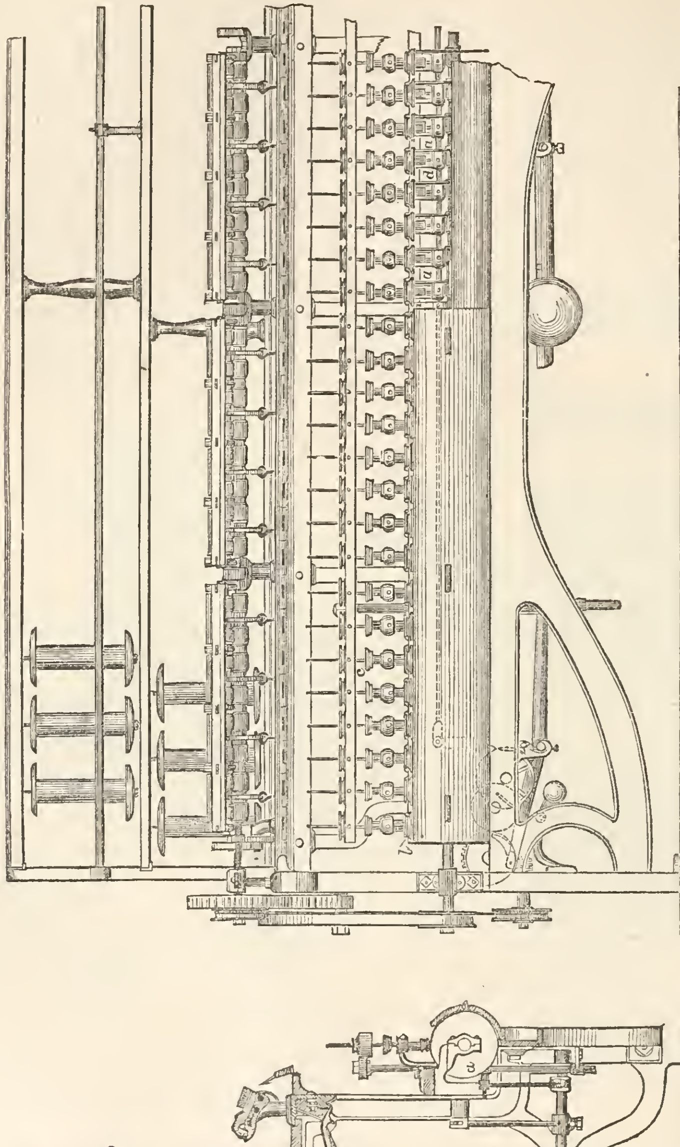
Fig. 3416 is a vertical section of the machine through the centre of one section, showing the roller stands *s*, the manner of weighting top rolls by the weights *g g*, the bearings for the side shafts, stands for the spindles, guide-rod *d* for raising top or ring rail, &c.

C is a collar on spindle in which the bobbin rests. *b* is the whirl on spindle resting on the friction disk *a*. E, weight to balance-rails. *u* is the heart, combined with geers and segment, which gives motion to the ring rail which forms the shape of the bobbin.

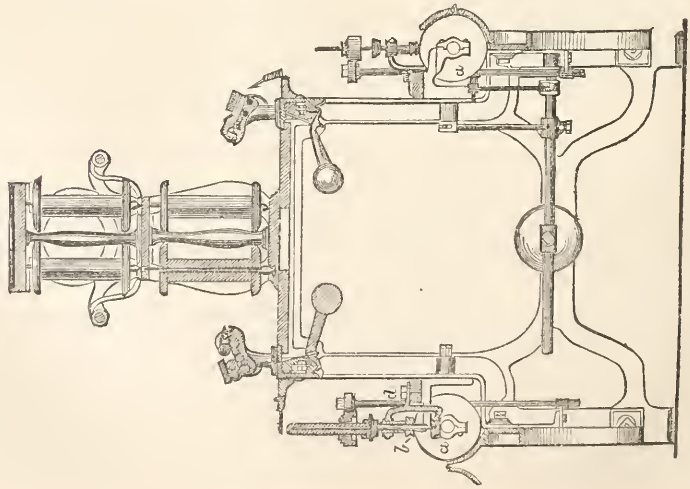
These frames are capable of being run at a great speed. The front roll may run at 1[illegible]0 revolutions per minute for No. 14 yarn.

The live spindle, a great improvement upon the method first adopted by McCulley, is the application

3415.



3416.



made by the Lowell Machine Shop, who build frames of this kind to run with *each side separate*, thereby stopping only half of the spindles while doffing.

In general arrangement, this machine differs but in the mode of driving from other ring-throstles; and in all respects but this the description applies to all ring-throstles. The older mode of driving is by a central drum, from which bands, passing round whirls on the spindles, give motion to the same.

This latter mode of driving, by the friction of the whirl on the edge of a revolving disk, is fully tested and very largely in operation. It gives a stronger, more regular and uniform motion to the spindle than is given by bands, and is applied to driving the spindles, flyers, and bobbins of all kinds of throstles, also to worsted frames, and to doublers and twisters, with similar advantages.

TIMBER BENDING. The usual way of bending planks to curved forms, has been by straining or heating the pieces and bending over a mould or frame, and leaving them keyed in this position till they had by cooling taken a set. This process not only strained the fibre of the wood, but was inapplicable to the formation of curves of short radius in large scantling. In 1849 letters patent were granted to Thomas Blanchard for improvements in bending wood and other fibrous substances. This patent claimed the bending timber by placing a powerful pressure on the ends of the body; and while the pressure was continued, it was forced around a mould to the desired curve. The pressure upon the ends of the timber prevented the elongation of the fibre outside of the curve, while the inside was necessarily shortened, thereby preventing the rupture or breaking of the same.

It was found, in the course of experiment in bending heavy timber for ships' knees, requiring short curves, that the timber, in the process of conforming to the mould, spread or bulged, much to its defacement. To remedy this defect, Mr. Blanchard was employed to construct another machine, in all respects adapted to bending ship timber. This was accomplished by encasing the timber on all sides, and effectually preventing its spreading in any direction. This improvement was of vital importance in bending heavy timber, and without which large knees could not be made. Previous to being subjected to the pressure, the fibres of the wood are softened by steaming, which also incidentally by dissolving the acid contained in the capillary vessels, increases the durability of the timber.

The fibres of wood have their origin in cells, generally shaped like a double cone, greatly elongated, and placed close and parallel to one another, with the various extremities of one set wedged in between those of another set. These fibres are generally collected together into layers, so arranged as to present the greatest resistance to forces tending to displace them in the longitudinal direction. The masses of fibre contain assemblages of cells which retain the air, fluids, gums, and resins of the tree.

In the application of heavy lateral forces to a body of wood, as in the operation of bending, the result is but a compression of its fibres to a solid mass, by the breaking up of the cells of which the fibres are only the coat or covering. These fibres will remain under the action of any force, entire and continuous throughout the body, through their flexibility and elasticity, most hard woods being taken as a standard. The grain of the wood or fibre is easily traceable, even at the point of greatest tension and displacement, the angle at a short curve, where they interlace and lock each other so firmly as to hold the extremities of a stick in position, after being bent to a right angle.

The aggregation and complication of the fibres at the angle of the curves, gives the greatest strength where it is most required, as at that point one-fourth of every inch lost in bending the interior side of the curve, is there gained. The severest tests have shown the impossibility of restoring a stick of timber, of whatever size, to its original form, after being subjected to this process; fracture would first ensue, but at those parts quite removed from the centre of the curve. Additional strength and elasticity are given to a bent piece of wood, by the interstices and cellular spaces being filled up by the solid fibrous material.

In 1856 tests were made at the Brooklyn Navy Yard, under the direction of officers of the navy, with the following results:

The knees upon which these tests were made, were of the largest size commonly used for hanging knees. In order to make the test analogous to the appliance in the vessel, a piece of oak timber of equal siding size with the knees, was fastened to the body, representing a timber of the ship's frame; also another to the arm representing the beam of a vessel. The body was secured upon an iron frame, in which the press rested, while the power was applied to the arm, on some, to contract the angle of the knee, by drawing it inward to a point of rupture; and on others, to thrust the arm outward to the rupturing point. In several cases, the fastenings were found inadequate to hold the beam and arm together, although placed in about equal quantity, size and distribution, to the proportion commonly used in vessels. It should be considered, however, that the knees were of more than ordinary stamp in quality.

Result of Trial.

No. 1—Bent knee, sided 10½ inches; moulded 10 inches at throat; remainder of size in throat made up of chock on the corner; angle of knee, 95 degrees; power applied, 5.37 feet, from corner of arm; and fulcrum at right angles with a point on the body, 1.92 feet from corner:

Bent inward, at ½ inch required......5 500 pounds.	Bent inward, at 1½ inch, required......8 500 pounds.
" " 1 " " ......7.500 "	" " 2 " " .....10.000 "

No. 2.—Natural, or grown, sided 10¼ inches, moulded to corner; angle, 96 degrees; power, fulcrum, and fastenings, same as No. 1:

Bent inward, at ½ inch, required......3.500 pounds.	Bent inward, at 1½ inch, required......7 000 pounds.
" " 1 " " ......5.500 "	" " 2 " " ......9.500 "

No. 3.—Bent knee, sided 10½ inches; moulded 11 inches in throat, and filled out to corner with chock, angle, 88 degrees; power applied as in No. 1 and 2; fulcrum at middle of throat; fastenings as before distributed:

Bent inward, at $\frac{1}{2}$ inch, required......6.500 pounds.	Bent inward, at $1\frac{1}{2}$ inch, required.....10.000 pounds.
" " 1 " " ......9.500 "	" " 2 " " .....11.000 "

NOTE.—This knee, (No. 3,) was bent inward six inches, when the fastenings giving way, the knee was allowed to return, which it did; was re-fastened, and again bent inward, when it sustained within about 9 per cent. of its first pressure.

No. 4.—Natural or grown knee, sided $10\frac{1}{2}$ inches; moulded to corner; angle square, or 90 degrees; power applied, same as those before bent; fulcrum at middle of throat, at angle of 45 degrees, with arm and body:

Bent inward, at $\frac{1}{2}$ inch, required......5.500 pounds.	Bent inward, at $1\frac{1}{2}$ inch, required.......9.000 pounds.
" " 1 " " ......7.500 "	" " 2 " " .....10.500 "

No. 5.—Bent knee, sided $10\frac{1}{2}$ inches; moulded 11 inches; filled out to corner with chock; angle right, or 90 degrees; leverage as before, 5.37 feet from corner; fulcrum at right angles from middle of throat, = to 3.08 feet:

Bent outward, at $\frac{1}{2}$ inch, required.....8.000 pounds.	Bent outward, at $1\frac{1}{2}$ inch, required...18.000 pounds.
" " 1 " " ...14.000 "	" " 2 " " ...22.500 "

NOTE.—This knee, (No. 5,) was bent outward 10 inches, without the least rupture, and the highest resisting pressure =38.000* pounds; and on being relieved, returned to within $4\frac{1}{2}$ degrees of its former angle; was again subjected to pressure, and when at $11\frac{1}{2}$ inches from its relieved position, the pressure amounted to 36.500† pounds.

No. 6.—Natural or grown knee, sided $10\frac{1}{2}$ inches; moulded to corner; full and well-grown, with 5 feet arm, the very best the Navy or market could furnish: was prepared at the navy yard, angle 82 degrees; fastenings, leverage, and fulcrum as before applied; one inch larger in body at commencement of throat. This knee had two trials, in consequence of the necessity of re-arranging to secure equality of position.

On First Trial.

Bent outward, at $\frac{1}{2}$ inch, required.....7.500 pounds.	Bent outward, at $1\frac{1}{2}$ inch, required...26.500 pounds,
" " 1 " " ...20.000 "	" " 2 " " ...33.000 "

On Second Trial.

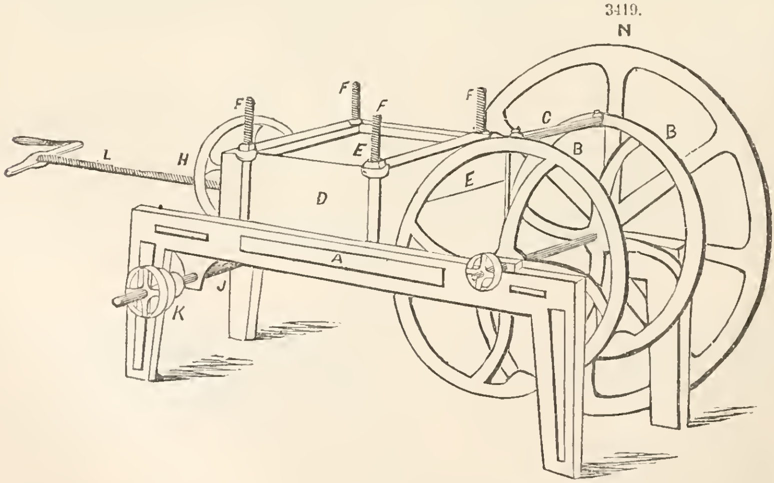
Bent outward, at $\frac{1}{2}$ inch, required...11.500 pounds.	Bent outward, at $1\frac{1}{2}$ inch, required...31.500 pounds.
" " 1 " " ...22.500 "	" " 2 " " ...38.500 "

It broke at two inches in the throat, the rupture being complete. Blanchard's patent has passed into the hands of the Timber Bending Co., who have now nearly ready for operation an improved machine, with capacity to bend timber fifty feet long and twenty inches square.

TOBACCO-CUTTING MACHINE. This is a superior constructed tobacco-cutting machine, the invention of A. P. FINCH, Red Falls, Greene Co., N. Y. Its workmanship is of a very superior kind, strong, correct, and simple, and there can be no question of its qualities.

A, Fig. 3419, is the frame; B B are two wheels on which is fixed the cutting-knife C, across the end of the box D; E is the lid of the box, under which is pressed down the tobacco to be cut, by four screws F F F F. As the tobacco to be cut has to be pressed down to a very solid bed, two cross-bars extend under the nuts of the screw-bolts across the box D, on the top of the cover E, and there are notches in

3419.



the sides of the box to allow these bars to descend with the cover on the top of the tobacco as it is screwed down. H is a cog-wheel on the screw L. The screw passes through it, and as there is a thread in the interior of the wheel, the screw will be moved forward or backward by the motion of the wheel. On the end of the screw in the box there is a square block pressing behind the tobacco to move it gradually towards the knife. This is the office of the screw. Therefore as the knife cuts up the tobacco under E, at the right end of the box, the screw pushes up the compressed tobacco to present alternately a new layer of tobacco to the knife at every revolution of the revolving cutter-wheels B B. N is a fly-wheel on the cutter-shaft, and the pulley on the left of the cutter is for a band to drive the shaft. The cog-wheel F, at the left end of the box, is driven by a worm-wheel J, (scarcely seen,) under the bottom of the box. K is a set of pulleys on the shaft of J to drive the said shaft, so that the screw may receive a forward or backward motion by the changing of the band. The handle on the end of the screw is merely to show the manner in which it may be turned.

TOOLS. The great and manifest importance of tools to the mechanic is so self-evident that it is extraordinary the subject has not hitherto received that investigation which it obviously deserves. The vast improvements in modern machinery are mainly attributable to the excellence and accuracy of the tools used in preparing and completing the various parts of which every machine is composed.

By the expression tools, according to the definition given by Mr. George Rennie, we understand instruments employed in the manual arts for facilitating mechanical operations by means of percussion, penetration, separation, and abrasion of the substances operated upon, and for all which operations various motions are required to be imparted either to the tool or the work.

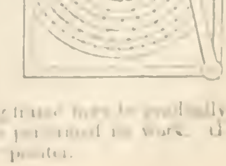
For the sake of distinctness it would be desirable, so far as is practicable, to treat the subject under two points of view: 1st. Where motion is given to the tool, as in handicraft work; 2d. Where motion is given either to the tool or the work, as in self-acting or automatic tools. Now, in the case of the turning-lathe the tool usually remains fixed, while the object invariably moves—in that of the planing-machine the tool or cutter may either remain fixed or be made to move, according to the duty required to be performed. In almost all the other machines which come under the denomination *tools*—such, for example, as are intended to perform the various mechanical operations of slotting, key-grooving, punching, drilling, nut-trimming, cutting the teeth of wheels, boring, screw-cutting—the tool receives motion, although in some cases, particularly in the nut-trimming and screw-cutting machines, the tool may be either movable or fixed.

It would afford much matter for curious and instructive inquiry to trace the early history of tools, as there can be little doubt that the use of handicraft tools is coeval with the earliest ages; and assuming the recent researches of modern travellers to be satisfactory proof of the fact that the ancients were acquainted with almost all the tools now in use, we cannot fail to admire the patient perseverance of the workman, whose skill, combined with manual labor, enabled him to produce so many beautiful specimens of his art—a circumstance the more remarkable when we consider the rude and simple implements by the aid of which this extraordinary degree of excellence was attained.

The gradual improvement in tools, which of late years have reached a very high point of perfection, is well illustrated by the wheel-cutting and dividing-engine. We therefore propose very briefly to sketch the history of those machines and appliances which come under the general name above prefixed.

While the art of constructing wheel-work was in a less advanced state, the dividing of the circumference of a wheel into the requisite number of parts, and cutting out the tooth spaces by a manual operation, was not only a tedious but also an extremely imperfect way of proceeding. To facilitate such manual operation by a file, the simple platform described by Peré Alexandre, in his Treatise on Clock-making, was invented; this platform was simply a circular plate of brass, of ten or more inches in diameter, with concentric circles traced thereon corresponding to the numbers of teeth in the wheels and pinions of clock-work. In the centre of this platform was fixed a stud or fast arbor, round which an index, with a straight edge pointing to the centre, turned freely into any given point of a required circle, by means of which the divisions of any given circle were transferred to a wheel placed on the central arbor under the index already described, by a marking point. This mode of dividing a wheel is still practised in some branches of the mechanical arts, and is, doubtless, an easy way of transferring divisions from a larger to a smaller circle for various purposes, where rigid accuracy is not required. But one great difficulty still remained to be surmounted: the spaces necessarily required to be cut by hand with a file. At length a small frame was mounted on the index, which was contrived to direct and confine the file in such a way as to cut the notches in a wheel placed over the index, with less deviation from the truth than could be managed by mere manual dexterity. It is extremely probable that this addition led to the adoption of a circular file or cutter, and of such other appendages as completed the construction of a simple *wheel-cutting machine*, and it is asserted by M. Le Roy that Dr. Hooke was the first person who contrived such an arrangement as could merit the name of a cutting-engine. The machine thus converted into a self-acting piece of mechanism was made up of the strong frame, the sliding-bars for supporting the platform or plate, with a horizontal screw for adjusting the distance from the circular file, the divided plate with a revolving arbor to receive the wheel to be cut, and the alidade or index fixed to the great frame in the position of a tangent line to any of the divided circles, and applying its bent and rounded point to any of the pierced marks of division on the circle successively, as the plate revolved, during the operation of cutting the successive teeth of a wheel. The construction of the engine is very nearly identical in principle to that used in the present day, more especially for cutting the teeth of small wheels, as shown in Fig. 3120. Here A shows the arbor on which the wheel to be cut is fixed. B, the cutter. C, a toothed wheel worked by the handle E, and taking into the pinion D, which being on the same axis as the cutter B, imparts to it a velocity proportionate to the number of teeth in the wheel C, and the pinion D. F is a lever handle by means of which the swinging frame may be gradually depressed as the cutter B is brought into operation, or raised when it has performed its work. G the horizontal screw of adjustment, H, the division plate, and I the index or pointer.

3120.



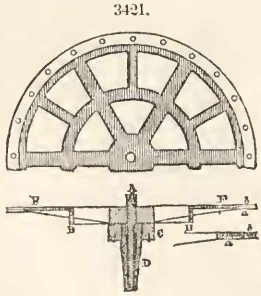
The original divisions of the circle, namely, 360, 300, 150, 90, 60, &c., are commonly retained in the ordinary engines, although many of the smaller numbers are included in the larger ones, and are, therefore, superfluous; for, taking every fourth hole in the circle of 360, gives precisely the same result as using the circle of 90, or every sixth as using the circle of 60, and, in like manner, taking every other hole in the circle of 300, will be precisely the same in effect as using the circle of 150. It must, we think, be obvious to every one, acquainted with the ordinary process of cutting the teeth of wheels, that engines, of the construction just described, are very limited in their operations, by reason of their powers extending only to the numbers marked on the divided circles, or the factors of which those numbers are composed, and because the prime numbers are not usually inserted. To remedy this defect, and at the same time render the engine of greater practical utility, appears to have been a favorite study with different ingenious artisans, whose daily avocations admirably qualified them to appreciate the improvements we have already referred to, as well as to devise such additional apparatus as would make the engine more perfect.

It is unnecessary to pursue further the minute details of this subject, but it is to be observed that the only true and accurate method of circular division, namely, by a tangent-wheel and endless screw, first contrived and used by Dr. Hooke in 1664, for the purpose of dividing astronomical instruments, has been from time to time advantageously applied to the wheel-cutting engine by eminent mechanicians.

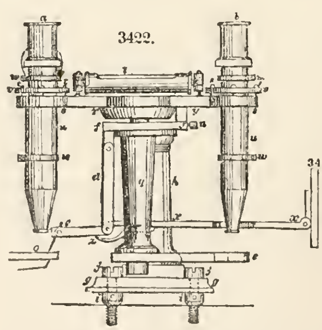
We now proceed to the dividing-engine, of which it has been justly observed, that "none has so much contributed to the interest of navigation considered as a science;" indeed the facility, and at the same time the accuracy, with which the measuring portion of any astronomical or mathematical instrument, however portable, can now be divided by our best engines, are truly astonishing; the fine lines of division which in many instances are scarcely visible to the naked eye, are, when magnified by a suitable lens, perceived to be laid down with perfect equality, as to relative distance, so much so, that no one who has not examined the means by which the result is produced, can conceive the possibility that the expedition with which the divisions are made, is equal to the accuracy with which they are measured and marked down.

Several trials were made at the Greenwich Observatory, by Flamsteed, the Astronomer Royal, but the method was found defective, probably in consequence of imperfect workmanship, and was soon abandoned. In Mr. Smeaton's paper, read before the Royal Society of London, November 17th, 1785, on the "Graduation of Astronomical Instruments," he mentions an engine made by Mr. Henry Hindley of York, which indented the edge of any circle in such a way that a screw with fifteen threads acting at once, would, by means of a micrometer, read off any given number of divisions, so as to answer the purpose of subdividing the circle. Mr. Ramsden, in consequence of the reward offered by the Board of Longitude to Mr. Bird, for his method of dividing, in the year 1760, turned his attention towards the contrivance of an engine that would divide nautical instruments with sufficient accuracy, without resorting to the delicate and tedious process of manipulation, practised by Mr. Bird. He completed an engine with an indented plate, or wheel of thirty inches diameter, which, though it did not entirely answer his expectations to their full extent, yet was found very useful for dividing theodolites, and such like instruments, with great facility. This was effected before the spring of 1768; and in 1774, a much larger and more efficient engine was produced, with an indented plate of forty-five inches diameter, which divided a sextant for Mr. Bird's examination so accurately, that the Board of Longitude, ever ready to remunerate any successful endeavor to promote the lunar method of determining the longitude at sea, did not hesitate to confer a handsome reward on the inventor, but on the express condition that the said engine should be at the service of the public, and that Mr. Ramsden should publish an explanation of his method of making and using it.

3421.



3422.



In 1820, Mr. James Allan was rewarded by the Board of Longitude with one hundred pounds, for his improvement on Ramsden's dividing-engine. This improvement consists in the method employed to cut or rack the teeth around the periphery of the great circle, worked by an endless screw, upon which the arc to be divided is placed, so as to insure perfect equality of size, as regards the teeth, in all parts of the circle. This extremely ingenious, though simple contrivance of Mr. Allan, is described in the transactions of the Society of Arts. The great circle of bell-metal, a semi-plan of which is shown in Fig. 3421, is mounted upon an axis A, and its surface made truly plane and perpendicular to the axis; the section shows the figure of the axis, and the central ring B, to give the greatest strength to the circle; C is a section of a portion of the frame of the engine; and D, a socket into which the axis A is fitted; the circumference of the large circle is then turned to such a figure as to receive a ring of brass *a*, which is united firmly to it by a number of pins. Upon this ring a second, *b*, is placed, the two making the same thickness as the circle, a sectional view of which is here introduced. The inside of the ring b, and the outside of the bell-metal circle, are fitted to each other with the greatest accuracy, and great care taken to turn the same truly fitting concentric with the axis of the circle; the brass rings a and b are held together by twenty-four screws, and a groove corresponding to the curvature of the screw which moves the circle is then turned in the outside of the two; in this state the racking of the teeth is performed by a screw similar to that afterwards used to turn the circle to its divisions, but notched across the threads so that it cuts like a saw, when pressed against the circle and turned round, and removes the metal from the spaces between the teeth, which are by this means formed around the edge of the circle; when this has been performed all round, two fine lines are drawn across the brass and bell-metal circles, diametrically opposite to each other; the twenty-four brass screws are then withdrawn, and the upper brass ring turned exactly half round, which is determined by the lines before mentioned; and by this means the teeth of the circle are divided into two thicknesses, and being put together again in opposite directions, if any error arose in racking the teeth, it would be shown by the upper and lower halves of the teeth not coinciding when reversed, and by racking them while reversed, the screw would cut away the inequalities, and make all the teeth of the same size and distance from each other; this reversing the teeth is performed several times, till the teeth are brought to a perfect equality in all parts of the circle; four steady pins are accurately fitted into the two rings to hold them together in any of the positions in which they have been racked together, and it is upon them that dependence is placed for the coincidence of the teeth, the twenty-four screws being merely to hold them fast together, and fitted rather loosely in their holes that they may not strain the steady-pins.

We have purposely omitted any mention of the improved engine by Mr. E. Troughton, in whose hands the art doubtless arrived at a high degree of exactness, because, to adopt the language of a competent judge, there are various difficulties in the application and construction of the apparatus, to avoid which was the avowed object of the engine now in part to be described, by adopting principles perfectly independent of mechanical action, and governed only by vision, assisted by the most powerful optical means. For this really scientific piece of mechanism we are indebted to Mr. Alexander Ross, mathematical instrument maker, to whose ingenuity the Society of Arts of London, in 1831, awarded the Gold Isis Medal and fifty guineas.

Fig. 3422 is a side view of Mr. Ross's apparatus for cutting original divisions, and consists of the following parts: a small circle 10 or 12 inches diameter, divided into spaces of 3° 45′ or 96 parts, by the usual dividing-engine or by any ordinary means—two micrometer microscopes, represented at $a\,b$ an arc $c\,c$ of the length of 3° 45′ of the circle to be divided—a cutting-frame $d\,e$, and a frame $f\,f\,g\,g$ to support the apparatus. The frame $f\,g$ consists of a bottom and top plate connected by two strong pillars, one of which is represented at h, the front one being removed to show the other parts. In the bottom plate are screwed the nuts $i\,i$ which form adjustable feet for the frame; these nuts are perforated, and the screws $j\,j$ pass through and fasten the whole securely, after being levelled by the nuts i and the level l. The upper plate is secured to the pillars h by two screws and collets, moving on the one as a centre, and adjustable at the other by the pushing screw n for the purpose of setting the cutting-point o, which is attached to the upper plate f, to cut a radiating division on the circle to be divided: an arc and index not capable of being shown in a side view, indicate the inclination given. To the upper plate is likewise attached the hollow centre q; in this works a male centre, the flanch of which is seen at r; this supports the bar $s\,s$ which carries the microscopes $a\,b$ and the level l. The microscopes are secured to this bar by two pulling and two pushing screws $t\,t$, $t\,t$, passing through a flanch v, and acting in and on the bar s. The microscopes are secured to the flanch by fitting into strong tubes $u\,u$, and when adjusted to distinct vision can be fixed in that position by the clamping-rings $w\,w$. The handle $x\,x$ for the cutting-frame is attached to the perpendicular sling d, having a double joint at the point where it is fixed, in order to prevent any unequal pressure from producing a lateral motion of the cutting-point; the other end is connected to the upright dovetail slide 31, which forms part of the apparatus for moving the cutting-point. (See article Automatic, in 1st volume of this Dictionary.)

From a consideration of the foregoing sketch we draw the following conclusion, namely, that the difficulties and failures which have from time to time checked the progress of inventive genius are to be traced to two sources: first, a limited knowledge of elementary principles; and secondly, the defective construction and consequent imperfect performance of the tools employed.

One of the most valuable aids to the more perfect construction of machinery is due to Mr. Joseph Whitworth, of Manchester, who has recently introduced the simple process of *scraping*, instead of the dirty and unsatisfactory operation of grinding, as a means of producing plane metallic surfaces. It is essentially required in a surface for mechanical purposes, that all the bearing points should be in the same plane, that they should be equidistant from each other, and that they should be sufficiently numerous for the particular application intended. Where surfaces remain together in fixed contact, the bearing points may, without disadvantage, be fewer in number, and consequently wider apart; but in the case of sliding surfaces the points should be numerous, and in close approximation.

A little consideration will make it evident that these conditions cannot be obtained by the process of grinding. And first, with regard to general outline, how is the original error to be got rid of? For if it be supposed that one of the surfaces is concave, and the other a true plane, then the tendency of grinding, no doubt, would be to reduce the error of the former, but the opposite error would at the same time be created in the true surface. The only case in which an original error could be extirpated, would be when it was met by a corresponding and contrary error of exactly the same amount in the opposed surface; but it is evident that where only two surfaces are concerned, the variety of error in the general outline is not sufficient to afford any probability of mutual compensation. It will further appear, that if the original error be inconsiderable, the surfaces must lose instead of gaining truth. It results from the nature of the process that certain parts are acted upon for a longer time than others; they are consequently more worn, and the surfaces are made hollow; nor is there any probability of obviating this source of error except by sliding the one surface entirely out of the other at each move, a method which is clearly impracticable.

It may be mentioned as an additional cause of error, that the grinding powder collects in greater quantity about the edges of the metal than upon the interior parts, producing the well-known effect of the bell-mouthed form. This is particularly objectionable in the case of slides, from the access afforded to particles of dust, and the immediate injury necessarily occasioned thereby. Another circumstance materially affecting the durability of ground slides is, that a portion of the emery becomes fixed in the pores of the metal, and can never be entirely eradicated therefrom, causing a rapid and irregular wear of the surface.

If, then, grinding be not adapted to form a true general outline, neither is it to produce accuracy in the minuter detail. There can be little chance of a multitude of points being brought to bear, and distributed equally under a process from which all particular management is obviously excluded. To obtain any such result, it is necessary to possess the means of operating independently on each point as occasion may require, whereas grinding affects all simultaneously. It is subject neither to observation nor control, there is no opportunity of regulating the distribution of the powder, or of modifying its application, with reference to the particular condition of the different parts of the surface. The variation in the quantity of the powder and the quality of the metal will of necessity produce inequalities, even supposing they did not previously exist. Hence, if a ground surface be carefully examined, the bearing points will be found lying together in irregular masses, with extensive cavities intervening. An appearance indeed of beautiful regularity is produced, to which, no doubt, we may trace the universal prejudice so long established in favor of the process; but this appearance, so far from being any evidence of truth, serves only to conceal error, and under this specious disguise surfaces pass without examination, which if unground would be at once rejected.

In addition to what has been stated, it must be remembered another great evil of grinding is that it takes from the mechanic all sense of responsibility and all spirit of emulation, while it deludes him with the idea that the surface will be ultimately ground true; hence he slurs his work over in a slovenly manner, trusting to the effect of grinding, being conscious that it will efface all evidence either of care or neglect on his part.

Thus it appears that the practice of grinding has altogether impeded the progress of improvement. A true surface, instead of being, as it ought, in common use, was until lately almost unknown; few mechanics have any distinct knowledge of the method to be pursued for obtaining it, nor do practical men sufficiently advert either to the immense importance or to the comparative facility of the acquisition. The expression "true surface" may appear contradictory, and therefore require qualification. Absolute truth is confessedly unattainable; moreover, it would be possible to aim at a degree of perfection far beyond the necessity of the particular case, the difficulty of which would more than counterbalance the advantage; nevertheless it is certain that the progress hitherto made falls far short of this practical limit, and that considerations of economy alone would carry improvement many degrees higher. The extensive class of machinery denominated tools, affords an important application of the subject; here every consideration combines to enforce accuracy. It is implied in the very name of the planing engine, the express purpose of which is to produce true surfaces, and it is itself constructed of slides, according to the truth of which will be that of the work performed; and when it is considered that the lathe and the planing engine are employed in the making of all other machines, and are continually reproducing surfaces similar to their own, it will manifestly appear of paramount importance that they should themselves be perfect models. Indeed it would be difficult to mention any description of machinery which would not serve as an illustration of the importance belonging to truth of surface, and at the same time offer abundant evidence of the present necessity for material improvement; nor is there any subject connected with mechanics, the bearings of which, whether regarded in a manufacturing or scientific point of view, are more varied or more extensive.

The tool employed for scraping is not only simple but easily made; it should be of the best cast-steel, and carefully sharpened to a fine edge on a Turkey-stone, the use of which must be frequently repeated; but worn-out files may be converted into convenient scraping-tools. A flat file with the broad end bent and sharpened will be most suitable in the first instance, and afterwards a three-angled file sharpened on all the edges. The process of scraping is equally simple, requiring rather care than skill on the part of the workman, whilst it affords a certain and speedy means of attaining any degree of truth that may be deemed necessary, thus tending to the gradual establishment of a higher standard of excellence, the influence of which cannot fail to affect beneficially all mechanical operations, opening at the same time to the mechanic himself a new field in which he will find ample scope for the exercise of skill, both manual and mental.

We are now in a condition to proceed with the matter more immediately under consideration. The value of every cutting instrument depends upon the excellence of the steel of which it is made, the care bestowed during the several processes of forging, hardening, and tempering, and the just adaptation of the angle or bevel which forms its edge to the work it is intended to perform. Generally speaking, this angle is determined by the hardness of the substance to be operated upon. Thus we see chisels for cutting soft woods are thinner than those used for the harder species, and these again are more acute than chisels employed for cutting metals, or in other words, the greater the resistance offered by the material to be cut, the more obtuse must be the angle of the tool. This definition is not propounded as rigidly correct in all cases, although it is susceptible of abundant practical illustration; for example, in hand-turning, the workman is enabled by raising or lowering the T of the rest, to vary the direction and limit the cut of the tool employed, according to circumstances. This one fact, amongst a multitude of others equally palpable that could be adduced, might have been expected to induce inquiry and investigation. On the contrary, we have the authority of Mr. Nasmyth for stating that the form of tools, more especially those used in turning and planing iron, brass, &c., has not hitherto received either that attention which the importance of the subject calls for, nor has any attempt been made to reduce it to plain and general principles, of which it is highly susceptible, and if so treated would be of much service to those in whose hands the management of such tools is for the most part intrusted. So many considerations of a practical nature are inseparable from this subject, that the quality as well as the quantity of work produceable from turning lathes and planing machines depends entirely upon the skill of the workman in giving to his tools the proper form.

The general principle propounded by Mr. Nasmyth, which is equally applicable whether the motion be horizontal, circular, or vertical, is deduced from a consideration of the direction in which the metal is to be cut or penetrated. With regard to the first case, as in the planing machine, it is manifest that the face of the tool is at right angles to the plane of the material to be cut, and consequently, if its point or cutting edge be made in the form of a very obtuse angle, it will possess little or no penetrating quality—such a tool would not cut, but rather abrade, or probably crush off the particles of metal. Again, if we resort to the other extreme, and give to the cutting edge the shape of an extremely acute angle, we shall find, however *sharp* it may appear, a total absence of penetrating quality, or at all events in the required direction, and what is equally objectionable, the point being weak would snap off, incapable of resisting the least applied force.

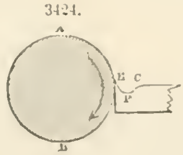
From an investigation of these and other obvious facts, Mr. Nasmyth concludes that a tool of the form shown in Fig. 3123 fulfils the requisite conditions, as it combines a high degree of acuteness with sufficient strength—the former in the direction of the cut, and the latter behind the point or cutting edge, where it is most needed. Hence the following principle may be established, namely, that in forming and setting a tool to cut any surface, it is essentially necessary so to place it that *the end shall form the least possible angle with the surface to be cut*, or in other words, as nearly parallel as possible, and whatever degree of acuteness may be deemed necessary must be obtained by hollowing out the face E C, on which the shavings slide. An apt and very familiar illustration of the principle may be drawn from the common plane of the joiner. An artificial end being given to the plane-iron, which is here the cutting tool, by means of the sole of the plane, this necessarily limits the penetrating quality in all directions except that in which it is required to remove the material. Further, it can scarcely have escaped observation that the bevelled surface of a chisel is invariably placed outwards, and the flat surface next to the wood, so that the face of the chisel next the wood and the surface of the wood itself shall form the least possible angle.

The same principle is similarly true in the case of turning-tools, and indeed in every tool, from the smallest and most delicate of the clock and watch maker, up to the largest and most powerful tool in an engineer's lathe or planing machine.

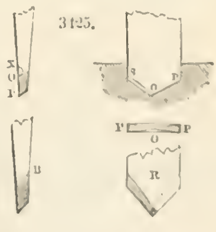
As regards circular motion, we have a clear exemplification of the principle by merely considering the tool already described as a turning-tool. In Fig. 3424, A B shows a section of a cylindrical bar in the lathe, and E F so placed as to be, as nearly as circumstances will permit, a tangent, that is, at right angles to the radius of the curve—the requisite acuteness being obtained, as before, by hollowing out the face E C.

3423.

3424.



3425.



The same principle applies to drills. Thus Fig. 3425 being the end view of a drill, the edge O P should be in the least degree prominent or out of the plane of the surface, of which the bounding lines are the edges, O S being slightly less prominent than O P, so that the penetrating quality at the edge O P may be limited as much as possible. An adherence to these rules will produce a drill that shall cut a smooth and equal hole, without chattering, as is commonly the case when the edges are bevelled very much back, as shown at R. The necessary acuteness to the cutting edge of the drill is easily obtained by merely observing the principle laid down in respect to turning-tools, that is, by hollowing out a groove at X, on each cutting face.

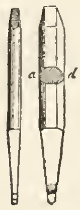
Every mechanic is sensible of the value of good tools as necessary appliances to the performance of his work more quickly, with less exertion, and more accurately than can be done with inferior ones; yet how few are in a position to answer this apparently simple question, what constitutes this quality denominated *goodness?* The excellence of cutting tools is generally decided by their relative degrees of endurance, but how many incidental circumstances may, and frequently do, interfere to vitiate any accurate comparison. As regards hardness, nearly the only test is the resistance the objects offer to the file, a mode extremely fallacious, because files differ among themselves in hardness, and at best only serve to indicate in a very imperfect manner, to the touch of the individual, a vague notion without any distinct measure. Take, for example, two chisels for turning iron, both of cast steel, and from the hands of the same maker, and although precisely alike in outward appearance, the one may be absolutely worthless and the other equally valuable. Nay, one portion of the same chisel may be good and the other bad. If during the process of fabrication of two cutting tools the same treatment be pursued with similar care, we should naturally expect, all things being coincident, that the one would correspond with the other. Experience shows the fallacy of this mode of reasoning. Nearly every metal turner makes his own tools, and for this plain reason, that he cannot place any dependence on those he purchases. The smith who forges, hardens, and tempers these tools, rarely uses them, he labors to produce a certain number in a given time, and if they satisfy the eye his object is attained. The good or bad quality of a tool depends more on the care and attention bestowed during the process of forging than is commonly imagined, and the defects, whether of texture or edge, which so often present themselves in articles manufactured of steel, are to be traced not so much to any natural imperfection or partial conversion of the metal, as to a slovenly and hasty mode of forging. (See STEEL.)

The tool employed for chipping is simply a chisel with an edge assuming the shape of an acute wedge; it is ordinarily made from square or oval steel of the best quality, rather spread out at that end which is intended to form the edge, so as to afford a greater surface. Whatever may be the length of the chisel, whether *six* or *eight* inches—and this must depend in some measure upon the nature of the work—the form of the cutting edge is in all cases nearly similar; observing, however, that it is advisable to have the chisel drawn out by the smith, by which precaution the edge, when injured, may be more easily restored on the grindstone. The operation of chipping is materially facilitated by the use of the *cross-cutting* chisel, of which Fig. 3426 shows a front and Fig. 3427 a side view, *a a'* in the latter figure being a section. The cutting edge of this extremely useful tool varies in breadth from one-sixteenth to five-sixteenths of an inch; its utility and application will probably be rendered more obvious to the reader by a diagram than by any lengthened verbal explanation.

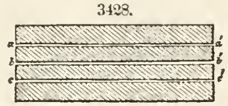
Suppose the surface of a block of cast-iron, represented by Fig. 3428, to require chipping. In the first place, the workman cuts longitudinal grooves *a a'*, *b b'*, *c c'*, throughout or across the entire length or breadth of the surface by means of the cross-cutting chisel, and at such a distance from each other as is rather less than the width of the chipping chisel intended to be subsequently employed; by which means the corners of the edge of the chipping chisel are essentially preserved from injury, as under ordinary circumstances it is found that the corners of the chisel first give way, and require constant repair.

The interior portions of any piece of metal are usually removed by a tool called a drill. Boring differs from drilling principally, as we shall hereafter show, in being applied to larger works. The class of tools which come within the general description of drills, or cutters, is extremely numerous; that more commonly employed is too well known to require description, more especially as we have already given Mr. Nasmyth's improved form of this tool. The pin-drill and half-round drill are, in certain cases, extremely useful; the only objection to the former is, that it requires a small hole to be first cut in and through the metal in which the pin of the drill works and necessarily follows; it answers, however, for

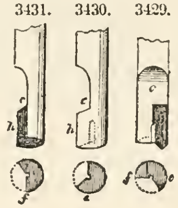
3426. 3427.



3428.



3431. 3430. 3429.



all ordinary purposes, and performs its work extremely well, although it cannot be depended on in cases where rigid accuracy is required. The half-round drill offers little or no security whatever as regards piercing in a right line; it is, however, a very useful tool, and may, in many instances, be advantageously employed. Perhaps the most effective form of drill yet introduced, more especially if applied to any metallic substance revolving in a lathe, is that invented by M. Collas, an eminent French mechanician. This tool, of which Fig. 3429 is a front view, and Figs. 3430 and 3431 side views, taken from from *e* and *f*, is turned truly cylindrical throughout its entire length, except at that end which is intended to fit into the brace, or if used in a lathe a small portion of the metal is filed square, or the edges taken off to admit of any convenient mode of preventing the drill turning. At the other or opposite extremity of this cylinder of steel, and through the centre a small hole is drilled in proportion to the size of the tool; one half of a portion of the bar is then cut away, leaving the remainder cylindrical; this part is then equally divided into three, and one of them filed out, as is clearly shown in the plan views of Figs. 3429, 3430, and 3431, by which process the central hole is cut into two equal parts, and becomes a small semicircular groove. With regard to the angle of inclination to be given to the cutting end of the drill, this must depend principally upon the resistance offered by the material.* This tool manifestly cuts circularly, except at the centre, where it forms a small projecting pin, which enters the central groove and serves as a conductor; in proportion as the tool advances this pin increases in length until it reaches the extremity of the groove, when it necessarily breaks and comes away with the chips. It is important to observe that this groove must be rather less than greater than a semicircle, otherwise the pin of metal which enters therein, being cylindrical, could not leave it during the progress of the operation, and the distinguishing feature of this tool would be destroyed.

Small drills are commonly made of a single piece of steel wire, upon which, near to the middle, a pulley or drill-barrel is driven. Occasionally a small mandrel is used, provided at one end with a square

* Drills or boring-bits ought to have the angles of their edges varied according to the nature of the metal to be bored; thus, wrought-iron would require a very different angle from that used for cast-iron. If, in use, the bit trembles or jars, it is a sign that the angle is too acute, and must be made more obtuse, or nearer to a right angle with the plane or flat face of the drill. Again, if the obliquity of the other, or crossing angle, be too great, the tool will also have too great a tendency to form a nipple or cone in the centre of the bottom of the hole, and to bore the hole gradually wider and wider instead of truly cylindrical, as it will do when properly formed; and that fault must therefore be corrected by grinding the drill or bit so as to reduce its obliquity, or bring it nearer to a right angle with the sides of the bit.

hole about half an inch deep, into which drills of various dimensions can be inserted. The disadvantage of this mode of construction is, that the drill is rarely placed true in the mandrel, which necessarily causes it to perform indifferently; it is, therefore, but seldom employed by practical men who have the convenience of readily supplying themselves with drills of various dimensions as required.

When small drills are used they are held horizontally and kept up to the work by a breast-piece, which is usually made of wood, armed with a plate of steel superficially pierced with holes of different dimensions, in one of which the blunt end of the drill works. The drill receives a reciprocating motion from an elastic bow, the spring of which is coiled once round the pulley. Common bows are ordinarily made of stout cane, those of a better description of steel, and the string of catgut, but the strength of both must necessarily be proportioned to the size of the drill.

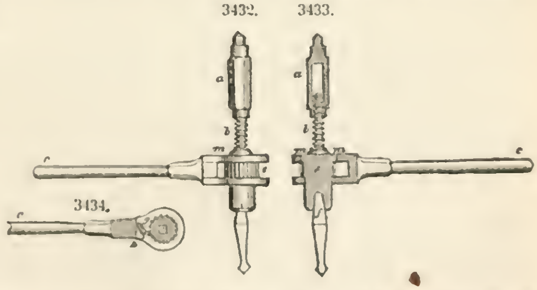
In order to cut large holes more force is obviously required than can be imparted by the method just described, instead of which a brace, not very dissimilar to that used by carpenters, is employed, and the drill itself is fitted as a boring-bit; but with this difference in the mechanical arrangement, instead of the stock remaining stationary, we have in this case a long tapering spindle, which being nothing more than a continuation of the brace, is necessarily carried round at the same time, and the motion becomes continuous. The upper part of this spindle works in an iron or steel plate, which is attached to the under side of the beam, called the drill-beam. One end of this beam turns upon a transverse pin, between two uprights, pierced with various holes, to allow facility of fixing it by means of the pin at different elevations. The other end of the beam traverses between two uprights, and carries a heavy weight, which acting as a lever necessarily keeps the drill to its work, and the point of the drill being placed upon that part of the metal to be bored, the brace is revolved by the hand of the workman.

The shank of the drill should be accurately fitted in the brace, and the apparatus is generally so arranged that the work may be held in a strong bench-vice during the process.

The difficulty of applying a press or lever drill in confined situations appears to have been very generally felt. In Bergeron's *Manuel du Tourner*, there is a plan of a brace worked by a pair of bevel-wheels, and Mr. George Rennie, in the last edition of Buchanan *on Mill-work and other Machinery*, has given two views of a portable drill, invented by Messrs. Nasmyth, Gaskell, & Co., of Manchester, which consists of a cast-iron frame, carrying an upright drilling spindle, the top of which is formed into a screw, so that it may be raised or depressed by a handle-wheel, while the requisite revolving motion is imparted to it by two small bevel-wheels. When required to drill a hole in any piece of machinery, it is first of all set in its proper place; after this is done the handle or small fly-wheel is turned round for working the drill, and by a slow revolving motion given to the upper handle, communicating by means of the screw, the drill while working is made gradually to descend.

The contrivance we have now to describe is, we are informed, the invention of a practical mechanic, then in the employ of Mr. Hague, of London. The distinguishing feature of this tool is the introduction of a ratchet-wheel and click, which obviate the necessity of turning the brace completely round, so that the effective power of the workman is constantly acting at the greatest advantage. Fig. 3432 shows an elevation of the complete tool. Fig. 3433 is a section of the same; and Fig. 3434 the ratchet with its appendages, and the arm separately. It is composed of two parts: the first distinctly shown in the sectional view, and distinguished by the letter *a*, which is simply an elongated nut; the second is a circular piece of wrought-iron, terminating in a square threaded screw *b*, and working into the aforesaid nut *a*. The combined length of these two, which constitute the principal part of the tool, as shown in Fig. 3432, may be lengthened or shortened at pleasure, by means of a nut *a*. The bottom piece *b* has a square hole, slightly tapered, cut in its extremity, and in a direction with its axis for receiving the drill *f*. The handle or third portion of the tool, shown separately in Fig. 3434, fits on to *b*, for which purpose a square hole is cut in it as shown at *e*; the handle has a portion of it at one end cut out to receive the ratchet and its appendages, as is apparent from inspection of the figure, and is kept in its place by the ring or cap, shown in section at *m m*, Fig. 3433. The action of the ratchet wheel is plainly restrained to one direction by means of the click *g* and spring *h*, so that when the handle is moved with a backward pull, the drill does not move.

3432. 3433.

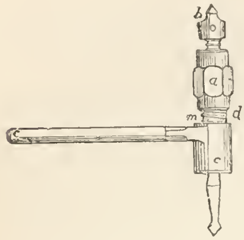


3434.

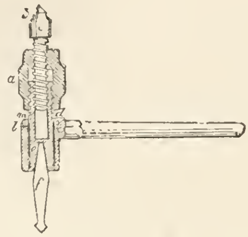
In working, the conical point of the brace is placed under a temporary framing of cast iron; the tool being thus fixed is set in motion by means of the handle *e*, the drill being pressed down when necessary, or, in technical language, "kept to its work," by unscrewing the upper portion or nut *a*, by means of a piece of pointed iron which enters a hole cut for that purpose, and obviously urges the drill downward.

Such, with some unimportant modifications, is the form in which this very useful implement has till recently been constructed. Its advantages may be enumerated in few words: it requires less exertion than any form of brace or drill-stock previously introduced, and it performs its work with greater accuracy. It is not, however, free from defects; the ratchet wheel, click, and spring, are liable to derangement, and require to be frequently replaced, and the noise which is produced in working the instrument is far from agreeable. These objections are obviated by an arrangement recently proposed by Mr. Shanks of Johnstone, England, which, we think, will be found in every respect superior to the old form, and only requires to be more generally known to insure its preference and adoption. The principal peculiarity of Mr. Shanks' hand drill is the substitution of a spiral steel band, or clutch, embracing the drill-stock, and acting upon it by friction for the more complicated combination of ratchet-wheel, click, and spring. Fig. 3435 shows an elevation, and Fig. 3436 a section of this improved form of the tool, *a* is the hallow nut for adjusting the drill to different lengths, *b* the screw for feeding the drill, *c* the handle of the same form, and worked in the same manner as that already described, but made with a cylindrical socket *c'*, which embraces the spiral riband *k*, and of which Fig. 3437 is a detached view. This spiral riband or clutch is bored truly cylindrical to fit the drill-stock *e*, and rests without being fixed upon a collar at the lower end of the stock; it is fixed to the upper part of the socket *c'* by the screw *l*, and the washer *m* secures all these parts.

3435.

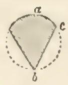


3436.



3437.

3438.



3439.

The mode in which the tool works will be sufficiently obvious from the above description and an examination of the section, Fig. 3436. When the handle *c* is turned in the direction in which the drill *f* cuts, the clutch *k* by its friction firmly embraces the drill-stock *e*, and turns the drill, however great the resistance may be. When the handle is returned the clutch relaxes and slips upon the stock, thereby preventing the return of the drill.

The class of tools which come within the general description of rose-bits, countersinks, wideners, or broachers, is far too numerous to admit of any specific description in an article like the present. Some are intended partially to enlarge a hole previously drilled, others to do so throughout its entire depth. M. Lenseigne, a French mechanician, has made a great and decided improvement in the form of his broaches. It is a well-ascertained fact that pentagonal broaches do not perform their work very accurately, more especially when applied to enlarge a hole drilled through a thin plate of metal. The motion of the brace has a tendency to render the hole sensibly larger at the mouth. To correct this defect some workmen turn the broach truly cylindrical and then remove a portion of two sides with a file, as is shown in the sectional view, Fig. 3438: the part *a*, which is a segment of a circle, bears against the sides of the hole, and serves as a conductor, and whilst the acute angular edge *b* quickly removes the material, the obtuse angle *c*, which follows, corrects any inequality of cutting. This form of broach is unquestionably preferable to any previously introduced; nevertheless it has this defect: if a chip of metal gets between the round part *a* of the broach and the side of the hole, the angular edge *b* is necessarily thrust forward, and the truth of the work is destroyed. To avoid this difficulty, M. Lenseigne gives to his broaches the form shown in section in Fig. 3439. Here there are three segments of a cylinder which serve as guides, and the metal is removed by the obtuse angular edges. A tool thus formed cuts nearly as fast and much more accurately than that shown in Fig. 3438; it also possesses the advantage of being more easily made than those which are either pentagonal or hexagonal.

We have now to consider the method of cutting a screw or spiral thread upon any cylinder of metal by a manual operation. Before describing the tools by which this effect is produced, we propose to lay before the reader a brief analysis of Mr. Joseph Whitworth's excellent and thoroughly practical essay on a *Uniform System of Screw Threads*, as applied to bolts and screws, used in fitting up steam-engines and other machinery. The difficulty of ascertaining the exact pitch of any particular thread, especially when it is not a submultiple of the common inch measure, occasions extreme embarrassment, an evil which would be completely obviated by uniformity of system, the thread becoming constant for a given diameter. The same principle would also supersede the costly variety of screwing apparatus required in many establishments, and remove the confusion and delay occasioned thereby; it would likewise prevent the waste of bolts and nuts which is at present unavoidable.

It does not appear that any combined effort has been, hitherto, made to attain so desirable an object; as yet there is no recognized standard, and this will cease to be a matter of surprise when it is considered that any standard must, to a great extent, be arbitrary. On the one hand, it is impossible to deduce a *precise* rule from mechanical principles, or from any number of experiments; and, on the other, the nature of the case is such that mere approximation would be unimportant and unsatisfactory, absolute identity of thread being indispensable. To how great an extent the choice of thread is arbitrary will appear from a cursory consideration of the principles affecting it. Without attempting to discuss these in detail, which would be foreign to the present purpose, it may be interesting to notice the general outline and bearings of the subject.

The use of the screw-bolt is to unite certain parts of machinery in close and firm contact, and it is peculiarly adapted for this purpose by the compact form in which it possesses necessary strength and mechanical power. The extreme familiarity of the object tends to prevent the observation of its peculiar fitness, yet among all the applications of mechanics there is, perhaps, no instance of adaptation more remarkable. The ease with which distinct parts of machinery can be united, the firmness of the union, and the facility with which they may be separated, are conditions of the utmost importance, which by no other contrivance could be combined in an equal degree.

While, however, the utility of the screw in this application is abundantly obvious, it is by no means evident what may be the precise formation most advantageous under all circumstances. No exact data of any kind can be obtained for calculation, and the problem will be found to be capable only of approximate solution.

The principal conditions required in the screw-bolt are power, strength, and durability—the latter having reference to the wear occasioned by frequent fixing and unfixing. But none of these conditions can be reduced to any definite quantity. We cannot, for example, determine the exact amount of power necessary to draw the parts of a machine into due contact, of the precise degree of strength which may suffice for resisting the strains to which they may be exposed. Hence we cannot lay down any rule for determining the diameter of the screw-bolt required for a given purpose. Practical men can judge of the proper size with considerable accuracy, but they have no means of ascertaining it with absolute precision.

If the diameter be given, and it be required to find the proper thread, the nature of the question is not essentially altered. The amount neither of power nor of strength, nor indeed any other condition, is thereby determined. A certain limit is assigned, but within that limit the proportions of strength and power, &c., may vary indefinitely according to the actual formation of the thread. There are three essential characteristics belonging to the screw thread, namely, pitch, depth, and form. Each of these may be indefinitely modified independently of the others, and any change will more or less affect the several conditions of power, strength, and durability. The mechanical power of the screw clearly depends on the pitch, which, for a given diameter, determines the angle of the inclined plane, and on the form of thread which regulates the direction in which the force applied will act. The strength of the screw, as regards the thread, varies with each of the three characters; in the centre part being as the area, it is little affected, except by change of depth. The durability of the thread also depends chiefly on its depth, and the proper degree of the latter is determined principally with reference to this condition. In the selection of the thread considerable latitude of choice will be found to prevail with reference to all the characteristics; therefore no definite rule can be given for determining any one of them. It may be manifest that particular threads are too coarse or too fine, too deep or too shallow, but there are clearly intermediate degrees, within which the choice of thread, like that of the diameter, is arbitrary, and must be guided rather by discretion than by calculation.

The mutual dependence of the several conditions required in the thread may be noticed as having a tendency to perplex the choice. Thus, increase of power, according to a known law, is necessarily attended with diminution of strength, and the square thread which has the advantage in respect of power is proportionally weaker than the angular thread. A fine thread loses in strength while it gains mechanically as compared with one that is coarser; and deep threads, while they are more durable than shallow, materially detract from the strength of the bolt.

The selection of the thread is also affected by the mutual relation subsisting between the three constituent characters of pitch, depth, and form. Each of these, as already observed, may be separately modified; but practically no one character can be determined irrespectively of the others. The pitch of the square thread is usually twice that of the angular, for the same diameter, to retain similar proportions of power and strength. Coarse threads should be deep as compared with fine to provide against the wear from friction, and a coarse angular thread will require additional depth, not only to preserve the due proportion of power, but also to prevent the longitudinal strain from being thrown too much sideways on the nut. Hence each character acts as a limit to the variation of the others, and in some instances, that is, in the case of certain diameters, it will be found that the leading considerations in fixing one character is the resulting effect on another. Thus, in some of the smaller sizes screws, the pitch is determined principally by reference to the depth, a coarser thread being objectionable, because the extra depth would obviously tend to weaken the centre part of the bolt, while the necessary shallowness of a finer thread would render it too liable to wear with friction.

The proportionate strength of the thread and centre part of the screw is regulated mainly by the depth of the nut, which is usually of the same measure as the diameter of the bolt. Assuming this dimension as fixed, the proportion of strength between the two parts will necessarily vary with the different characters of thread, and more particularly with the depth. The centre part not being liable to wear, while the thread is obviously subject to friction and accidental injury, the original proportion of strength ought to be considerably in favor of the latter.

Such being the variety and vague character of the principles involved in the subject, a corresponding degree of latitude might naturally be expected in their practical application. Accordingly we find, instead of that uniformity which is so desirable, a diversity so great as almost to discourage any hope of its removal. The only mode in which this could be attempted with any probability of success would be by a sort of compromise, all parties consenting to adopt a medium for the sake of common advantage. The average pitch and depth of the various threads, used by the leading engineers, would thus become the common standard, which would not only have the advantage of conciliating general concurrence, but would, in all probability, be nearer the true standard for all practical purposes than any other.

Some years ago Messrs. Whitworth & Co. altered the threads of their screwing tackle on this principle, and the result of the experiment has proved abundantly satisfactory. An extensive collection of screw-bolts was made from the principal workshops throughout England, and the average thread carefully observed for different diameters. The $\frac{1}{4}$, $\frac{1}{2}$, 1, and $1\frac{1}{2}$ inch were particularly selected, and taken as fixed points of a scale by which the intermediate sizes were regulated, and the only deviation made from the exact average was such as was absolutely necessary to avoid the great inconvenience of small fractional parts in the number of threads to the inch. The following table shows the number of threads to the inch, standard measure, for each diameter.

It will be observed that above one inch diameter the same pitch is used for two sizes. This was unavoidable without introducing small fractional parts; moreover, the economy of screwing apparatus is promoted by repetition of the thread.

Diameter in inches.	Threads to the inch.	Diameter in inches.	Threads to the inch.
$\frac{3}{16}$	24	2	$4\frac{1}{2}$
$\frac{1}{4}$	20	$2\frac{1}{4}$	4
$\frac{5}{16}$	18	$2\frac{1}{2}$	4
$\frac{3}{8}$	16	$2\frac{3}{4}$	$3\frac{1}{2}$
$\frac{7}{16}$	14	3	$3\frac{1}{2}$
$\frac{1}{2}$	12	$3\frac{1}{4}$	$3\frac{1}{4}$
$\frac{5}{8}$	11	$3\frac{1}{2}$	$3\frac{1}{4}$
$\frac{3}{4}$	10	$3\frac{3}{4}$	3
$\frac{7}{8}$	9	4	3
1	8	$4\frac{1}{4}$	$2\frac{7}{8}$
$1\frac{1}{8}$	7	$4\frac{1}{2}$	$2\frac{7}{8}$
$1\frac{1}{4}$	7	$4\frac{3}{4}$	$2\frac{3}{4}$
$1\frac{3}{8}$	6	5	$2\frac{3}{4}$
$1\frac{1}{2}$	6	$5\frac{1}{4}$	$2\frac{3}{8}$
$1\frac{5}{8}$	5	$5\frac{1}{2}$	$2\frac{5}{8}$
$1\frac{3}{4}$	5	$5\frac{3}{4}$	$2\frac{1}{2}$
$1\frac{7}{8}$	$4\frac{1}{2}$	6	$2\frac{1}{2}$

Further, it is important to remark that the proportion between the pitch and the diameter varies throughout the entire scale. Thus the pitch of the $\frac{1}{4}$ inch is one-fifth of the diameter; that of the $\frac{1}{2}$ inch, one-sixth; of the 1 inch, one-eighth; of the 4 inch, one-twelfth; of the 6 inch, one-fifteenth. It is obvious that more power is required as the diameter increases: but this consideration alone will not account for the actual deviation, which is obviously much less than it would be if the scale were calculated mathematically with reference to the power required. The necessary amount of power must be determined in relation to the muscular force of the human arm, aided by the leverage of the screw-key. Now in the case of smaller screws, there is a considerable excess of force, and consequently of power. Again in the larger we discover a deficiency of power, for with all the leverage that can generally be applied, it requires the united force of several men to fix a bolt of six inches diameter. Hence it is evident that at the two extremes of the scale the amount of power required is not the leading consideration in determining the pitch of the thread, and in the smaller sizes the necessary depth of a coarser thread, as already observed, would too much weaken the centre part of the screw. It may also be mentioned that coarse threads would render small screws apt to work loose for want of sufficient hold to prevent the effect of jarring; and, on the other hand, finer threads on large bolts, besides being weaker, and consequently less durable, might render it a matter of difficulty to unfix them when occasion required.

It may, perhaps, be necessary to remark that the threads, of which the preceding table shows the average, are used in cast as well as wrought-iron, and this circumstance has, doubtless, had the effect of rendering them somewhat coarser than they would have been if restricted to wrought-iron. The variation in depth among the different specimens, before alluded to, was found to be greater proportionally than in pitch. The angle made by the sides of the thread will afford a simple and convenient expression for the depth. The mean of the variation of this angle in one-inch screws was found to be about 55°, and this was also very nearly the mean of the angle in screws of different diameters. As it is obviously desirable that this angle should be constant, more especially with reference to general uniformity of system, the angle of 55° has been adopted throughout the entire scale; a constant proportion is thus established between the depth and pitch of the thread. In calculating the former, a deduction must be made for the quantity rounded off, amounting to one-third of the whole depth—that is, one-sixth from the top, and one-sixth from the bottom of the thread. Making this deduction, it will be found that the angle of 55° gives for the actual depth rather more than three-fifths, and less than two-thirds of the pitch. The precaution of rounding off is adopted to prevent the injury which the thread of the screw and that of the taps and dies might sustain from accident.

Two descriptions of tools are employed for cutting screws by hand; namely, the screw-plate and the screw-stock, with movable dies. The first, and doubtless the most ancient form, is simply a flat plate of steel, assuming the shape of a file, having a tang and handle at one or both ends; in this plate are one or more series of graduated screwed holes, so that by passing the bolt or pin successively through several a finished screw is obtained. This form of tool, however modified in its construction, is obviously imperfect, and but rarely used except for screws under $\frac{3}{8}$ inch diameter.

The first decided improvement with which we are acquainted is due to Mr. Peter Keir, who introduced a cutter, let into a groove sunk in one of the dies, which follows the lead obtained by the dies, and deepens the thread. This arrangement is more especially applicable to square-threaded screws.

In 1828, Mr. J. Jones submitted to the Society of Arts of London an improved form of screw-stock and tap, for which he received the thanks of the society. In this case, also, a cutter is used, secured by clamps on the face of the screw-stock, which necessarily follows the lead obtained by the dies, and completes the screw in an expeditious manner. The altered form of tap is a combination of the taper and plug tap, the part towards the point being conical, and the upper part cylindrical. The threads are rounded off both at top and bottom, and the tap is fluted with four or more rectangular grooves, one side of which is in a line with the centre, thus giving, in a cross section of the tap, a form somewhat similar to a ratchet-wheel. About one-third of the threads have their tops filed down to diminish the quantity of surface in contact, by which much labor is saved, as the greater part of the power requisite for screwing in the usual way is expended in overcoming the friction, and not in cutting away the superfluous metal. This form of tap answers perfectly well for nuts not exceeding one inch and a quarter, but for those of larger size, as two or three inches, it is advisable to insert a cutter in the body of the tap just at the part where the cone terminates, by which nearly the whole of the metal is cut out, and the upper or plug part of the tap has nothing to do but to equalize and smooth the thread.

In 1838, M. Gouet proposed a new form of screw-stock with four dies, two of which were conductors or guides, and the other two acted as a screw-cutting or chasing tool. In the *Bulletin de la Société Industrielle de Mulhouse*, we find a description of two forms of screw-stock, and an expanding tap by M. Lamorinière. The first is composed of three dies, two of which are of tempered steel, and the third of wood, intended merely to serve as a conductor. The second has four dies, very narrow and directly opposite to each other, which are made to approach by means of a circular plate, hollowed in an ellip tical shape, and its circumference cut into teeth. With regard to the expanding screw-tap the object of the inventor appears to have been to dispense with a series of taps of different sizes, to cut rather than press out the metal, and to allow sharpening on a grindstone when the cutting edges become impaired. M. Waldeck also invented a screw-stock with a series of cutters, which produced either angular or square threads, and the same mechanician subsequently introduced further improvements with regard to taps. The screw-stock invented and patented by Mr. Joseph Whitworth, of Manchester, next claims our attention. Of this tool there are two forms; the first is rather complicated: the dies, of which there are three, work in as many eccentric curves sunk in a metal disk, whose exterior edge is cut into teeth in the manner of a tangent-wheel, and worked by an endless screw, the action of which necessarily causes the dies either to approach or recede from a common centre.

This tool cuts the metal with great rapidity, requires but little exertion, and produces very excellent screws. The principal objection to it is, that the complication of its parts, and the wear and tear of the tangent-wheel render frequent repair necessary, more especially in the hands of careless or indifferent workmen.

The second, or guide screw-stock, is entirely new in form, and not liable to the same objection; moreover, it is alleged by the inventor that it will cut a screw scarcely inferior to that obtained in a slide-lathe from a true guide. The thread produced is not only true, and of the exact pitch required, but perfectly formed throughout, being cut clean, without distortion of the metal.

In all these respects the advantage of the guide over the common screw-stock is remarkable. The latter will not cut a screw in any degree perfect; the thread, besides being irregular, is never of the right pitch; it is also more or less swollen by the violence done to the metal, so that the diameter of the screw is frequently found to exceed that of the blank-bolt in which it is cut. These defects are attended with the most serious practical inconvenience; they frequently render it extremely difficult to obtain a fit between the screw and the nut, and consequently occasion a considerable sacrifice both of time and labor. They necessarily impair, in a very great degree, the efficiency of the screw-bolt, which cannot possess either the strength or mechanical power which it would have if the thread were cut clean and true.

The defects in question are variously modified according to the size of the master-tap used in cutting the dies. If they have been cut by a master-tap double the depth of the thread, larger in diameter than the bolt to be screwed, they will act very well at first, and the thread will be started true, but, as the operation proceeds, they become altogether unsteady and uncertain in their action. If, on the other hand, they have been cut by a master-tap of the same size as the bolt to be screwed, the thread is made out of truth in its origin. They first touch the bolt only on the extreme point of their outer edges, as shown in Fig. 3440, *a* being the die, and *b* the pin or bolt. Further, they have neither sufficient guide nor steady abutment till the operation is on the point of completion. It is not unusual to employ a master-tap of an intermediate size. In this case, however, it is obvious that the dies will combine in a modified degree the defects peculiar to each of the cases already mentioned. In the guide-stock this perplexity is entirely obviated, and the dies act with full advantage from the commencement of the operation to its conclusion. They are cut by a master-tap double the depth of the thread, larger in diameter than the screw-blank; while their general form and the direction in which they are moved forward, are such as to preserve their cutting power, and steadiness of action, undiminished to the full depth of the thread.

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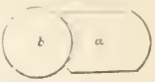

The plan of the guide-stock will be easily understood from Fig. 3441. The interior of the stock is shown in dotted lines through the top-plate *a*, which is fastened by the screws *b b′ b″*; *c* is a stationary or fixed die; *d d′* are moving dies simultaneously brought up by a piece *e*, sliding in a recess in the stock, and bearing with a distinct incline, as shown by dotted lines, against the back of each die. The piece *e* terminates with a square-threaded screw *e′*, and is drawn up by a nut *f*, on the outside of the stock. The dies having been cut by a full-sized master-tap, as already mentioned, the curve made by their outer edges is that of the blank-pin or bolt they are intended to screw. Hence, in starting the thread they bear at all points of the common curve, and the impression made by indentation is an exact copy of the thread of the die. The parts indented serve as a steady guide to the dies in cutting round the blank-pin. A groove in the stationary die facilitates the operation. Four cutting edges are brought into action, at points of the circumference nearly equidistant; so that by little more than a quarter turn, the thread is completely started round the pin, and the difficulty involved in the operation, by the common screw-stock, is entirely removed.

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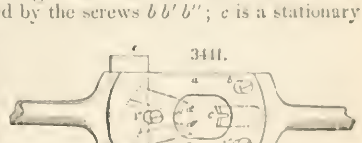


After the thread is started, the fixed die serves principally as a guide and abutment for the others. The moving dies are peculiar both in regard to their form and direction, which depend on the position of the arc in the shank of the die. The two sides have each a different inclination to the arc. As the die moves forward one side becomes prominent towards the screw bolt, and its cutting edge continues in contact with the thread, till it is cut to the full depth required. The prominent sides of the moving dies are those turned towards each other.

The direction of the common die in screw stocks, of the old form, is necessarily towards the axis of the screw bolt. In the guide stock the direction of the moving dies is that of two planes meeting beyond the centre of the stock, in a line parallel to the axis of the screw-bolt, and considerably behind it.

This direction is determined by reference to the change which takes place in the relative position of the screw bolt as the thread is cut deeper. One of the three dies being stationary, there must necessarily be a constant change in the position of the screw bolt in relation to the two others, the effect of which, if not counteracted, would be to deprive the cutting edges of the requisite prominence; but by giving them the direction before mentioned the proper degree of prominence is secured, notwithstanding the change of position, and the latter when combined with the eccentricity of the dies, so far from being any impediment to their action, materially assists it. The newly formed thread is thereby kept in contact with the dies, for some distance behind their cutting edges, affording them the same kind of support throughout the operation which they have at the commencement; when, as already observed, the curve made by their outer edges is coincident with that of the screw-blank. This continued support, which is necessary to steady their action, could not be obtained without a change in the position of the screw-bolt. They would otherwise acquire too much clearance as they form the thread deeper, and their cutting edges would be apt to dig.

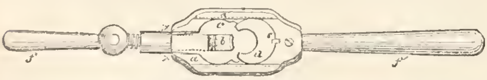
The steadiness of the guide-stock, and its easy action in screwing, are equally remarkable. In using it, not one-half the force consumed by the common stock is required. The inner edges of the moving dies, which principally act in cutting out the metal, are filed off to an acute angle; this enables them to cut with extreme ease, and without in any degree distorting the thread, while they take off shavings similar to those cut in the lathe; their action in cutting is in effect the same as a chasing-tool, to which indeed they bear an obvious resemblance in form, and they may be sharpened on a grindstone in the same manner.

A practical difficulty has hitherto attended the use of the screw-stock, arising from the wear of the taps and dies. The tap becomes less in diameter, and consequently taps the hole too small, while the opposite effect takes place with the dies, which, being unable to cut a full-sized thread, leave the screw too large. The only mode of counteracting this two-fold error, so as to obtain a fit between the screw and the nut, is by forcing the dies forward till they have reduced the diameter of the screw a proportionate quantity, and from what has been before observed, it is manifest that this cannot be done in the case of common dies, without injury to the thread. In using the guide-stock, on the contrary, it is attended with no disadvantage, and lest the diameter of the screw should inadvertently be reduced more than necessary, figures are stamped on the sides of the nut *f*, to indicate when the thread is full.

We have now to describe another screw-stock. This tool is constructed on the principle of the ordinary screw-stock, with such additions and alterations as appeared necessary. The principal objection to the old form is, that the metal is rather pressed out than cut, at the expenditure of much force; in that now under consideration, one die acts as a guide, and the other as a cutter, by which arrangement not only is a perfect thread produced, but the tenacity of the metal is preserved and less power employed.

Figs. 3442 and 3443 show Mr. Bodmer's improved screw-stock, with the lid removed in a plan and longitudinal section; *a a'* is the box made either of steel, wrought, or cast iron; *b* the vibrating tool or cutting-die, which is fixed in the die-holder *c*, in such a manner as to accommodate itself to the inclination of the thread when the die begins to cut on the surface. The die may also be a perfect fit in the die-holder *c*, but in that case it must be cut to a larger diameter than the screw itself would require, as usually done in common stocks; *d* is the guide-die recessed into the stock *a a'*, and which may be bored out to the full diameter of the bolt or pin to be screwed, or tapped in the ordinary manner. The guide-die *d* is prevented from turning by a small key *e*; the screw *f*, in the die-holder *c*, is not only the handle or lever by which the stock is worked, but also advances the cutting-die *b* as the operation proceeds. The cutting die-holder *c* is recessed into the stock, in a manner similar to *d*, and has as much room at x and x as is necessary to allow that part of the cutting-die which, when the stock is turned in the opposite direction would drag, to recede out of the thread so as to clear the thread and particles of metal cut out during the operation, by which arrangement the cutting-die will preserve its keen edge. Suppose the operation of screwing to have been commenced at the bottom of a pin, and the stock arrived at the top; the handle or screw *f* will require to be advanced a little, and then the stock is ready to work in the opposite direction. It is evident that the moment the handles *f f'* are pulled by the workman, the die will bite on that side which is moved deeper by the pull, and recede out of cut on the opposite side; it will therefore act and cut like a tool in a lathe or planing machine, and preserve its keen edge much longer, and remove filaments of metal much more easily than dies constructed in the ordinary way.

3442.



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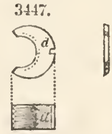

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Fig 3444 is an end view of the stock; Fig. 3445 a ground plan and an end view of the cutting die-holder, and Fig. 3446 the lid of the stock fitting the bevel or half V grooves of the same; Fig. 3447 is a plan and section of the guide-die *d*, and Fig. 3448 shows a mode of regulating the play or motion of the cutting-die *b*, by means of set-screws.

Fig. 3449 is a ground plan, and Fig. 3450 a section of a stock with two cutting-dies moving in a lateral direction; *a a'* is the stock or frame; *b b'* the handles or set-screws, acting upon the dies *c c'*, which are perfect fits in the stock, and against which the cutting-dies *d d'* slide laterally. These dies are confined between two plates which are screwed or riveted to the stock in the ordinary manner. It is evident that the two cutting-dies *d d'*, when tightened up against the piece which is to be screwed.

will recede in the contrary direction to that of the pull, as much as there is space left between the dies and the side of the stock, and in so doing will operate in the manner already described with reference to the vibrating dies.

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Fig. 3451 shows a longitudinal and end view of one of these taps. After having been finished to nearly the right measure in the screwing lathe, the taps are subjected to the operation of a mechanism in a tap-cutting lathe, by means of which the convolute form is given.

3451.

The advantage of this construction of tap is evident, because not only is the top of the thread eased in a convolute form, as usually done by hand, but likewise the bottom; the sides of the thread also are tapered, or relieved, in the same proportion, so that the tap cuts like an ordinary turning-tool, instead of making its way through the metal by sheer pressure.

The annexed table indicates the number of threads per inch both for angular and square threads.

V-Threads.		Square Taper-threads.	
Diameter in inches.	Threads per inch.	Diameter in inches.	Threads per inch.
5/16	18	5/16	9
3/8	16	3/8	9
7/16	14	7/16	8
1/2	12	1/2	7
9/16	11	9/16	7
5/8	11	5/8	7
11/16	10	11/16	7
3/4	10	3/4	6
13/16	9	13/16	6
7/8	9	7/8	6
15/16	8	15/16	6
1	8	1	5
1 1/8	7	1 1/8	4
1 1/4	7	1 1/4	4
1 3/8	6	1 3/8	3
1 1/2	6	1 1/2	3
1 5/8	5	1 5/8	2 3/4
1 3/4	5	1 3/4	2 1/2

To describe, within the limits of a brief article, the various tools used among the different classes of turners is manifestly impossible. They are so infinitely diversified both in form and size, according to the necessities, the ingenuity, and frequently, perhaps, the prejudice of those who use them, that a volume would scarcely suffice to do justice to the subject.

Gravers, triangular, square, round, pointed, heel or hook, and screw tools, with various other nameless sorts, the contrivance of individual skill, are used in turning hard bodies, such as bone, ivory, and the metals.

The graver is made from a square bar of steel cut off by an oblique plane at the end, which forms a lozenge or diamond face, and produces two inclined edges, at two of the flat sides of the bar; these are inclined opposite ways, so that the graver serves either for left or right hand work by merely turning it one quarter round to bring up another side. The point formed by the acute angle in which the two inclined edges meet, is better adapted for cutting than any other form, and is exceedingly strong; the flat sides give it an excellent bearing upon the rest. Another convenience of the graver is the ease with which it may be sharpened, an object of considerable importance in turning hard metal; it only requires to be held on the grindstone at the proper angle to grind the diamond face away, and thus make sharp edges with the two flat sides. The graver is principally used to rough the work, its point being applied to cut grooves all over the surface till it is true, and then the welved edge of the graver, or a square, or round tool, makes it smooth, and of a proper figure.

Triangular and square tools are so denominated from their respective sections being of these figures—they are flat at the end. The former have three cutting edges, namely, each arris in a longitudinal direction; the latter, which are principally used for turning brass, have four, that is, each arris at the extremity.

Round tools have the edges of a semicircular form, and are used for forming hollow mouldings.

The pointed tool has two inclined edges, forming a point, which cut grooves in any piece of work, or its edges may be used to turn shoulders either right or left.

Heel-tools are used for turning wrought iron, steel, and copper; they are made with all the edges already described, but the end where the edge is formed is bent, so that when it is presented to the work in a proper direction, the handle is inclined upwards in such a position that the end of it will rest upon the workman's shoulder, and he holds it down firmly with both hands, the heel of the tool being at the same time supported on the lathe rest. The metals above mentioned, being of a fibrous texture, turn away in a connected shaving; the tools are therefore presented in the direction of a tangent to the work, but as the drift of the work would force the tool endways, it is necessary to have a heel or angle which is placed immediately upon the rest: then the long handle serves to guide and fix it, and by elevating the end its edge cuts deeper.

Cast iron is turned by hook tools; their edges are formed in various ways, but invariably very obtuse, being nearly a right angle; in turning they are held in such a position that a line bisecting the angle of the edge is made to point nearly to the centre, and as the metal is usually hard and refractory, they are made with a hook, which, being laid over the rest, acts as a lever, and causes the edge to approach to or recede from the work by merely raising or depressing the end of the handle.

Screw-tools are very important appendages to a lathe, and in many cases indispensable; they are usually made in pairs, namely, an outside and an inside tool, and the teeth of both should be so accurately cut that on being placed together, the teeth of the one in the intervals between the teeth of the other, they should exactly fit, even to the exclusion of light. It may probably appear fastidious to insist on this rigid perfection in a tool which is apparently of simple and easy construction; a little consideration, however, will show that unless the teeth, whatever be their shape, are similar in every respect, it will be impossible to cut an accurate thread, since if one tooth be in the least degree larger than the others. it will necessarily destroy the proportion of the thread.

Many methods have been suggested to enable the mechanic to cut his screw-tools. M. Séguier, a distinguished amateur turner, recommends that a model be taken in lead or soft brass, by impression of the required screw, and then to place the pattern so obtained and the blank tool back to back in a vice, and with a triangular file remove the steel, until the projecting teeth exactly coincide with the model. To this we object that the form of a triangular file does not agree with the shape of a screw-thread—it is much too obtuse; what is called a slitting file is certainly more suitable. With very great care and dexterity in the use of the file, this method may answer, but the operation demands an aptitude and precision of hand rarely attained—added to which the loss of time and risk of failure are scarcely compensated by the probability of success.

We now proceed to explain a method very generally adopted to cut the teeth in screw-tools. A piece of cast-steel is turned cylindrical, and being suspended between the centres of the lathe, is made to revolve; upon the surface of this cylinder a series of concentric and equidistant circles are cut by means of a screw-tool, or a simple V-tool, which is held firmly and in a fixed position against the steel cylinder. When the teeth are sufficiently raised by the cutting action of the tool, the cylinder is removed from the lathe, and gaps or notches cut across its surface in a diagonal direction, so as to give to the teeth a cutting edge. It is then hardened, and tempered to a straw-color. This is technically called a *hob*, or *hub*.

The great objection to this method is, that it produces perpendicular and not inclined teeth in the screw-tool. This, however, is easily remedied by cutting a regular helix, instead of merely concentric circles, upon the surface of the hob; or still more readily by employing a common plug-tap, which answers the purpose perfectly well.

We will now suppose either a hob or plug-tap to be made to revolve between the centres of the lathe. The workman takes a blank screw-tool, which must be well annealed, and applies its face to the revolving hob; being careful to hold the tool very firmly, yet not to allow the hob at the commencement to bite too greedily, and supplying oil to the surface of the hob or tap, which essentially assists the operation. The blank tool may be held either above or below the centre of the hob. The latter is shown in Fig. 3453, and is in some respects preferable to the former, as it affords a better purchase for the tool. The method practised in Manchester of cutting screw-tools, is in many respects similar to that we have just described, except that it requires the aid of change-wheels and a slide-lathe. Nevertheless, as many of the details are common to both, the observations we are about to make will, in some measure, apply to manual as well as mechanical power.

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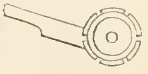

The first thing is to cut the hob, or hub, which is effected by a self-acting slide-rest. It is simply a screw cut on the surface of a solid cylinder of cast-steel, with diagonal grooves cut across the thread of the screw to act as cutters, as shown in Fig. 3452; the two necks of the hob have concave holes drilled in the ends to carry the centres of the lathe.

The hob is placed between the centre points of the lathe, by means of a dog or catch attached to one end in the usual way. Change-wheels are then put on to connect the mandrel or spindle with the guide-screw of the lathe, and which carries along the slide-rest. The wheels are so arranged that one turn of the mandrel causes the slide-rest to travel a distance exactly equal to one thread. The blank which is to be cut is firmly screwed down in the tool-box of the slide-rest, and made to stand above the centre of the hob, as shown in Fig. 3454. It is then pressed, by the screw of the slide-rest, against the hob; and the lathe being put in motion causes the tool to traverse along and against the hob, cutting it as deep as may be thought necessary. The face of the tool, when cut, is a segment of a circle, varying, of course, according to the diameter of the hob.

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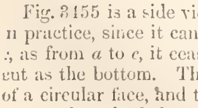

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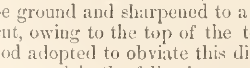

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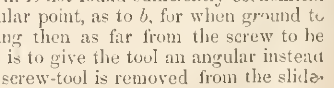


Fig. 3455 is a side view of the tool in this condition; but this form is not found sufficiently economical in practice, since it can only be ground and sharpened to a particular point, as to *b*, for when ground to *c*, as from *a* to *c*, it ceases to cut, owing to the top of the tool being then as far from the screw to be cut as the bottom. The method adopted to obviate this difficulty is to give the tool an angular instead of a circular face, and this is managed in the following way: the screw-tool is removed from the slide-rest, and as the hob revolves, the workman elevates and depresses the end of the tool which is in his hand, so as to present different points of the face to the cutting action of the hob, until by degrees he succeeds in obtaining a perfectly angular face, which allows the tool to be ground nearly or quite to the bottom, with a certainty of preserving a good cutting edge. In order to fix the blank which is intended to make an inside screw-tool, in the slide-rest, some little contrivance is necessary, the stem is usually bent, and afterwards, when cut, set straight previously to hardening.

The handles of turning-tools, it may be premised, must be varied in size, according to the manner in which they are intended to be held. For heavy work, more especially when the lathe is turned by machinery, they must be sufficiently long to reach to the shoulder, upon which one end rests during the operation of turning, besides being held by both hands of the workman at the same time. In using the foot-lathe the tools are held by both hands only, and the handles are rarely more than half the length required in the former instance.

The socket-handle for turning-tools, Fig. 3456, is an extremely ingenious and useful appendage to the lathe, as it is equally applicable to slide-rest tools. This handle is 9¾ inches long; the brass socket *a a'* has a longitudinal slot *b b'*, which terminates at the circular hole *c*. This socket is confined by the steel ring *d d'*, which has at one side a steel set-screw *e*, and at the other a pinching-screw *f*, which necessarily contracts the aperture, and consequently grips the tang of a tool placed within it. The slot *b b'*, as well as the opening for the tang of the tool and the pinching-screw, are more clearly shown in the end view.

The tool-gage is a very simple and convenient method of ascertaining whether a tool is ground or formed to the proper angle. It consists of a planed plate of metal, on whose surface there is, at one end, fixed a conical steel pin, whose taper, or the angle formed by the sides of the cone with the surface of the plate, is exactly that which is proper for the cutting face of the tool. The angle formed by the sides of the cone and the surface of the base plate should be about three degrees. By using this gage, all difficulty of forming the tools to the proper angle is at once removed. Moreover, this same gage will answer for every kind of planing or turning tool of whatever size.

We now proceed to a very important practical inquiry, namely, the velocity at which tools cut most advantageously for different kinds of material.

It cannot, we apprehend, have escaped the observation of such of our readers who are in the habit of turning metal, that if a velocity exceeding certain prescribed limits be imparted to the material, the edge of a cutting-tool applied to reduce the surface of that material is brought to a soft state and rendered obtuse. This is an acknowledged fact, and many ingenious contrivances have been, from time to time, introduced to meet the exigency of the case, or in other words, to regulate the speed of the lathe-mandrel according to the hardness and diameter of the metal or other substance to be turned. It is commonly supposed that for wood the velocity cannot be too great, yet this is probably a vulgar error, since if we allow the speed to pass certain limits the tool necessarily becomes hot, loses its temper, and ceases to cut. Wrought-iron requires a slow motion, and cast-iron, above all, ceases to be affected by the edge of the tool, unless a very slow and regular motion is preserved, as it appears to act by abrasion, and actually grinds away the face of the tool.

The opinion of practical men is much divided on this point—some name from ten to fifteen feet per minute as a *maximum* velocity, others allow thirty to forty feet, whilst others again regard this as the *minimum* speed which should be given to cast-iron, in order to obtain the greatest effect from the tool.

For turning or boring cylinders, or indeed any substance of which the diameter is nearly equal throughout, a uniform velocity fully answers the purpose, since the speed can easily be increased or diminished by means of conical pulleys placed in opposite directions, as also by many other mechanical contrivances* which are too familiar to practical men to require any extended description on this occasion. Suppose, for example, we have a cylinder of wood of considerable diameter to turn, we devise some method to control the speed, as, for instance, by diminishing the diameter of the fly-wheel, and increasing that of the pulley or mandrel-wheel; by this means the motion is made slower, and in some respects in proportion to the diameter of the material. Had the cylinder been composed of cast-iron instead of wood, we should have pursued a somewhat similar course, but carried to further limits than that we have just described. The facility afforded by two elongated cones, fixed in opposite directions, as regards their respective diameters—the one attached to or in immediate connection with the fly-wheel, and the other on the lathe-mandrel—enables us to regulate the velocity with a precision that in many operations is of the highest importance; but it must be remembered that the advantageous effects of this arrangement are limited to the circumference, or perimeter.

The back-geer lathe, Fig. 2538, p. 179, answers the purpose perfectly well for cylindrical turning. In this arrangement the driving cone *b* and pinion *p* are connected, and may either run loose or be locked to the spur-wheel *w*, but in the former case the speed of the lathe-spindle, and consequently whatever is attached to it, is greatly reduced, as indeed is manifest from inspection of the engraving; for supposing the spur-wheel *w* and pinion *p* to have respectively 52 and 13 teeth, and the spur-wheel *h* and pinion *i* on the back-geer spindle also 52 and 13 teeth, the ratio of speed of the driving-cone to that of the lathe-spindle would be as 16 to 1; or, in other words, the latter would perform 1 revolution for every 16 revolutions of the former.

M. Armengaud, a distinguished French engineer, has arranged the different degrees of velocity applicable to the several mechanical operations of turning, boring, drilling, &c., in the following manner:

The velocity at the circumference of the material, or of the tool for turning or planing cast iron, should be from 7 to 8 centimetres† per second.

The velocity of the tool at its circumference for widening or broaching cast iron is from 4 to 5 centimetres per second.

* Those who wish to investigate the subject will gather much information from the specification of Mr. Bramah's patent, long since expired.

† The centimetre, according to Professor Millington, is equivalent to 0.393 of an English inch, and M. Armengaud states that the latter, compared with the French inch, is as 25 : 27 very nearly; that is to say, the French inch containing 27 millimetres, the English inch contains only 25 mils. 4.

The velocity of cast-iron, turned by a hook-tool, held and guided by the hand of the workman, to finish or complete, is 12 centimetres.

For iron turned by means of the slide-rest, the velocity at the circumference of the work is about 14 centimetres. When the metal is turned by hand-tools, the speed at its circumference is from 18 to 20 centimetres to rough out, and from 28 to 30 centimetres to finish.

The difference of velocity of the work or the tool when the turning is effected mechanically or by the hand, is deduced from the obvious fact, that in the former case the contact between the tool and the work is constant and invariable, whilst in the latter it is intermittent.

The foregoing velocities are equally applicable to drills or cutters in boring machines.

The lateral progress of the tool varies according to the power of the machine; it is in general from ¼ to ⅓ of a millimetre for each revolution of the work, nevertheless it should be less for drills.

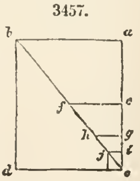
The annexed table indicates the average degree of speed, as well for turning as boring.

Diameter in inches.	Revolutions of spindle per minute.	Diameter in inches.	Revolutions of boring-bar per minute.
1	50	1	25
2	25	2	12·5
3	16·67	3	8·33
4	12·50	4	6·25
5	10	5	5
6	8·32	6	4·16
7	7·15	7	3·57
8	6·25	8	3·125
9	5·55	9	2·77
10	5·	10	2·5
15	3·33	15	1·66
20	2·50	20	1·25
25	2	25	1
30	1·667	30	0·833
35	1·430	35	0·714
40	1·250	40	0·425
45	1·12	45	0·56
50	1	50	0 5
60	0·834	60	0·417
70	0·716	70	0·358
80	0·626	80	0·313
90	0·554	90	0·278
100	0·50	100	0 25

If we have occasion to turn a plane surface accurately true, the motion of the lathe-mandrel, or what is the same thing, the substance affixed to it, requires to be accelerated or retarded in a ratio proportioned to the progress of the tool, either to or from its centre; then that portion of the plane where the tool takes effect would pass its edge always at the same velocity; and if a proper speed be obtained in the first instance not only will the tool preserve its originally keen edge for a very considerable time uninjured, but the surface produced by its action would be nearly perfect. This control and command of the movement obviously require that it be continuous; since if the lathe be stopped, a mark, or false cut, as it is termed, will be the unavoidable result.

Under ordinary circumstances, regular motion in surface-turning is not only prejudicial in relation to its effects, but it also involves great waste of time. We will suppose that a speed suitable for the circumference and the proximate parts is obtained, it is evident, as we approach the centre, the rotary movement becomes less effective; until at length near the centre it produces little or none, and the work does not proceed at all. The reason of this is obvious; the velocity continues unaltered, while the diameter of the material is progressively reduced. It is also manifest as an inevitable consequence to uniform motion in surface-turning, that presuming a suitable velocity be communicated when the tool is at the greatest distance from the centre of rotation, if it be made to advance regularly towards the same point, similar uniform speed being continued, the cutting edge of the tool would not, on its arrival at the centre, be more deteriorated than if the velocity had been increased in a proportionate ratio to its progress towards the centre. This, we believe, is an admitted fact by competent judges; but it must be remembered there would be a sacrifice of nearly *one-half* of the time employed. This statement, extraordinary as it may appear, is nevertheless susceptible of mathematical demonstration, a mode of proof which, we presume, few will feel inclined to dispute. Let the parallelogram, *a b c d*, Fig. 3457, represent the time that would be required to turn a surface. Draw the diagonal line *b c*; bisect the line *a c* at *e*, *e c* at *g*, and *g c* at *i*; then draw the lines *e f*, *g h*, and *i j* parallel to *a b*.

3457.



Let *c* represent the centre, *a c* equal the radius, and *a b* equal the circumference, or time of one revolution at its greatest diameter; therefore, the lines *e f*, *g h*, and *i j*, will also represent their circumference, or time of one revolution at their respective radii at *e g* and *i*; and as the lines *a b*, *c f*, *g h*, and *i j*, are one-half the length of each other, so will their revolutions be performed in similar proportions of time, and the velocity of the lathe-mandrel will be increased in the inverse ratio, as the length of the lines *a b*, *c f*, *g h*, and *i j*; consequently, the right-angled triangle *a b c* will represent the time that would be required to turn a surface, when the velocity of the lathe-mandrel is increased in the manner already described. The parallelogram *a b c d* will represent the time that would be required, if the velocity remain unaltered—that is, from the moment the tool is applied to the surface at its greatest diameter, to its arrival at the centre; for if the length of the line *a b* represent the time of one revolution at its greatest diameter, the line *c d* will similarly represent the time of one revolution when the tool reaches the centre; therefore, as the length of the line *c d* is equal to *a b*, so will all the intermediate revolutions be performed in similar spaces of time.

This inquiry may be usefully applied to determine the period of time necessary for surface-turning. Thus, if we wish to know what time would be required to turn a plane surface of cast-iron, the diameter being twenty-four inches, to make fifty revolutions or cuts in each inch of the radius, and to pass the tool at the rate of 15 feet per minute: Multiply the circumference, say 75·39 inches by the radius equal 12 inches, then multiply the product, 904·68, by the number of revolutions or cuts in one inch of the radius, in this instance 50, this will give 45,234 inches; divide this by 12, to reduce it to feet, and we have 3769·5; divide again by 15, which gives 251·3 minutes, and lastly dividing by 60, we have 4 hours, 11·3 minutes; consequently this would be the time, if each revolution were performed in equal portions of time, but if the speed of the lathe-mandrel be regulated so that the surface to be turned shall always pass the tool at the same velocity, then the time required to perform the work will be only one-half of the above; for in this case we must multiply the radius by one-half of the circumference, as that will be a mean proportion of the lengths of all the intermediate revolutions.

We have now arrived at a very important and interesting inquiry:—namely, the principle and mode of action of automatic or self-acting tool-machines.

If we consider the separate and distinct parts which combined make up a machine, whether simple or complex, to be disunited and viewed in detail, we shall find that their constituent parts, however numerous, are composed either entirely or partially of certain original geometrical figures, so that it is evident the more nearly the configuration of each individual part approaches strict mathematical truth, the more regular and perfect will be the performance of the machine.

But the accuracy and precision of workmanship here predicated, and which peculiarly distinguishes the machinery of the present day, is obviously unattainable by mere manual dexterity; it is principally to be attributed to the *slide-rest*.

The invention and introduction of this tool may justly be considered an era in the history of constructive mechanism; it has entirely superseded both manual labor and dexterity, which previously were required; added to which, it enables us to produce work infinitely superior, and in a much shorter space of time than could be effected by hand-turning: so many and so conclusive are the beneficial results consequent to the introduction of this tool that it is not affirming too much to assert that nearly all the improvements in modern machinery are in a greater or less degree to be attributed to its almost universal application in some or other of its many and varied forms.

It constitutes no part of the present inquiry to investigate the principles of turning, except so far as is absolutely necessary to illustrate the subject in hand. Let us suppose then, that instead of the tool being held and guided by the hand of the workman, assisted merely by muscular strength, the same tool is firmly fastened to the lathe-rest, so that during the operation of cutting, it could be slid along the bed of the lathe, in a direction parallel to the axis of the work, the result of this operation would necessarily be a cylinder; if, however, the tool move in a line forming an angle with the axis of the mandrel, a conical form would be obtained, and if it operate at right angles to the same axis a plane surface would be the result. Such are the elementary principles on which this important, and in many respects invaluable tool is constructed, the details of which, and the different forms, we defer for the present, thinking it preferable in the first instance to describe the machine of which it forms an appendage.

One of the primary and most indispensable requisites of a well-constructed lathe is, that the centre of the cone-spindle should coincide exactly with the adjustable centre of the movable head-stock, or, in other words, that each of these parts should be in the same line, parallel to the face of the lathe-bed.

The spindle is a very important part of the lathe, as upon its truth and accuracy of motion the circular rotation of any work attached to it mainly depends; it is usually made of iron, but the working parts of the two extremities are altogether of steel, which are hardened after being turned and finished; they are then ground in their places to fit the collars or bearings with finely pulverized Turkey stone and oil; the left-hand end has a hole bored exactly in its centre to receive the point of a screw, which supports and retains it in its place, as shown in Figs. 2523 and 2524, p. 176.

The other, or right-hand end of the spindle, is somewhat larger, and has a conical hole bored in the direction of its axis for the purpose of receiving a centre point; this is disengaged when necessary by means of any tapered instrument which, being inserted in a slot cut in the mandrel, acts as a lever and forces the centre forwards.

In the larger class of lathes the spindle is usually fitted up to run in divided collars of brass or gun-metal; these slide on V-shaped grooves cast in the head-stock, and are adjusted to fit the neck of the mandrel or spindle by means of screw-bolts which pass through a cap or plate of wrought-iron, fitted on the upper surface or top of the head-stock.

Various contrivances have from time to time been suggested to avoid the inconvenience of a back-screw, and at the same time insure uniformity of position under all possible circumstances. The boring and turning machine, pp. 180, 181, and 182, offers an example of this modification: here the spindle works in divided collars, but has shoulders at the necks, by which contrivance all longitudinal motion is entirely avoided. The method adopted by Mr. Whitworth, of Manchester, to effect this object is extremely ingenious, and peculiarly entitled to the distinctive epithet, self-sustaining; as a specimen of the adaptation of mechanical means applied to produce certain results, it is probably unrivalled.

In this lathe the inner journal of the spindle is turned conically, but at two different angles, that part next the nose being more acute than the remaining portion. This arrangement meets the great difficulty attendant on conical bearings, as the base of the cone is opposed to direct pressure, and consequently removes all danger of the spindle becoming fixed or jammed in its collar. The sliding cone which is placed upon the spindle for working in the outer bearing, becomes, as it were, a part of the spindle, but having longitudinal motion; it tends to balance the effect of pressure applied directly to the screw.

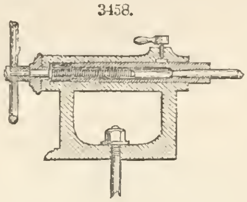
The method shown in the sectional view, Fig. 2532, p. 177, is by no means so well contrived as in this case; a set screw is introduced to counteract longitudinal motion by direct pressure against the left hand end of the spindle.

The movable or right-hand head stock now requires consideration. The first decided step towards improvement in this part of the lathe may doubtless be traced to the substitution of a plain cylinder for a screw, both terminating alike in a conical point; in the former case the cylinder turning upon itself, the apex of the cone is not so liable to deviation, but this does not compensate for the absence of regular pressure, which can be imparted at will, and at any moment, by means of a screw and that in a degree exactly required by the nature of the case; nevertheless this great inconvenience must not be overlooked, the screw is extremely liable to vary relatively to the centre line. If, for instance, either the pin or the thread be slightly twisted, which it frequently and unavoidably is, the point will describe a small circle at each revolution, and however well and carefully the thread of the screw may be cut it is almost impossible to make it perfectly regular and mathematically true; consequently, if the central line of the cone, which forms the point, be not that of the screw itself, the same effect will be produced

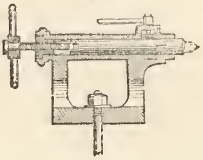
These and other considerations of a like nature that might be adduced, probably suggested the arrangement shown in Fig. 2538, which combines the simplicity and uniformity of position of the cylinder with the mechanical power of the screw. In this case the sliding cylinder in the head-stock is deprived of rotary motion, its outer end being connected by a coupling to a second cylinder of smaller diameter, which constrains both to move in a parallel direction; between these, a square-threaded screw works, which is capable only of longitudinal motion, being connected to the aforesaid coupling, so that the screw being worked to the left hand, compels the cylinder in the head-stock to travel with it, as is evident from inspection of the figure.

The form of head-stock just described probably suggested that generally known as the cylinder head-stock. This was invented simultaneously, we believe, by M. Collas, of Paris, and Mr. Joseph Clement, of London. The arrangement now usually adopted is shown in section in Fig. 3458. The head-stock is bored out true and an iron or steel cylinder ground therein so as to insure an accurate fit; this receives a forward and backward motion from a screw which is rendered endless by means of a collar or

3458.



3459.



cap, and is worked by a handle-wheel. The sliding cylinder is fixed when requisite by a pinching-screw, which presses against a piece of iron let into the head-stock. A sectional view of another mode of fitting up is given in Fig. 3459. This is unquestionably not so expensive to get up as that just described, but it is liable to the objection, that nearly the whole amount of pressure is thrown upon the driving-screw connected with the cylinder and attached to the handle-wheel. In this latter example the mode of fixing the spindle in its required position is superior to that shown in Fig. 3458. A malleable iron ring, bored out so as accurately to fit the spindle, is let into a recess in the head-stock, and tightened up by means of a handle passing through a screwed shank projecting from the ring.

In some cases it is desirable to possess the means of moving the shifting head-stock in a direction at right angles to the bed of the lathe. A very convenient mode of effecting this is shown in Figs. 2523 and 2524, by means of the screw *f*, which causes the head-stock to move transversely, an arrangement which is peculiarly applicable to conical turning.

In heavy lathes the sliding head-stock is usually moved along the bed by means of a train of bevel-wheels, as in Fig. 2542. Here a bevel-pinion attached to a horizontal spindle, which is worked when necessary by a crank-handle fitted upon the square end *o*, gives motion to a bevel-wheel upon one end of a vertical shaft, which has its bearings inside a hollow column cast in the body of the head-stock for that purpose. On the other end of this shaft is a bevel-pinion; this again geers with a small bevel-wheel keyed upon the spindle *p*, which works in bearings attached to the sole of the head-stock and also carries a pinion which works into the rack M, fixed upon the bed-plate of the lathe, and thus obviously completes the connection, enabling the workman to adjust the sliding head-stock in any required position with ease and facility.

Cones or speed-pulleys are very important adjuncts to tool-machines in general, and more especially the lathe, as from the nature of the operations performed by it, it is a primary requisite that the range of variation in the velocity of the spindle should be as large as possible. Professor Willis has investigated the mechanical principles of their adjustment in a very clear and satisfactory manner.

Supposing a pair of cones or speed-pulleys to be arranged upon two parallel axes and in opposite directions, we have an easy mode of changing the ratio of the angular velocity of the shafts by simply moving the belt from one pair of speeds to another.

In this case it is evident that the diameters of each pair of opposite pulleys should be so adjusted that the belt shall be equally tense upon any pair of the whole series; this, as may be easily demonstrated, is attained by making the sum of each pair of opposite pulleys equal throughout the whole series.

We have now to describe the slide-rest, a tool which has unquestionably contributed more than any other to the improvement of modern machinery. The invention of this truly important tool is claimed by Mr. Nasmyth for the late Mr. Henry Maudslay; but, as it appears to us, the conclusion arrived at by that gentleman has been hastily adopted and without sufficient inquiry, inasmuch as a form certainly similar in all important details was well known and commonly used by rose-engine turners long previously, added to which we may remark that the original slide-rest constructed by Mr. Maudslay for Mr. Bramah bears so slight a resemblance to that now in use as scarcely to be capable of identification; moreover, it is extremely doubtful whether a form of rest, known as the parallel rest, as well as a tool very similar in principle, invented by the late Earl Stanhope for turning metallic surfaces of large dimensions truly plane, did not precede the slide-rest of Mr. Maudslay.

It is foreign to our purpose to pursue the subject further, nor are we disposed to depreciate the great merit of an ingenious and highly talented engineer; nevertheless, as the principle has been so extensively and so successfully applied to modern tool machinery, we have been solicitous to perform an act of justice in attributing to those who have in any way contributed to the invention of this important tool a fair share of commendation.

The form of slide-rest shown in Figs. 2542 and 2543 is a very convenient arrangement in many of its details, and the one most commonly adopted. Here J is the saddle-plate upon which the slide-rest K is supported, and the longitudinal slide L which carries the tool-holder is firmly secured upon the part K by the screw *u*; the parallel motion of the tool-holder is obtained by means of the screw *r*, and similarly a transverse motion of the same in order to place the tool in and out of cut by the screw *s*; these necessarily work at right angles to each other, and the tool itself is made fast on the tool-holder by the two clamps *u*. The adjustment requisite for setting the tool to the work is effected by disengaging the sole K from the saddle-plate J; the nuts on the bolts which pass through the slots, shown in the plan view, Fig. 2543, being released, by this means the sole K may then be moved to the requisite distance from the longitudinal axis of the lathe, and to a certain extent in the line of that axis by shifting the bolts in the dovetail grooves of the saddle-plate, should that operation be more convenient than to shift the latter on the bed-frame of the lathe.

A transverse adjustment to a limited extent may be obtained by means of the screw *s*, and the tool-carrier may be adjusted longitudinally by the screw *r*.

The slide-rest we have now to describe is due to the ingenuity of Mr. Joseph Whitworth. It is unquestionably an excellent specimen of constructive mechanism, combining the requisite stability with great accuracy of motion, and the manner in which the details are worked out displays considerable ability and mechanical talent. Figs. 3460 and 3461, the latter being a section, show the rest set for facing a circular plate; that is, the motion of the upper slide is in a line at right angles to the lathe-bed A A, which is bolted in the usual manner to the supports B B.

The saddle upon which is placed the carriage of the rest is simply a broad and strong plate of cast-iron C C, planed true and finished by scraping upon both horizontal faces. The slides *a a*, similarly planed and dressed, are screwed to the lower surface of the saddle on either side of the lathe-bed, to enable it to traverse with uniform motion its entire length without shake or play, and so arranged as to compensate for wear and tear by means of lateral screws countersunk in the cheeks of C C.

When the saddle is required to remain stationary during the work, as, for example, when a circular or other plate is to be faced, it is firmly fixed on the lathe-bed A A by means of a single screw-bolt *b*, the nut of which is screwed up by the lever-handle *c*.

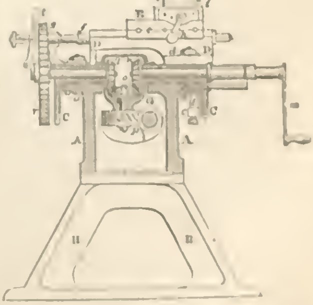
The carriage of the rest is composed of three principal parts: the first D D, which rests upon the saddle, and is susceptible of different positions; the second E is a plate movable upon the preceding, and the third F which carries the tool. The base or carriage is of cast-iron, planed and finished by scraping not only on the two horizontal faces, but also on the two upper lateral edges, which are angular like those of the lathe-bed, so as to receive the slides *e e* fitted on each side of the rectangular plate E. A screw-bolt *d*, the square head of which is lodged in a gap sunk in the saddle C C, serves to adjust the carriage D D upon the saddle-plate, and this adjustment obviously depends upon the diameter of the piece to be turned.

The rectangular plate E is rendered movable in the direction of the length of the carriage D D by means of an endless-screw *f*, which is entirely sunk in its thickness, and receives a rotary motion either from the handle *g* or from the lathe itself. This endless-screw works in a brass nut fitted under the plate E, and being deprived of endlong motion, it necessarily follows that in its rotation it imparts a forward and backward motion to the nut, and consequently the tool-carrier.

The part F, which may properly be designated the tool-carrier, is susceptible of another movement—that is, in a direction exactly at right angles to that just described—by means of a second endless-screw smaller than the former; this is intended to be worked only by the handle *h*, and that in the event of its being necessary to regulate in an exact manner the position of the tool with regard to the piece upon which it is to operate. This endless-screw works in a brass nut attached to the plate E, and consequently imparts a forward and backward motion to the tool-carrier F, which moves between two slides screwed upon this plate.

The tool *i*, which is intended to act upon the material either for turning or screw-cutting, is securely fixed on the tool-carrier F by vertical pinching-screws *j j*, which are screwed through the thickness of the upper plate or cap; these screws, four in number, are placed at the angles of the cap, an arrangement which allows the tool to be fixed in different directions, and in such a manner that it is always acted upon by two screws. This disposition enables the workman to employ two tools which shall act at the same time or nearly so upon the material; for instance, the one to rough out and the other to complete the work.

3460.



Motion is communicated to the carriage, and consequently to the tool slide, by a peculiar arrangement of the guide screw, which is so formed as to be alike capable of performing the office of a rack as well as that of a screw; to this end the thread is rounded off both at top and bottom, instead of being either triangular or square. It is thus enabled to work either in a nut or with a tangent-wheel.

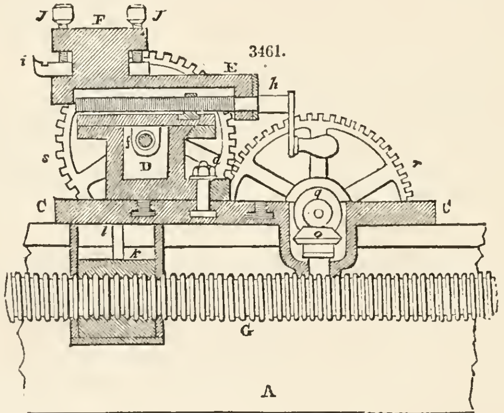
This guide-screw is shown at G, Fig. 3460. It is placed within the lathe-frame, not in the direction of the axis of the machine, but rather on one side, in order to screen it from the falling turnings, and the nut *k*, when needful, is taken out of geer by the pin *l*. When the guide-screw is required to answer the purpose of a rack—as, for instance, to bring the saddle, and consequently the carriage to any particular position—the nut *k* is disengaged, and the handle *m*, the socket of which is fitted on a horizontal spindle carrying the small mitre wheel *n*, which geers with a larger one *o*, keyed on one end of a vertical shaft placed in the centre of the saddle C, and on the other extremity of this shaft is a tangent wheel *p* which works with the guide screw of the lathe. Now as this last is deprived of rotary motion, it is ev dent that by turning the handle m, the tangent-wheel p, driven as already described, will produce precisely the effect of a rack; that is to say, the saddle and carriage will receive a traversing motion in the direction of the length of the lathe-bed.

In actual work the saddle, and consequently the rest itself, is placed in any required position, the handle m being removed and the nut k brought into connection with the guide-screw G, which, actuated and regulated by a train of wheels attached to the lathe, causes the saddle with its appurtenances to travel with any degree of speed that may be required.

By a peculiar and ingenious arrangement, the guide-screw is made to drive the carriage and tool carrier in a direction at right angles to the axis of the lathe. This is effected in the following manner:—with the mitre-wheel o a similar but smaller one q geers; this is keyed on the end of a shaft in the same straight line as that which carries the small mitre-wheel n. At the opposite extremity of this axis is a spur-wheel r which geers with a similar spur-wheel s mounted on an iron spindle, which terminates at the other end in a grooved shoulder; this axis is movable in a socket which forms a support and is fixed to the saddle C, and by means of an ingenious contrivance the forked lever t is made to connect or disconnect at pleasure the spindle that carries the spur-wheel s, with the square end of the screw f of the carriage D D.

It is obvious, if we suppose the saddle to be fixed on the lathe-bed—and to effect this it is merely necessary to screw up the bolt c—that the guide-screw G giving motion to the tangent-wheel p determines the motion of the toothed-wheels, and consequently that of the screw f, which after this manner gives motion to the carriage and the tool-carrier, to which we have given, by anticipation, the position shown in the sectional view, Fig. 3461. It is evident that when this transverse motion is not required, it is only necessary to throw the wheels out of geer by means of the forked lever t, and then these wheels will revolve on their axes without producing any effect.

3461.



The collars or bearings in which the axes of the bevel-wheels n and q revolve freely, are nothing more than long hollow cylinders bored out true, and fixed on the saddle or bed-plate c, and to avoid the injury which might result from these wheels becoming clogged by chips of metal, they are usually protected by a metallic cover either of tin or sheet-brass.

In the construction of steam-engines and engineering work generally, there are a great number of parts, such as steps, bushes, &c., which require their outer diameter to be turned truly concentric with the hole bored through them. The most general method of accomplishing this, is by driving the work upon a mandrel sufficiently tight to withstand the action of the turning-tool. The common mandrel, which is perhaps the most universal adjunct of the lathe, is a cylindrical bar of steel, turned with an exceedingly slight taper to fit the central hole of the work.

The time lost in preparing these mandrels, and the great weight of useless metal which must thus be kept in stock, prove serious objections to their use, and led Mr. Hick to the invention of the expanding mandrel, by which various sizes of holes may be fitted.

Figs. 3462 and 3463 represent a longitudinal section and an elevation of the mandrel, the expanding wedges being shown in two different positions. a is the mandrel, the central portion of which is turned conically as at b. This cone is provided with four dovetail grooves c running in the direction of the axis of the mandrel, and fitted to receive the four wedges $d\,d$, shown in Fig. 3462, in their highest position. The dotted circles in the end view represent the work, which is placed upon the four wedges; these are pressed onwards by the hollow conical collet e, urged by the nut f, working on the screw-threads cut on the mandrel. In this manner the wedges d are driven up the inclined grooves, and thus fix the mandrel concentrically within the hole of the work so that any diameter of hole may be readily fitted, which is within the range of the travel of the wedges.

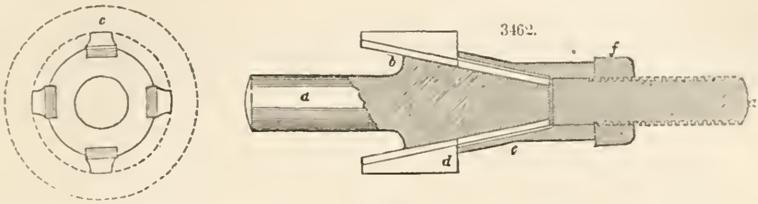
Another equally important appendage of the lathe, is the universal chuck. Various views of this chuck are given in Figs. 2542—2545, pp. 180–2. For turning or boring articles of a regular external configuration, this arrangement has a decided advantage over the common chuck, where each adjusting screw is moved separately; and effects a considerable saving in time, in setting the work.

There are, besides the modification just referred to, various other species of chucks, among which we may class Mr. Bodmer's as one of the best.

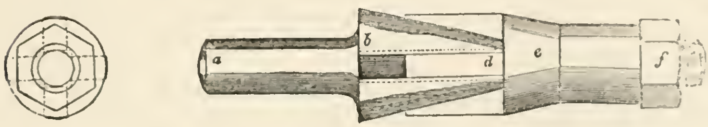
In this arrangement, the clutches are expanded and contracted by means of a series of radiating screws, each of which carries a pinion geering with a large central wheel on the front plate of the chuck; the work is fastened by setting the lathe in motion, and holding back the front plate until the wheel upon it shall have driven in the clutches worked by the screws sufficiently far to grasp it.

The object of change-wheels applied to a lathe is, generally speaking, to obtain a screw of any required pitch; that is, in relation to the leading or guide screw* by which the cutter is moved in a longitudinal direction.

3462.



3463.

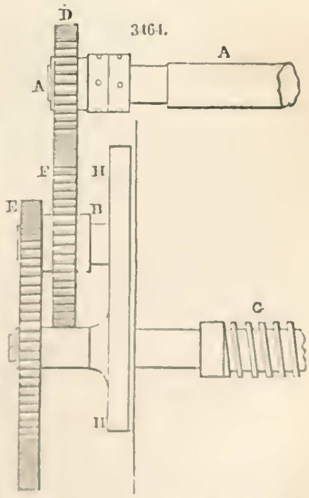


If a spur-wheel be attached to the left-hand end of the lathe-spindle, and so arranged as to geer with another spur-wheel similarly fixed on the axis of the guide-screw, and continuous motion be communicated to the lathe-spindle, it is evident that this motion will be transferred by means of the aforesaid wheels to the saddle of the slide-rest; consequently a screw-tool attached thereto, will receive direct rectilinear motion, and thus trace the spiral thread of a screw on the exterior surface of any revolving cylinder opposed to its action.

The relative proportions of these wheels obviously determine the pitch of the screw to be cut, as compared with that of the guide-screw of the lathe; so that if they are of equal diameter, or, what is the same thing, have an equal number of teeth, the result will be a screw of the same pitch as that of the leading screw; but if the driving-wheels be larger than the driven—suppose in the proportion of two to one, then will the pitch of the work be exactly double that of the guide-screw, and if these proportions were reversed a contrary result would follow.

It is obvious in such a case as we have here supposed, that, as the wheel fixed on the lathe-spindle and that upon the guide-screw, each revolve in contrary directions, all screws cut by this arrangement will be the reverse of the guide-screw, or left-hand threaded. In order, therefore, to cut a right-hand screw, it will be necessary to introduce an intermediate wheel geering with both wheels, so that the direction of motion of the work shall be the same as that of the lathe-spindle.

3464.



The principle of this arrangement is shown in Fig. 3464, entirely disconnected from the frame-work of the lathe, and without strict regard to proportion, it being intended merely to exhibit the parts as distinctly as possible. Here A A′ is a portion of the lathe-spindle, to which is attached in the usual way a cylindrical rod, for the purpose of cutting a thread upon it. G represents the leading or guide screw revolving in suitable bearings, and giving motion by means of a nut to the saddle, and consequently the carriage of the rest, upon which is firmly clamped a suitable tool intended to cut the screw.

In this arrangement it is manifest that every revolution of the guide-screw G will cause the rest to advance through a space exactly equal to its own pitch, or, in other words, supposing the guide-screw to have four threads in the inch, it will, in every revolution it makes, advance the rest, and consequently the tool or cutter, one-fourth of an inch end-long upon the work, so that if the lathe-spindle revolve with the same velocity as the guide-screw, the tool will produce a screw of precisely similar pitch; but if, on the contrary, A A′ revolve with less velocity than G, then the effect will be a greater pitch, and *vice versa*. Now if the lathe-spindle and the guide-screw be connected by a set of change-wheels, we have the means, by properly choosing the numbers of these wheels, to obtain any desired pitch. This is practically effected by an intermediate axis which is supported by a grooved bearer; this carries an arrangement of additional change wheels, according to circumstances and the conditions of the case. The mode of action is as follows:—the leading or guide screw which communicates motion to the saddle of the slide rest is driven by a train

* Screw-cutting and boring machines are reducible to the principle of aggregate motion. For the cutting of a screw is in fact the tracing of a spiral upon the surface of a cylinder, and the motion of boring is also the tracing of a spiral upon

of wheels which are in connection with the spindle of the lathe, it passes through and forms the axis of a movable piece H, and at its extremity carries the fast-wheel I, which geers with a pinion E; this and the wheel F, which geers with the pinion D upon the end of the lathe-spindle, are carried by a stud B fixed in a straight slot cut in the movable arm H, which has likewise a curvilinear slot near its end, through which two fixed studs pass; upon these studs pinching-nuts are placed, which being screwed up tightly, retain it securely, and by altering the angular position of H, a pinion of greater or less diameter than D may be used, and consequently the motion of the leading or guide screw regulated.

Having now explained the arrangement of geering necessary for effecting a change of speed in the guide-screw, we shall, for the sake of a practical illustration, give determinate values to the wheels D F E and J. Thus let the number of teeth in the wheels D and E be 30, and that in F and J 60 each, the pitch of the guide-screw G being $\frac{1}{2}$ inch, or in other words, that it has two threads per inch. It is now evident that one complete revolution of G will advance the tool through the space $\frac{\text{inch}}{2}$, and similarly one revolution of A will advance the tool through the space $\frac{30 \times 30}{60 \times 60} = 0{\cdot}25$ turns of G, or $\frac{1}{8}$th inch, and consequently the pitch of the screw cut by this arrangement will be $\frac{1}{8}$th inch. In this manner any desired pitch of screw may be cut by proportioning the change-wheels accordingly. This may be much facilitated, by arranging the various pitches of screws in a tabular form and placing the respective change-wheels required for each opposite to them, so that all computation during the actual progress of the work is avoided.

In order, however, to meet emergencies, it is necessary that the process of calculation for any given pitch should be thoroughly understood, and for this purpose we shall give an example as a guide.

Suppose it is required to cut a screw which shall contain 13 threads in the inch. Here the ratio of speed between the cone-spindle and the guide-screw is required to be as $6\frac{1}{2}$ to 1 $\left\{ \frac{13}{2} \right\}$, so that we have $\frac{(J)\,130.\ \ 156}{(D)\ 20.\ \ 24}$ &c. $= 6\frac{1}{2}$. In this case, the wheels D and J are supposed to be geered together merely by a single carrier-wheel; but as this arrangement is not always convenient, we shall now find the ratios of the wheels as given in Fig. 3464, where four are used. Here we must remember that the condition of the case is that the numerator divided by the denominator of the expression (13) shall be $6\frac{1}{2}$. We will assume 28 and 56 as the respective values of D and J, or $\frac{J}{D} = 2$. Hence we have only to find such values of F and E, so that $\frac{E}{F} = \frac{6\frac{1}{2}}{2}$ or $3\frac{1}{4}$, which informs us that E must have $3\frac{1}{4}$ times as many teeth as F. Suppose then F has 32 teeth, we have $32 \times 3\frac{1}{4} = 104 =$ the number of teeth in E, the whole set of wheels standing as follows: D = 281, J = 56, F = 32, E = 104. This result is capable of verification as follows: $\frac{56.\ \ 104}{28.\ \ 32}\,2 = 2.\ 3\frac{1}{4}.\ 2 = 13$, or the number of threads per inch of the screw to be cut. Thus in all cases of calculations of this nature, the expression in general terms stands thus:

$$\frac{(\text{No. of teeth in J,})\ (\text{No. of teeth in E}}{(\text{No. of teeth in D,})\ (\text{No. of teeth in F}} = \frac{\text{No. of threads per inch of screw to be cut.}}{\text{No. of threads of guide-screw.}}$$

The following table shows the train of wheels to be used in cutting screws varying in pitch from 1 to 70 threads in the inch; the leading or guide screw is supposed to have two threads per inch, yet may the table be still employed where the leading screw has four threads to the inch, for the same train of wheels would suit for cutting screws of double fineness; and similarly when the leading screw has only one thread to the inch, a screw of only one-half the fineness will be produced with any train given in the table.

In the first columns it will be observed that the wheel and pinion carried by the stud B are omitted; these not being required in cutting screws of the pitches there stated, are displaced, and a simple carrier-wheel substituted for them. To facilitate this arrangement, the wheel J, on the leading screw, has the boss of its socket longer on one side than the other; so that when reversed, as in this instance, it is brought into train with the carrier-wheel, placed upon the stud; and this again is placed in train with the pinion D.

Such are the general principles of screw-cutting for single threads; but when it is required to cut a multi-threaded screw, it is evident that some additional apparatus will be requisite to effect the requisite exactitude of division, so as to bring in each parallel thread in its proper place.

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the surface of a hollow cylinder; the tool being in both cases the describing point, and the plain cylinder the surface. Now as the tracing of this spiral is resolvable into two simultaneous motions, one of revolution with respect to the axis of the cylinder, and the other of transition parallel to that axis, we have in the construction of machines for boring and screw-cutting the choice of four arrangements:

(1.) The cylinder may be fixed and the tool revolve and travel. This is the case in all simple instruments for boring and tapping screws, in machines for boring the cylinders of steam-engines, and in engineers' boring machines.

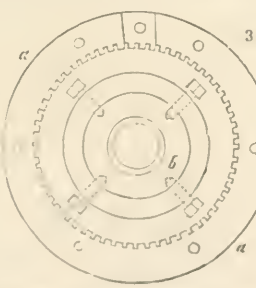
(2.) The tool may be fixed and the cylinder revolve and travel. Screws are cut upon this principle in small lathes with a traversing mandrel.

(3.) The tool may revolve and the cylinder travel. The boring of the cylinders of pumps is often effected upon this principle.

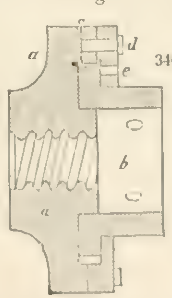
(4.) The cylinder may revolve and the tool travel. Guns are thus bored, and engineers' screws cut in the lathe.

No. of threads per inch of screw.	No. of teeth on		No. of threads per inch of screw.	No. of teeth on				No. of threads per inch of screw.	No. of teeth on				No. of threads per inch of screw.	No. of teeth on			
	Mandrel pinion D.	Leading screw-wheel I.		Mandrel pinion D.	Stud-wheel F.	Stud-pinion K.	Leading screw-wheel I.		Mandrel pinion D.	Stud-wheel F.	Stud-pinion E.	Leading screw-wheel I.		Mandrel pinion D.	Stud-wheel F.	Stud-pinion E.	Leading screw-wheel I.
1	80	40	8¼	40	55	20	60	18	40	60	20	120	32	30	80	20	120
1¼	80	50	8½	90	85	20	90	18¾	80	100	20	150	33	40	110	20	120
1½	80	60	8¾	60	70	20	75	19	50	95	20	100	34	30	85	20	120
1¾	80	70	9½	90	90	20	95	19½	80	120	20	130	35	60	140	20	150
2	90	90	9¾	40	60	20	65	20	60	100	20	120	36	30	90	20	120
2¼	80	90	10	60	75	20	80	20¼	40	90	20	90	38	30	95	20	120
2½	80	100	10½	50	70	20	75	21	80	120	20	140	39	40	120	20	130
2¾	80	110	11	60	55	20	120	22	60	110	20	120	40	30	100	20	120
3	80	120	12	90	90	20	120	22½	80	120	20	150	42	50	140	20	150
3¼	80	130	12¾	60	85	20	90	22¾	80	130	20	140	44	30	110	20	120
3½	80	140	13	90	90	20	130	23¾	40	95	20	100	45	30	90	20	150
3¾	80	150	13½	60	90	20	90	24	65	120	20	130	45½	40	130	20	140
4	40	80	13¾	80	100	20	110	25	60	100	20	150	50	30	100	20	150
4¼	40	85	14	90	90	20	140	25½	30	85	20	90	52	35	130	20	140
4½	40	90	14¼	60	90	20	95	26	70	130	20	140	52½	40	140	20	150
4¾	40	95	15	90	90	20	150	27	40	90	20	130	55	30	110	20	150
5	40	100	16	60	80	20	120	27½	40	100	20	110	56	30	120	20	140
5½	40	110	16¼	80	100	20	130	28	75	140	20	150	60	30	120	20	150
6	40	120	16½	80	110	20	120	28½	30	90	20	95	65	30	130	20	150
6½	40	130	17	45	85	20	90	30	70	140	20	150	70	30	140	20	150
7	40	140	17½	80	100	20	140										
7½	40	150															
8	30	120															

Two separate contrivances have been devised for this purpose. Pihet's apparatus is shown in Figs. 3465 and 3466; the former of which is a front elevation and the latter a section in a line with the axis of the lathe. *a* is a cast-iron disk cut with a female screw to fit the nose of the lathe-spindle, and on the face of this disk is fitted the division-plate *b*, the tubular portion of which also answers for chucking the work. The circumference of this disk is divided by notches, into 60 equal parts, numbered respectively from 0 to 60, into which the spring-catch or stop *c* takes, so that when the disk *a* is put in motion, and the catch put down in any notch as required, the whole moves together as in one piece.



3165.



3466.

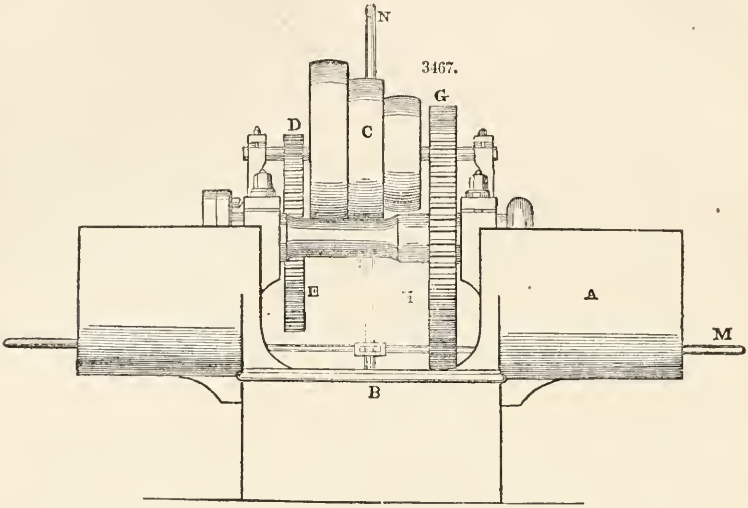
The disk *b* is held in its place merely by friction generated by the pressure of the ring *e*; this ring is shown removed in Fig. 3165, in order to show the graduation of the disk *c*, which is bolted to the disk *a*, and carries in one portion of its circumference a screw *d*. This screw passes through the external ring *e*, and is screwed into the stop *c*, so as to fix the latter in any required division of the plate *b*.

In cutting a multi-threaded screw by this apparatus, it takes the place of the common chuck, the workman fixing his work to it, by means of the radiating screws in the tubular portion of *b*.

Supposing it is required to cut a triple-headed screw, the first operation which is necessary is the detaching of the stop *c* from the disk, so that the latter may be turned round alone, until the division *o* comes opposite the hole in the external ring seen at *e*, in Fig. 3166; the screw *d* is then adjusted so as to connect the division-plate with the disk *a*, and the first thread of the intended screw is cut throughout its whole length. Now as the thread is to be a triple one, it is obvious that the circumference of the work must be divided into three equal parts, so that each thread may be equidistant when cut; accordingly the stop is again detached, and the division plate carrying the work turned round until the notch 20 arrives at the hole *e*; the stop is then replaced, and the second thread is cut in a similar manner as before. Lastly, the division plate is moved round, until the notch 40 is seen through the hole *e*, when the remaining thread is cut, the three having the same reference to each other as the divisions 0, 20, and 40 relatively bear to each other.

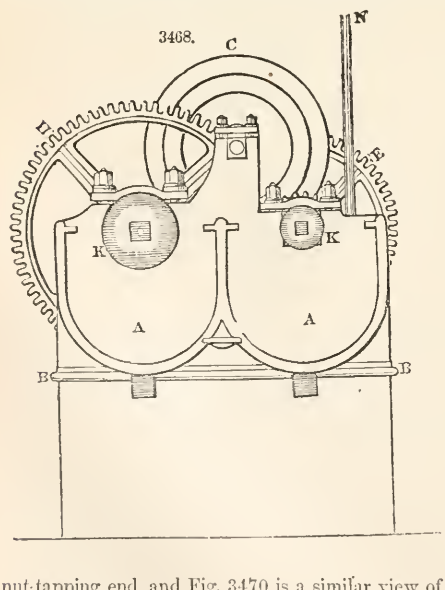
In the production of the minor screws and bolts used in engineering work, the lathe is superseded by the screwing and tapping machine, in which the thread is formed by a travelling die working upon the revolving-bolt intended to be screwed. The principle of the action of this machine will be understood by referring to Fig. 3275, in which we have given an elevation, ground plan, and different detailed views of a single screwing machine of great simplicity. In this arrangement the frame containing the dies travels upon the parallel guide-rods R R, the work being fixed in the chuck L, and entered into the dies which are then contracted until they embrace the bolt sufficiently to be drawn along its surface by its revolution. The quick return motion of the die-frame is produced in the ordinary manner as applied to planing machines. This machine is objectionable on account of its want of compactness; otherwise it is a pretty fair specimen of its class.

3467.

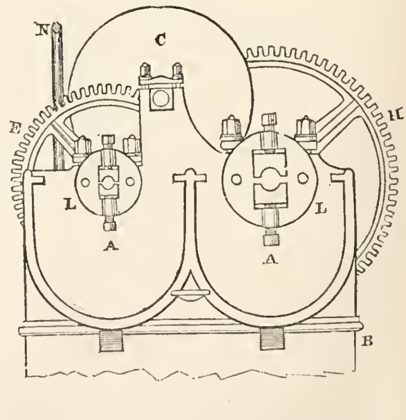


The double screwing machine by Messrs. Randolph, Elliot, and Co., of Glasgow, is a much more complete and useful workshop auxiliary than the last, and has, besides, the merit of great compactness. Fig. 3467 is a side elevation of the machine, Fig. 3469 is a ground plan, Fig. 3468 is an elevation of the

3468.

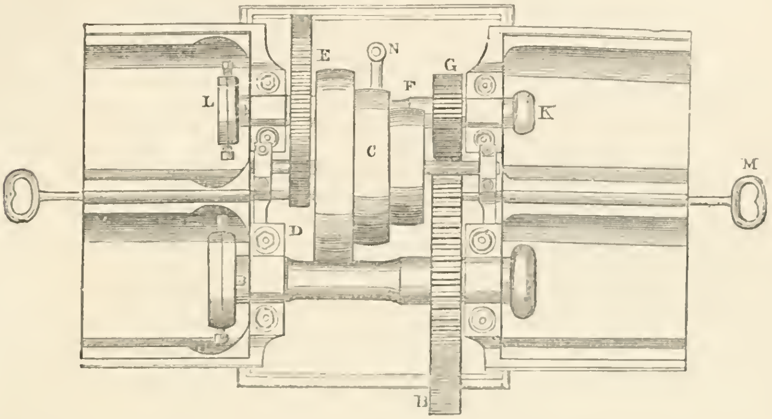


3470.



nut-tapping end, and Fig. 3470 is a similar view of the bolt-screwing end. The frame-work of the machine A A, and the sole-plate B B, are cast in one piece. The driving-cone C is supported by the upright frames near the centre of the machine, and carries a pinion D, of 15 teeth, which geers with the wheel E, of 56 teeth, keyed on the smaller screwing-spindle F; thus the relative speeds of the driving-cone and the spindle F are as 3·73 to 1. The spindle F again carries a pinion G of 18 teeth, geering with the wheel H of 72 teeth, keyed on the larger screwing-spindle I, the ratio of speed in this case being as 4 to 1. In the end view the chucks K K are shown with square recesses, for the purpose of receiving the heads of taps for tapping-nuts. In the view of the contrary or bolt-screwing end, the chucks L L are provided with plates grooved for the purpose of receiving the screwing-dies, which are adjusted by means of two set-screws, which press against the backs of the dies so as to suit them to any diameter of bolt. The motion of the spindles is stopped or reversed by the handles M M, at each end of the machine. They are connected by a lever with the vertical rod E, which carries the shifting-strap forks. The top driving-geer consists of three pulleys, a fixed central one, with a loose one on each side, all being on one shaft, which also carries a cone of three speeds exactly similar to C.—the last carries the driving-belts communicating directly with the machine. The centre pulley of the set of three is much narrower than that on each side of it, so as to allow of the release of the cross-strap before the open one comes upon it, and *vice versa*. For another somewhat similar arrangement, see Figs. 3282 to 3287.

3469.



Analogous to the subject just discussed, is that of nut-cutting, an operation formerly entirely performed by manual labor, a tedious and uncertain process, but now effected with facility and precision by self-acting machinery.

In Figs. 2974 to 2976 we have given detailed views of a complete machine for this purpose, by Mr. A. Mylne, of Glasgow. The nut to be cut is fixed on the upright spindle of the support *r*, and is brought in contact with the revolving-cutter *x* by means of the screw *y*, the requisite division of the faces of the nut being effected by means of the circular table, which is provided with six equal notches fitted with a spring-catch from the lever *n*. This machine is also provided with a self-acting feed motion, by which the nut is gradually moved up to the cutter while in action. This is effected by the shaft *c* of the speed-pulley *e*, which carries a worm *s* geering with the wheel *h*, upon the shaft of which is fixed a pinion geering with a rack on the lower side of the table carrying the nut. This motion may be dispensed with when thought necessary, and the work may be carried forward by hand, by means of the hand-wheel and shaft *b*.

This machine is very compact and fully answers the purpose of dressing-nuts of any number of sides, by using differently divided plates. In many engineering works, nuts of all numbers of sides are forged in swages made for the purpose; the accuracy and beauty of finish of which is nearly equal to nuts cut by the machine, and answer all purposes where extreme finish is not required, the expense of production being at the same time very greatly diminished.

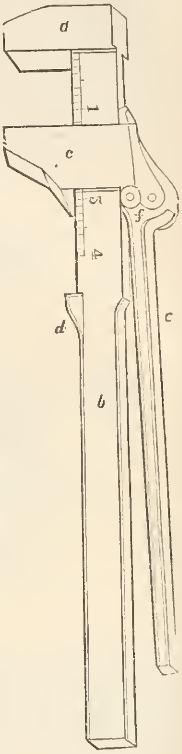
The subject of nut-cutting leads us now to the consideration of screw-keys, by means of which all nuts of screws used in the connection of the different portions of machinery are adjusted to suit the ever-varying exigencies of mechanical contrivances. The common screw key with fixed jaws must be so familiar to our readers as to render any description of it unnecessary, and we shall therefore point out a few examples of attempts to remedy the defects of this most necessary instrument. In the dissection of any piece of machinery, even of the more simple species, we invariably find a multitude of different sized bolts, the nuts of which of course each require a key suited to its own particular size. A reference to the number of gradations of size of nuts, given in a previous portion of our pages, will immediately point out the necessity of some contrivance for dispensing with the number of these instruments, and introducing an adjustable apparatus, by which a number of different sized nuts may be worked without entailing the awkward drawback of keeping so many all but useless workshop appendages.

The earliest contrivance for this purpose is what is technically called a *monkey*, the use of which, previous to the introduction of the more refined species of tools, was almost universal.

But a more elegant instrument for this purpose is the coach wrench, which is equally applicable to the working of nuts and all similar purposes.

Our example of this key, Fig. 3471, is capable of receiving nuts from the smallest size up to four inches, and is of course sufficient of itself for all ordinary purposes. The end jaw *a* is in one piece with the lever handle *b*. The movable jaw *c* is mortised to slide upon that portion of the lever between the end a and the fixed stop d; it is held in its place when set for any nut by means of the second lever e, which works on a centre-pin in the projecting portion of the jaw. This lever also carries a projection at f, by which it is jointed to a thin wedge, passing between the top of the lever b and the interior surface of the slotted portion of the movable jaw. Thus, when the latter is set to the size of nut required, a slight pressure upon the side of the lever e forces down the wedge, and secures the jaw immovably. (See WRENCH.)

3471.



The peculiar merit of this species of key is, that all allowance for wear is made up by the wedge, which will never permit any looseness in the jaw, as the only difference caused by the wear of the surfaces in contact will be a greater travel of the fixing wedge. Practical men who have made use of those keys which are adjusted by means of nuts will at once see the value of this advantage.

Next to the turning-lathe in its importance to the engineer, the planing machine stands foremost in rank of constructive machines. The primary idea of planing by machinery was doubtless brought into existence by the necessity which constantly presents itself of diminishing the enormous amount of labor expended in producing plane surfaces on wood by hand, as practised by means of the common joiner's plane. Next to the process of sawing, there is no operation connected with the working of wood, which consumes so much time, and adds so much to the expense of the conversion of timber as the production of the hand-planed surface.

The first attempt to obviate this difficulty with which we are acquainted, was made by General Bentham, in 1791, who took out a patent for a method of effecting this object. In this scheme, the plane or cutting-edge, which was movable, was made of the full width of the board intended to be cut, and on each side of it were fixed fillets which projected below the face of the plane, a distance equal to the amount of the thickness intended to be taken off the board. Several plans were adopted for obtaining a good surface from a very thin board, but the whole scheme eventually proved all but abortive—the machine was never practically worked by mechanical power, but whether thus driven, or by the hand of the attendant workman, the idea had still the advantage, that it exonerated the latter from the charge which he had of his tool in the ordinary operation of planing, rendering a common workman as useful as the skilful joiner for this purpose. The next epoch in the history of mechanical planing is the improvement produced by Mr. Bramah, who, in 1802, patented a method of producing "straight, smooth, parallel, and curvilinear surfaces on wood and other materials." This invention embraced the original machine for producing spheres, the principle of which is still preserved in all machines of a similar nature to the present day. Bramah's planing machine, as constructed for the Royal Arsenal at Woolwich, gives us a specimen of an embodiment of his ideas at this period.

Here the cutters are attached to a horizontal disk keyed on a strong vertical spindle. This disk is put in rotation at a speed of about 90 revolutions per minute, the material to be cut being attached to a sliding cast-iron bed, which is moved by hydrostatic pressure. A pipe communicating with a hydrostatic press is carried in below the bed of the machine, and terminates in a plunger-barrel, the plunger of which carries a rack-geering with a pinion on a rag-wheel shaft. This wheel is provided with teeth, over which a pitch-chain attached to the table of the machine is carried.

In all planing machines as at present constructed, the cutter is invariably the fixed portion, the work being passed beneath it in the act of cutting, by means of a sliding-table. The particular species of planing machine which has been most lately introduced, is termed the hand-planing machine.

In Figs. 3477 and 3479 we have given three views of a simple and effective hand-planing machine, as suited for small work generally, such as links and connecting-rod ends for locomotive engines, and other portions of machinery where a plane surface of small extent is required.

The table of the machine is here supported in the usual manner, as employed in similar tools of a larger class, upon a bed bolted to the top of two standards attached to the floor. The lower surface of the table carries a rack M, which is driven by a pinion F, upon the shaft G, supported in bearings attached to the fixed bed of the machine. Motion is given to this shaft in either direction, by the cross-handle H, worked by hand in a similar manner as applied to small presses.

The cross-slide C is supported by two uprights bolted down to the bed; this slide carries the tool-holder D, which is traversed across the bed of the machine by means of the horizontal screw b. The automatic action of the transverse feed motion of the cross-slide is effected by the movable stud S, attached to the travelling-table; this stud, being movable in a groove in the side of the table, is capable of being set at any point in order to suit the required length of stroke for the work. The pressure of this stud, upon a short lever keyed on the small shaft carrying the piece n, depresses it, and the latter, by its connecting-rod r, acts upon the ratchet-plate K, upon the horizontal screw b.

The amount of travel thus given to the screw is varied by shifting the position of the sliding-studs in the pieces m and n. The front plate of the tool-holder is provided with two short circular slots, through which bolts pass from the back plate; in this manner the tool may be set at any angle to suit the nature of the work required. The tool-holder or cross-slide is raised or lowered to suit the circumstances by the vertical screws $f\,f$, driven by bevel-geering in the usual manner.

A somewhat similar but more useful machine of this species has been introduced by Mr. Charles Walton, of Leeds. In this machine the bed is so arranged that it may be fixed upon the workman's bench, and may be driven either by manual or steam power. Immediately beneath the bed of the machine is placed a horizontal grooved disk, driven by bevel-geering, either from the pulley-shaft of the workshop or by a winch. This disk is grooved directly across its upper surface for the purpose of receiving a pin, which is connected by a link with the lower surface of the short travelling-table. In this manner a reciprocating motion is given to the table in the simplest manner, and the length of stroke is capable of variation according to the distance of the pin in the horizontal grooved disk, from the centre of motion. The feed motion of the cross-slide is effected by a stud fixed on the under surface of the horizontal disk; this stud works a short lever keyed upon a shaft working in bearings attached to the side of the bed. This shaft again carries a second lever outside the bed, and is jointed by a link to an arrangement of ratchets. For all small machines, this method of giving motion to the table is decidedly the simplest and most compact, and although the introduction of the disk has the effect of producing a variable speed in the cutting, being greatest at the middle of its stroke and least at each end; yet as the disk is confined to machines of a short stroke, its diameter is not so great as to bring about a detrimental variation in the speed. Small machines of this species, which are quite an innovation in the workshop, are now becoming indispensable where much small work is required, and have served in a great measure to banish that most expensive of all tools, the file, and thus rendered an important service in cheapening engineering work in general. So much indeed is this the case, that it is an established fact that different portions of machinery, the configuration of which is made up of curved and plane surfaces, are now entirely finished by means of the lathe and planing machine, without the necessity of touching them with the file.

As a specimen of a step higher in the order of completeness and general usefulness in machines of this kind, we must now refer the reader to Figs. 3080 and 3080², where we have given very complete views of the machine invented by Mr. Mylne, of Glasgow. Here the system of working the vertical and horizontal slides is similar to that made use of in the hand-machine, Figs. 3077 and 3078.

The chief peculiarities in the present machine are the arrangement of the geering for travelling the table, and the great completeness of the tool-holder. The forward or cutting motion of the table is obtained from the large pulley A, the shaft of which carries a pinion D geering with the large wheel E upon the rack-pinion shaft.

This shaft carries two pinions geering with two racks of similar pitch bolted to the under side of the travelling-table. These racks are so placed that each tooth of the one shall be opposite to each space of the other; in this manner the irregularity of motion so much complained of in ordinary rack-worked machines, as producing a waved surface on the work, is to some extent avoided. A more effectual method of attaining this end has been introduced by Mr. Collier, of Manchester; this plan consists in making the teeth of the rack and pinion on what is technically termed the *step* system, that is, each tooth is divided in its breadth into three parts, each division being set a distance equal to one third of the true pitch of the teeth behind its neighbor. The practical result of this arrangement is, that although the strength of the original coarse pitch is preserved, yet the teeth work with the steadiness due to a pitch three times finer, or so many times less as the number of divisions of the teeth amounts to. This plan is now universally adopted in all rack machines, as it is simple, easy of application, and completely effectual.

This, although in our opinion not the best, is probably the most universally used species of driving geering applied to planing machines. Of the two remaining systems, the *chain* and *screw*, the latter, for excellence of workmanship, is decidedly to be preferred. Mr. Whitworth's planing machine is perhaps the most finished specimen of modern tool-making extant.

The principle of anti-friction rollers acted on by a screw, as a means of obtaining a rectilinear motion, was first introduced by Mr. Whitworth, in 1835, when he employed it as a motion for the carriage of the self-acting spinning mule. In his planing machine the rollers are placed parallel, face to face, on opposite sides of the screw, their axes revolving in bearings attached to the under surface of the bed, and their peripheries projecting into the spaces between the threads of the driving-screw. It will be seen that each periphery has two opposite points of contact, acting alternately according to the direction of motion of the screw, which, as it revolves, brings its threads to bear upon the rollers, causing them to revolve, and at the same time to carry forward the table to which they are fixed. The friction which would occur if the threads of the screw bore simply against a fixed nut, is thus transferred to the axes of the rollers, where the velocity is reduced in the proportion existing between their peripheries and the circumference of their axes. The proportion found to answer best for this arrangement is as 7 to 1. The advantage which this mode of driving has over the common rack and the chain will be perceived at a glance, as not only is the motion rendered perfectly uniform, a condition essentially necessary to the proper action of the cutter in producing a good surface, but the construction of the driving geering is rendered to the last degree simple.

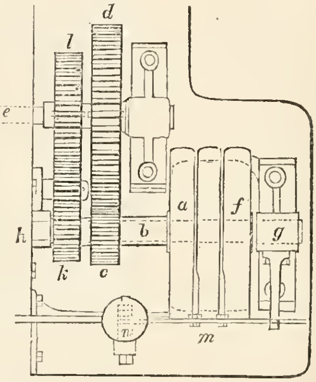
The arrangement of catches employed by Mr. Mylne is good, but the geering connecting the catch-shaft with the strap fork is capable of much simplification.

Referring to Figs. 3080 and 3080², it will be seen that there are two adjustable catches *n n* set in a groove running along the side of the table; these catches are not set in the same plane, but one projects out beyond the other in order to suit the levers *g*, which are cast to a tubular shaft working loose on the driving shaft. When the table is moving forward one of the catches comes in contact with its lever and turns it over, as seen in the end view of the machine. The boss of these levers again carries a third lever connected to the weighted lever on the end of the bed, which again communicates by a shaft running along the side of the machine, with the strap fork shaft C; the latter thus causes the shift of the straps from one pulley to the other, and reverses the motion of the table. Upon the return of the table, the catch which has just acted now returns without coming in contact with its lever, as its former motion has placed it out of its reach, having at the same time raised the second lever on the same shaft to an upright position, so that it may be acted upon by the other catch at the contrary end of the table, when the straps are brought back to their primary positions.

As a driving and reversing geer for small planing machines, Mr. Nasmyth has applied the mangle-wheel motion, so called from its adaptation as a continuous forward motion for common clothes-mangles. It consists of a large disk, having near its circumference a circle of pins bolted through the metal at right angles to its plane; these pins answer as a set of teeth, into which a small driving-pinion geers, working alternately on the outside and inside of the teeth so as to effect the desired reverse motions. In Mr. Nasmyth's arrangement, the driving-pulley is keyed upon a light shaft passing transversely beneath the table of the machine. The contrary extremity of this shaft, which projects beyond the edge of the bed, carries the mangle-pinion geering with the pins of the mangle-wheel. The latter is keyed upon a central transverse shaft which passes beneath the table of the machine and carries a large chain-pulley. Round this pulley a chain is passed twice, and its two extremities are passed round two fixed pulleys placed at contrary ends of the bed, and attached to the opposite ends of the travelling-table. The reversing of the mangle-wheel, and consequently that of the table, is effected in the following manner: at two points in the circumference of the mangle-wheel, one or two of the pin-teeth are removed, and a sloping guide or stud is placed at each point, so that when the driving-pinion arrives there, this guide causes it to traverse in or out, as the case may be, to geer with the inner or outer sides of the pins, under which conditions it is easy to see that the two contrary motions of the wheel will be the result. The guide supporting the pinion-shaft is slotted horizontally to allow of the traversing of the shaft as well as to prevent its running beyond the point of geer with the pins of the mangle-wheel, the bearing on the opposite end of the shaft next the driving-pulley being arranged to swivel on a centre, so as to permit of this motion. This movement of the pinion-shaft is also taken advantage of in giving the feed motion to the cross-slide of the machine, being connected to the vertical rod carrying the catches for the ratchet-wheel of the transverse screw.

This movement, although ingenious, is destitute of the advantage of an increased speed in the return stroke, consequently much time is lost by it when applied to single-acting machines.

3472.



The arrangement applied by Messrs. Nasmyth and Gaskell to the rack-planing machines is a very convenient though somewhat cumbrous motion. Fig. 3472 is a ground plan of this geering, in which *a* is the forward motion driving-pulley, keyed on the hollow shaft *b*, which carries a pinion *c* geering with a large spur-wheel *d*. The latter is keyed directly on the rack-pinion shaft *e*, shown in dotted lines passing beneath the table of the machine. The backward-motion pulley *f* is keyed on the solid shaft, passing through the hollow one and revolving at one extremity in the bearing *g* fixed on a pedestal attached to the bed-plate, and at the other in the bearing *h* bolted to the side of the bed. This latter shaft carries another pinion *k* geering by means of an intermediate carrier-wheel, with the spur-wheel *l* also keyed on the rack-pinion shaft. The centre pulley is of course loose, serving merely to carry the strap when the machine is stopped, and during the transfer from the forward to the backward pulley. Thus it will be seen that the return stroke of the table will be so much quicker than the cutting one, as the difference in diameter of the two wheels *l* and *d*, or rather, as the ratio which exists between the wheels *k* and *l* and *c* and *d*.

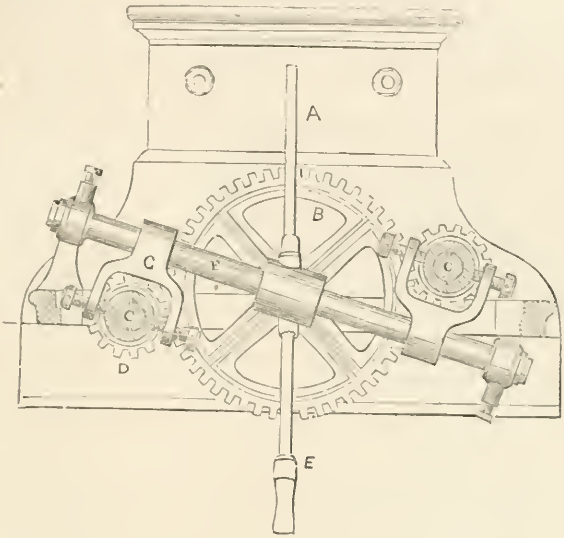
The strap-fork is seen at *m*; it is worked by catches fixed on the other side of the table, a connecting-shaft from which passes beneath the bed where it is attached to the fork; *n* is a weighted lever for the purpose of giving a sudden shift to the strap, so as to give the workman a better command over his machine.

Of chain-worked planing machines, the modification introduced by M. Decoster, of Paris, is perhaps one of the most complete. In his machine he has made use of the driving-geer as applied by Mr. Whitworth to his screw-machines. In the example by M. Decoster, to which we refer, the chain-motion is applied to give motion to the tool-slide, while the table of the machine remains stationary. This plan is found extremely useful in planing heavy and unmanageable pieces of metal, as the latter may be firmly secured to a foundation independent of the machine, while the tool alone traverses over it; and consequently no more power is absorbed by a heavy casting, than by the lightest possible piece of metal. The driving geering before referred to is here placed alongside the bed of the machine, near one end; the pinion on the central bevel-wheel geers with a large spur-wheel, on a shaft passing transversely across the bed of the machine, below the table. The latter shaft carries two rag-wheels, placed near its two extremities just within the frame of the machine. Round each of these wheels is passed an endless chain, which passes along the whole length of the machine, returning round a similar pair of wheels revolving loosely on studs at the contrary end of the bed. The upper length of this chain is attached to the lower surface of a V-grooved slide, working in corresponding grooves planed in the upper surface of the bed. This slide carries a second horizontal slide supporting the tool-holder in the usual manner. The feed-motion of the cross-slide is ingeniously effected by two ratchet-catches attached to the spur-geering on the end of the horizontal screw. The lower extremities of these catches are set to come in contact with movable tappets attached to the fixed frame of the machine, so as to give the proper amount of motion to the screw of the cross-slide. The method of attachment of the driving-chains adopted by M. Decoster has the advantage of giving a steadier pull to the tool-slide than can be obtained by the central mode of fastening, with a single chain.

The principle of the movable tool and fixed table has also been adopted by M. Cavé and Mr. Hick, of Bolton. In M. Cavé's machine, the driving motion is given to the tool-slide by an endless strap. The driving-pulley is placed immediately over the centre of the bed of the machine, the strap from which passes below two fixed tension-pulleys, placed just beneath the driver, and thence round two fixed pulleys attached to the opposite ends of the bed. The attachment of this strap to the sliding-frame of the tool is effected by passing the strap in contrary directions round two separate pulleys, each carrying a pinion geering with a central driving-wheel. The shaft of the latter passes across the bed of the machine, and carries two pinions, geering with two racks, placed within the framing, and running along the whole length of the bed.

The arrangement of the spur reversing-geer will be understood by referring to Fig. 3473, which is a side view of the tool-slide, frame, and geering, with the driving-pulleys removed. A is the travelling tool-slide, carrying the central driving-wheel B, keyed on the pinion-shaft—the shafts C C each carry a loose driving-pulley, capable of connection by means of sliding clutch-boxes with the two pinions D D. These latter work loose on the pulley-shafts, and geer with the central wheel B, so as to drive it in either direction accordingly as the clutch-boxes are set.

3473.



Two movable inclined tappets are fixed to the bed of the machine, which alternately come in contact with the lever E on the oblique shaft F, so as to move it in and out according to the motion of the slide. The shaft F carries the two forks G, connected to the clutch-boxes of the pinions D D, which are placed, one on each side of it, so that when the lever E is pressed upon by its tappets, the hold of the two clutches is changed accordingly—one being thrown out of geer at the same time the other is put in. In this manner, as the two pulleys on the pinion-shafts revolve in different directions, a reciprocating motion is given to the travelling-slide.

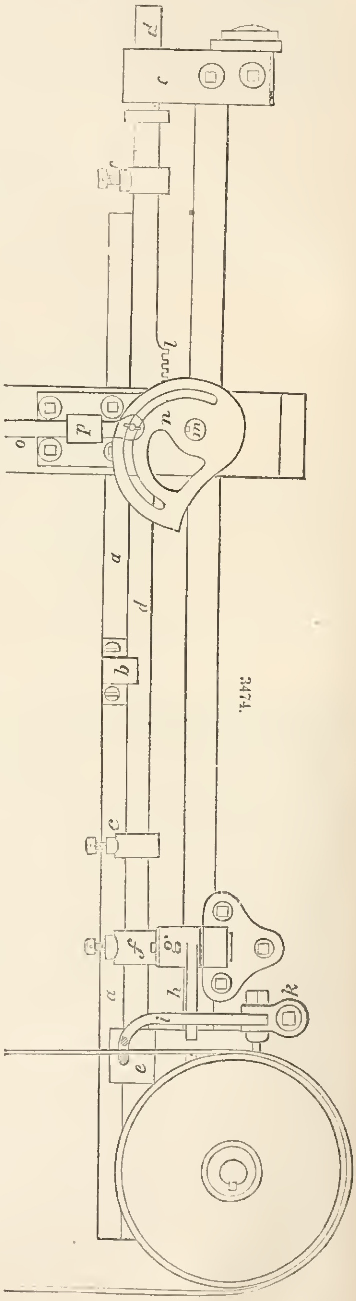
The cross-slide of this machine is provided with two tool-holders, one on each side, so as to cut in both directions; this improvement effects a great saving of time, as the return stroke is rendered equally as effective as the forward one.

In Mr. Hick's movable tool-slide machine, the traversing motion is given to it by means of steel belts. The driving-pulley of the machine is alternately worked by a cross and open strap; the shaft of this pulley is connected, by means of spur-geering, with a transverse shaft carrying two pulleys working outside the frame of the machine. These pulleys each carry an endless steel belt, running alongside the frame, and passing round two similar pulleys placed at the contrary extremity of it. The steel belts are attached to projecting levers on the cross-slide by means of tightening screws, so as to communicate an alternate motion to it, accordingly as the open or crossed strap is working on the driving-pulley.

As the speed of the travelling table of this machine is the same in each direction, it is arranged to cut both ways, by the adaptation of Mr. Whitworth's revolving tool holder, subsequently described.

It is a matter of considerable importance in planing machines, to have a compact arrangement at command, both for reversing the motion of the table, and also for giving the self-acting feed-motion to the cross-slide. As regards the reversing motion, in planing delicate or complicated work, it is often requisite to be able to stop the motion of the table within the shortest possible limits, as, for instance, in planing up to an abrupt shoulder; in such a case, if the tool does not proceed sufficiently far, a surface of metal is left which must be removed by some more laborious means; or, on the other hand, if it proceeds a little too far, the tool strikes against the obstacle and causes an injury either to the work or to its own geering. In small machines this is easily avoided, by the use of the crank or grooved disk, which allows of the greatest exactitude in the length of travel; but in machines of the larger class we are driven to some other expedient to attain the end. Where the change of motion is effected by the pulley-belt, the simplest and most effective system of quick stoppage is the addition of the weighted balance-lever attached to the strap-fork; the sudden fall, in either direction, of this weight causes an instantaneous motion of the strap, and stops the table within very short limits. Where still greater nicety is required, possibly the addition of a movable clutch-box may be of some assistance. Some makers, indeed, have applied the clutch-box instead of the shifting-strap, the clutch being arranged to throw the two side bevel-wheels in geer alternately with the centre one.

As a compact and efficient self-acting reversing and feed motion, we give that adopted by Mr. Whitworth, as one of the best. Fig. 3474 is a side elevation of the apparatus; *a* is the table of the planing machine, on the side of which, at the centre, is screwed the fixed catch *b*, which, in the course of working, alternately comes in contact with the movable catches *c c*, adjustable on the shaft *d* which runs alongside the table, sliding in the bearings *e e* at each end of the frame. This shaft carries a third adjustable catch *f*, connected with a short lever cast on the boss *g* working loose on a stud screwed to the frame. The same boss has also cast upon it a second lever *h*, at right angles to the former one, the end of which works in a slot in the scrap-fork *i*. The latter oscillates on a centre attached to the bed at *k*; when the catch *b* comes in contact with one or other of the studs *c*, the shaft *d* is carried along laterally, and gives motion, through the arrangement of levers just described, to the strap-fork so as to shift the strap from one pulley to the other, and reverse the table.

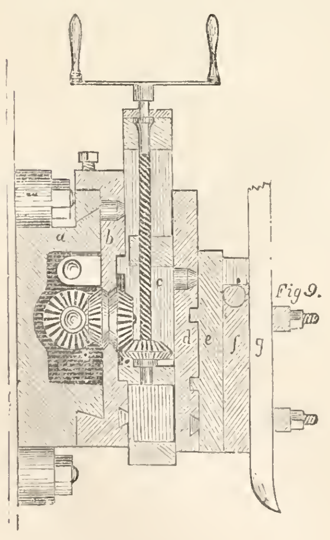


3474.

The self-acting feed-motion of the cross-slide is effected in the following simple manner: on the sliding shaft or rod *d* a few rack-teeth *l* are cut, which geer with a segment of a spur-wheel keyed on the shaft *m*, working in bearings screwed to the upright frame of the machine, and carrying the eccentrically-grooved disk *n*, which revolves with it; *o* is the vertical rod carrying the ratchet-catches for working the horizontal screw of the cross-slide: it is guided by a bearing *p* screwed to the frame, and carries at its lower extremity a pin working in the eccentric slot of the disk *n*. Thus when the rod *d* receives its motion from the catch *b*, at the termination of the stroke of the table, its short rack causes the disk *n* to make a portion of a revolution, so as to raise or depress the rod *o* by means of the eccentric groove. This motion is at once effectual and easy of application, besides possessing that great desideratum in all tools, compactness.

We now come to the consideration of tool-holders. The specimen of a tool-holder given in Mr. Mylne's machine, is one of the more complicated variety, being provided with a double set of slides and appropriate screws, for the purpose of planing at two different angles with one adjustment of the tool. The saving in time, however, by this arrangement, is more than counterbalanced by the increased cost of the tool-box,

3475.



and the disadvantage which it entails upon the machine, by throwing the point of resistance in cutting so far from the surface of the supporting frame as to render the cutting action unsteady.

A somewhat simpler modification of the same variety of holder is represented in Fig. 3475, where the self-acting down cut motion is obtained by one screw; a is a transverse section through the cross-slide of the machine, to which is fitted, by dovetails, the horizontal sliding-plate b. The latter again carries the down-cut slide c, being attached to it by dovetail-headed bolts working in a circular groove in the former. The slide c is fitted with a central screw carrying a nut fixed on the front sliding-plate d, so that the latter may be moved at any angle to the bed of the machine according to the angular position of the screw; e is a front plate, checked into the slide d, to which is hinged the tool-holder f, carrying the tool as shown at g.

The self-acting feed-motion is given to the screw in the plate c by bevel-geering, similar to that employed in Mr. Mylne's machine. The hinge at the upper end of the tool-holder is for the purpose of allowing the tool to give way in case it comes in contact with any obstacle during the return stroke of the machine. In all properly constructed tool-boxes, the mechanism is arranged to lift the tool out of the way at each return stroke, so that it never rests upon the surface of the work in the back motion. This is effected by a separate transverse screw placed parallel to the main traversing screw, and worked by the same geering. In Mr. Bodmer's tool-boxes this screw carries a nut with a slotted projection fitting to a pin in the upper end of the front plate, which oscillates loosely on a fixed centre. The nut being carried along with the tool-slide by the revolution of its screw, remains always immediately above the centre of the tool-holder; at the termination of a stroke, the reversing geering is so connected with the screw as to give the latter a lateral sliding motion, the nut upon it then moves the front plate by the pin in its upper side. This plate carries a small inclined pin, which in its motion presses against the front of the hinged tool-holder, thus raising it out of connection with the work.

The self-feeding down-cut motion is also given by the same oscillating plate. The latter is provided with a toothed sector screwed to it near its lower extremity, and geering with a small bevel-pinion on the down-cut screw-spindle. The latter being fitted with a ratchet-wheel, receives at each stroke of the machine an amount of motion proportioned to the material to be cut. This is probably one of the most complete and effective of all single-acting tool-holders, and is a good specimen of the high degree of eminence which Mr. Bodmer has attained as a maker of constructive machinery.

In addition to the common rectilineal planing machine, machinists have of late years found a powerful auxiliary in the circular machine; this may be defined, in general terms, as a lathe with a vertical spindle. The tool is either fixed or movable, the former being the preferable and more general arrangement. The advantages which these machines possess over common turning-lathes, are, firstly, the greater facility of adjustment of heavy castings preparatory to planing them; and secondly, the greater latitude they allow for acting on masses of metal of great diameter, as the driving-wheels of locomotive engines, fly-wheels, &c. Of this species of tools, perhaps Mr. Bodmer's modification stands highest in the scale of usefulness. It consists of a heavy foundation plate, in the centre of which a strong vertical spindle revolves, having a horizontal circular table of large diameter keyed upon it, and provided in the usual manner with slots for fixing the work. The fixed cutter is held in a tool-box precisely similar to that adopted in the common planing machines. It is placed on a strong horizontal cross-slide, which is adjusted to work freely in a vertical direction upon two upright frames, placed one on each side of the revolving-table. The tool-holder being fitted with a down-cut motion, is readily adjusted with great nicety to suit the work, besides which its horizontal motion on the cross-slide, combined with the vertical motion of the latter upon the uprights of the frame, permit the tool to be set to any portion of the radius of the table. The machine is fitted with a self-feeding motion; this is found very serviceable in turning up the tires of locomotive and carriage wheels, the rims of small fly-wheels, &c. Machines have been constructed which combine the advantages both of the rectilineal and circular machines, with a view to the finishing of more complicated work than can be effected by either of these separately. The machine is provided with a rectilineal sliding-table, as ordinarily used, supported on a fixed bed. A horizontal shaft passes transversely below the bed, and carries a plain sector of considerable radius, to which a chain is attached, and is connected to the opposite ends of the table. Motion is given to this sector by a plain grooved disk, as usually applied to slotting machines; this is driven by over head geering, supported by the upright framing which springs from the bed of the machine. The pin of this disk is attached by a suitable connecting-rod to a crank keyed on the extremity of the shaft of the sector, which thus communicates a reciprocating motion to the table, of a length dependent on the position of the pin in the radius of the disk.

When continued circular work is required, the driving disk is thrown out of geer, and the driving-shaft is connected with an upright spindle revolving in bearings attached to the upper framing of the machine, and carrying an adjustable cutter in a projecting arm at its lower extremity. This cutter is provided with suitable slides, by which it may be set at any required distance from the centre of motion of the spindle, so as to act upon any given circle. When thus arranged it may be used as a powerful boring machine, by detaching the facing cutters, and fitting the proper tools as applied to the usual boring bars. When the combination of the straight and circular movements is required, as for finishing the flat sides and circular ends of strap-links, &c., both movements are effected by the same driving shaft as follows:—On the end of the driving-shaft are keyed two toothed sectors, arranged to give alternately a semi revolution to the wheel on the driving disk for the rectilineal motion, and that on the train for giving the circular motion to the cutter spindle—each wheel being alternately held by a detent while the other is being driven. In this manner various kinds of work may be finished in a very superior manner, such as the plane and circular surfaces of plummer blocks, connecting-rod straps, &c.

In addition to these two descriptions of machines for obtaining a *plane* surface, a third species for planing curves has latterly filled an important office in the engineer's workshop. The tool to which we refer is the compound machine by Messrs. Nasmyth and Gaskell. This little machine forms another link in the catalogue of automatic contrivances for superseding the delicate manipulations of file labor. By its assistance the circular ends of levers, connecting links, &c., are correctly cut out, and finished with a degree of celerity that sets manual labor at defiance. The essential principle of the machine is identical with a slotting machine with a horizontal tool movement, the tool-slide being worked in a similar manner by a circular slotted disk. In planing the circular ends of levers, &c., the work, after being drilled, is fixed on an ingenious adjustable mandril, with its rectilineal surface in a line with the direction of the traverse of the tool. A self-feeding motion causes the work to revolve slowly in the action of cutting, similarly to the same arrangement in the slotting machine. By detaching this geering the tool becomes available for the production of plane surfaces at any angle by an appropriate adjustment of the tool-holder—thus it unites the offices usually consigned to separate tools, and is a very useful auxiliary to the engineer.

Though not in immediate connection with the subject of planing, we may here mention Mr. Bodmers stand-cutting machine. This tool is a species of planing machine, provided with a revolving cutter, and is used for the purpose of cutting out the recesses in the small stand bearings, &c., in cotton and other machinery, a species of work which requires the utmost precision and exactitude of management. In preparing and fitting up the supporting pedestals used for the rollers of spinning machinery it is essentially necessary to preserve their line of bearing perfectly level, otherwise the rollers will undergo an injurious strain in the working. To accomplish this in a speedy manner, Mr. Bodmer fixes a row of pedestals upright on a movable bed, constructed like an ordinary planing machine. The upright framing in the centre of the machine carries a revolving cutter, similar to the steel cutters used for cutting the teeth of wheels; the row of pedestals, which are placed in a line with the motion of the bed, are then passed slowly beneath the cutter, thus securing an accurate adjustment of the height of each.

A machine similar in principle is used for fluting the wooden rollers of flax machinery, mechanism being introduced for the purpose of causing the rollers to make a portion of a revolution after the cutting of each groove.

Slotting machines, in their general principle of action, may be defined as planing machines with movable tools. The period of their introduction to the workshop dates among the latest of the automatic tools of the day, as, until a short time back, the species of work now executed by them was entirely performed by the file and chipping-tool. As a finished specimen of this tool we may refer the reader to Messrs. Caird & Co.'s machine, Figs. 3337, 3338, 3339, 3340.

The method of transmitting motion from the driving-geer to the reciprocating tool is here very simple, and the machine, as a whole, has a very handsome appearance. The table, in addition to the usual rectilineal and circular motions, is provided with apparatus for setting it at any angle to suit the different varieties of work. This angular motion is useful in cutting the key-seats of wheels, where a slight inclination is necessary to suit the shape of the fixing-key.

In such a machine as the one before us, it is evident that the size of the work capable of being operated upon by it, is circumscribed by the distance from the cutting centre to the edge of the supporting pillar. If this distance is increased in order to suit the dimensions of wheels and castings of a large size, a greater disadvantage ensues, namely, an increased amount of unsteadiness of action. Messrs. Nasmyth & Gaskell have remedied this disadvantage most efficiently by doing away with the supporting framing of the machine, and causing the tool to cut from below upwards. The machine is, as it were, entirely reversed in this modification, the driving disk and geering connected with the slotting-bar being placed under ground in a pit made for the purpose. The cutting end of the slotting-bar projects upwards, through a fixed cast-iron table on the floor of the workshop, upon which the work is laid in the act of slotting. As in this arrangement there are no supports to interfere with the work on the table, it is evident that this tool possesses an unlimited range of action. In another modification by the same firm, this object is attained by supporting the tool-slide in a bottom-plate attached to the floor, to which are attached four strong pillars, carrying a square table for the support of the work, at the height required for the convenience of the workman. The driving-geer, in this instance, consists of a horizontal shaft, passing under the table, near the level of the floor, driven by a strap, and carrying a pinion geering with a large spur-wheel, which, at the same time, serves to communicate the reciprocating motion to the slotting-bar, being grooved across one side, for the purpose of receiving the traversing-pin of the connecting-rod. The self-acting motion of the table is extremely neat and convenient. The spur-wheel shaft carries a small eccentric, the rod of which communicates with the ratchet-wheels of two shafts running horizontally at right angles to each other, beneath the movable sides of the table. Each of these shafts carries screws, one of which, passing beneath the centre of the table, gives the rectilineal motion, while the other geers with the screw teeth cut round the circumference of it, and, consequently, traverses the table in a circular direction.

We have already discussed the philosophy of the true form of cutting edge for drills, as well as the minor species of tools of this class; it remains for us, therefore, now to enter upon the construction of what are more properly termed drilling *machines.* The varieties of these useful machines, as used by the engineer, are so numerous, that we can only find space to touch upon a few of those best adapted to the wants of the workshop. Practically speaking, drilling machines are divisible into two classes only, namely, the common vertical pillar, or wall-side drill, and the radial machines.

For a good example of the former of these varieties we may refer the reader to the detailed views in Figs. 1122–1128, of Mr. Whitworth's vertical drill. This machine, which probably takes the first rank in its class, is independent, being provided with its own separate frame intended to be screwed to the floor without the additional support of a pillar or wall. Motion is communicated to the drill-spindle by an arrangement similar to the back geer of a lathe, contained in an opening in the upper portion of the frame. The rectilineal feed motion of the drill-spindle is self-acting; it is a beautifully ingenious arrangement, and is pre-eminently deserving of attention. The upper portion of the spindle between its bearings is screwed for the purpose of geering with the inclined teeth of a pair of worm-wheels, placed one on each side of it; the axes of which work in bearings attached to the front of the frame. A compact friction-clip worked by a vertical screw from below embraces the projecting ends of these axes, by which arrangement the revolution of the wheels may be completely stopped when requisite. Thus, we will suppose the tightening screw of the friction-clip to be screwed up so that the latter holds the worm-wheels firmly in their position; it follows, then, that if the drill is set in motion, the threads upon the spindle will act upon the teeth of the worm-wheels exactly as in a nut, and a quick descent of the spindle will be the result. If now the friction is slightly relaxed, then the speed of the descent of the spindle will have diminished so much as is due to the slipping round of the worm-wheels. In this manner any amount of feed motion may be communicated to the spindle with a nicety unattainable by any other means, so that the varying hardness of the metal under action may be immediately accommodated by a speed exactly suitable for cutting most advantageously. The table of the machine is provided most completely with all the requisite movements, and may be raised or lowered to suit the work by a pinion working in a vertical rack attached to the front of the frame.

In Figs. 3652 to 3659 we have given complete views of Messrs. Nasmyth & Gaskell's drilling-machine, which differs from the last specimen in the fact of its being destitute of a self-acting feed motion. The downward pressure necessary for the feed of the tool being given by the pressure of the foot acting on a bottom lever, which is connected by a vertical rod at the back of the frame, with a second lever working on a bearing at the top. The front end of this lever works a sliding bearing fitting on the top of the spindle, which thus receives a downward motion according to the pressure of the foot, the counter-weight on the back end of the lever bringing up the spindle again, on the lever being released from the pressure of the foot. This, as an independent variable motion, is very convenient, though inferior in nicety to that used by Mr. Whitworth.

3476.

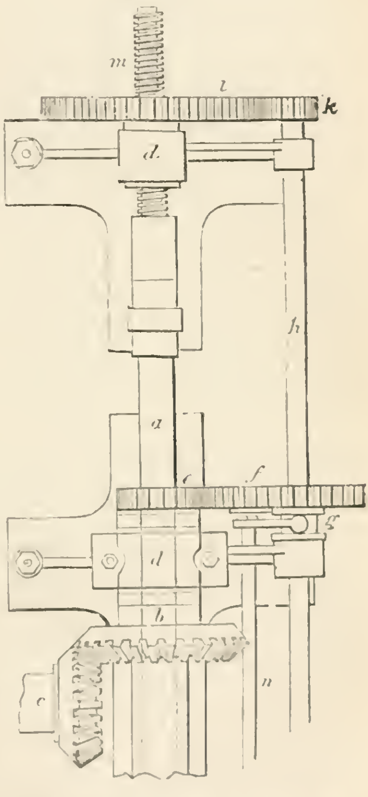


Fig. 3476 is a front view of the self-acting feed motion applied by Mr. Lewis, of Manchester, to a wall-side drill. Here the vertical spindle *a* carries a bevel-wheel *b*, into which a second bevel-wheel *c* on the driving cone-shaft geers. The spindle works in two bearings *d d*, attached to a vertical plate bolted to the wall. A small spur-wheel *e* is keyed on the spindle, a little above the lower bearing; this wheel geers with a second wheel *f*, which carries a sliding bush *g*, so that it may be thrown in and out of geer with the driving-wheel *e* at pleasure. The shaft *h*, carrying this latter wheel, passes up the side of the drill, and carries a second spur-pinion *k* at its upper extremity, geering with a large wheel *l*, the bush of which carries a nut working on the screw *m* on the spindle.

This motion may be driven by hand at pleasure by disconnecting the wheel *f* and working a hand-wheel fixed on the spindle *h*.

This may be taken as a specimen of the best kind of self-feeding motions: it is compact, effective, and inexpensive.

Of pillar drills, the modification introduced by Messrs. Randolph, Elliot & Co., of Glasgow, is one of the most compact. This drill is certainly the simplest and most generally applicable of its class, its component parts being confined to a set of brackets to carry the drill-spindle, without any additional frame, the office of which is supplied by any of the pillars of the workshop. The spindle-brackets, as well as those for supporting the table, are clamp-bolted to the pillar—the spindle being worked either directly through a speed cone or by double geering, as applied to lathes generally. The self-acting feed motion in its general details is similar to that of Mr. Lewis. The table is provided with a strong central foot, to which two projecting brackets at the foot of the pillar are bolted; it is thus fixed immovably, and so far lacks the important advantage possessed by a movable table. In some varieties of drills the feed motion is confined entirely to the table, which is worked by a rack and pinion movement, its weight being balanced by a counterpoise attached to a chain passing over a pulley on the top of the frame. In drills intended for boring to a considerable depth, this arrangement may have the advantage of steadiness of action, otherwise the movable spindle is in every respect preferable.

In Figs. 3650 and 3651 we have given two views of Mr. Whitworth's modification of the second class of drilling machines, the radial drill. A reference to this drawing will show that it is an arrangement on a principle quite distinct from that of the ordinary drilling machine. In the radial drill the motion of the spindle is not confined to the vertical direction, but is provided with a lateral motion, whereby it may be set to any portion of the work within the limits of the radial arm, thus superseding one of the rectilineal motions of the table, which in this arrangement need only travel in one rectilineal direction beneath the drill. This machine is likewise provided with the same feed motion as applied by this maker to his ordinary vertical machine.

Messrs. Hick make use of a somewhat different arrangement of driving and feed geer. The central frame of this machine consists in a short hollow circular bracket, having a nut fitted on its upper end for the purpose of receiving a strong square threaded screw, which carries the radial arm for the tool slide. The vertical motion of the drill is therefore not confined to the motion of the spindle in its own bearings, but the whole radial arm is capable of a considerable vertical movement by turning the nut on the central screw. The fast and loose pulleys for the driving geer are placed on a vertical shaft working in a bearing on the top of the radial arm immediately over the centre of the screw—motion being communicated from it to the drill-spindle by means of bevel geer as in Mr. Whitworth's machine The additional horizontal traversing motion of the spindle is effected by means of a pinion keyed on a hand-wheel shaft and geering into a rack on the radial arm; the downward motion for the feed is given by hand by means of an overhead ratchet lever connected to a ratchet-wheel on a short horizontal shaft, over which a chain connected to a cross-head on the drill-spindle is wound. A rod from this lever is brought within the reach of the workman, so that he can depress the spindle at pleasure, the upward motion being accomplished by means of a counter-weight attached to a chain-pulley on the ratchet-wheel shaft. A somewhat similar mode of central movement has been adopted by Mr. Bodmer in his improved radial drill. Here the main central support consists of a strong hollow circular pillar provided with wrought-iron centres at top and bottom, upon which it revolves. A screw passes down the centre of this pillar, and carries a nut attached to a bevel-wheel on a bracket projecting through a vertical slot in the pillar. This bracket is screwed to the radial arm of the machine, and is raised or lowered by a lever handle on a shaft carrying a bevel-wheel geering with the one referred to above as carrying the nut on the central screw. The driving geer consists of an overhead horizontal shaft carrying a bevel-pinion working in a large bevel-wheel on the top of the supporting pillar; the latter carries a spur-wheel geering with a pinion on a vertical grooved shaft working in bearings attached to the pillar. This shaft carries a sliding bevel-wheel provided with a key to fit its groove, so that it is at liberty to rise and fall with the radial arm without revolving loosely on its shaft. From this bevel-wheel motion is transmitted by a train of geering to the drill-spindle in the radial arm, in the usual manner. The self-acting feed motion is highly ingenious and effective; the horizontal driving-shaft of the radial arm carries a small band-pulley from which motion is given to a short horizontal worm-wheel shaft, the worm of which geers with a wheel on an upright shaft carrying a long pinion on its upper extremity. This pinion geers with a spur-wheel attached to the nut of the top driving-screw of the spindle, which thus receives a regular descending motion according to its boring speed. By detaching this geering, the long pinion may be worked by hand at pleasure. Although for some specific purposes this species of drill is highly useful, yet where great accuracy is required, it is inferior to the ordinary pillar or wall-side machine on account of its want of steadiness and rigidity.

Boring machines are, abstractedly, merely modifications of the larger class of drills, and are applied to the same purposes.

They are divisible into two classes, namely, horizontal and vertical machines. The latter species of machine is generally considered to be the most useful for engineering works, and there is no doubt that it possesses some great advantages over the former one. In the first place, the vertical position of the cylinder entails no transverse strain upon it, which would be pretty considerable in a cylinder of large size placed horizontally. Such a strain would, of course, render the action of the tool extremely uncertain, and would detract materially from the required true surface. Again, the boring-bar may in some sort be considered as liable to the same disadvantage which its vertical position remedies. Lastly, the action of the cutters is not at all impeded by the presence of the turnings, which immediately fall to the foot of the cylinder and leave the cutter free at each progressive step. The most convenient and secure place for a boring-machine of a large size is the corner of the workshop, where the two angular walls form firm supports for the framing of the machine.

Messrs. Nasmyth & Gaskell have produced a useful tool of this particular class; the framing consists of a stout circular bottom casting, provided with a clamping ring for holding down the cylinder in the act of boring, and an overhead cross-beam for carrying the upper extremity of the boring-bar spindle. The footstep of the boring-bar is placed beneath the ground floor of the shop, where, as well as for a portion of the driving geering, an excavation is purposely made to receive them. The driving-pulleys are placed outside this pit; they communicate with an oblique shaft, which carries a worm on its end, geering with a large worm-wheel near the foot of the boring-bar, to which motion is thus given. The cutter-boss is traversed in the usual manner by a longitudinal screw in the bar, but a different method is adopted for returning it after the first rough cut. Immediately this is accomplished the cutter-boss is detached from the nut of the traversing screw, and is hauled up alone by a small crane attached to the machine; the cutters are then reset and the finishing cut is gone over.

A machine somewhat similar, but of gigantic dimensions, has been constructed by the same engineers for the Great Western Steam Navigation Company, for the purpose of boring out the cylinders of the Great Britain steamer.

In this machine, the entablature carrying the upper end of the boring-bar is supported on two massive pillars of masonry, placed one on each side of the boring-bar. The feed-motion of the cutters is novel and ingenious in the extreme; it consists, primarily, of an internal screwed collar fixed on the upper surface of the entablature, and surrounding the boring-bar. A train of geering, terminating in a pinion working into a rack running down the side of the boring-bar, is attached to the latter and revolves with it. The first wheel of the train is a species of crown-wheel, its teeth being set at right angles to its axis of motion; this geers with the internal threads of the screwed collar before mentioned, so that by this means, the train is set in motion by the revolution of the bar, and the cutter-boss, which is attached to the lower end of the rack, is raised and lowered at pleasure.

Mr. Walton, of Leeds, has introduced a highly effective boring machine, with columnar framing intended principally for boring the apertures in the tube plates of locomotive engines. The machine is capable of drilling a series of parallel holes on a surface of five feet square, without refixing the object under operations, the tool-holder and the table being movable at right angles to each other. This boring machine may be considered as a magnified drill, as the spindle is fed longitudinally, no cutter-boss being attached. The framing consists of two plain columns, coupled at the top by a suitable entablature, and carrying two other transverse beams for the support of the drill-spindle and driving-geer The self-feeding motion is similar to that illustrated by Fig. 3476, and it may also be worked by hand in the same way

The spindle is capable of a vertical travel of 24 inches, and is consequently well suited for boring out the small cylinders of locomotives, &c., as well as for boring out the eyes of carriage and other wheels, which it will receive up to 6 feet in diameter.

Figs. 2547 and 2548 now introduce to us the second species of boring machine, the horizontal one. Our example is intended for the heaviest kind of work in the engine-shop, and is purposely very strongly constructed. The arrangement of the train of driving-geer allows of a considerable latitude of speed of the cutters; the changes by alteration in the geering permit of as small a variation as 1 to 1¼, so that any speed within the entire range may be obtained within ⅛th of the one required. In Figs. 2542 and 2543 we have given a still more complete tool by Messrs. Kinmonds, Hutton, and Steel, of Dundee. It is provided with a slide-rest and tool-holder, and thus becomes available for turning as well as boring. This is a very valuable machine, and where ground space is an object in the work-shop, will be found highly convenient from the saving of space which it effects. The proper speed at which the cutter should pass over the surface of the metal may be stated as from 6 to 7 feet per minute, though this must, of course, be dependent in a considerable degree upon the relative hardness of the metal. Until a few years back, cannon were cast with a core, in the same manner as steam-engine cylinders are now. Experience has, however, pointed out the fallacy of this method, as it was impossible to make a true bore, the cutter having a tendency to follow the inaccuracies of the yet rough surface. In addition to this, the guns, when cast hollow, have a tendency to become spongy near the inner surface of the bore. To remedy these defects, all ordnance are now cast solid, and thus the metal is rendered closer in the grain, and any "blown" or defective parts are confined to the centre of the metal, when they are cut out in boring. Guns are bored in a manner directly the reverse of that employed in preparing steam-engine cylinders. The bed of the machine employed for boring out guns is provided with two pedestals having bearings of a considerable diameter, in which the gun itself is caused to revolve, the cutter remaining stationary on a sliding-carriage. The cutter is kept up to its work by means of a weighted-lever, attached to a pinion-shaft beneath the bed of the machine. This pinion geers with a rack attached to the cutter-carriage, which is thus impelled forward towards the gun, until the weights in the loaded lever reach near the ground, when the lever is raised and the weights reset by a ratchet-wheel.

The punching machine, from being confined to the tin-smith and ornamental metal-worker's shop, has latterly become an instrument of no slight importance to the engineer, whose ponderous adaptations of this tool excite the greatest wonder in the mind of a stranger unaccustomed to their operations. Here the punch or cutting tool seems to pass through an enormously thick piece of cold metal, as if the latter was so much pasteboard, the whole of the operation being conducted without producing the least noise.

In Fig. 3174 we have given various views of a compact and convenient punching machine, constructed by Messrs. Caird, of Greenock. The framing consists of one solid casting, open in the centre for the reception of the large driving bevel-wheel on the horizontal punching-shaft. The driving geering and fly-wheel for steadying the motion are placed overhead, so as to be completely out of the way, and leaving a clear space all round the machine for the workmen. The shearing and punching apparatus being on two opposite sides of the machine, these two operations may be conducted at the same time, without any risk of confusion among the men.

Of late years, the system of riveting by steam power has made rapid progress, and promises in all large works to supersede entirely the old laborious and noisy process of riveting by hand. We are indebted to Mr. Fairbairn, of Manchester, for the introduction of this machine, who invented it upon an emergency to supply the loss of a set of hand riveters who had left their employment on account of some business disagreement. Mr. Fairbairn's machine, see Figs. 3226–7, is a highly elegant and efficient apparatus. The essential principle of the machine is that of the knee-joint lever, as applied to printing-presses. Motion is given to this lever by means of a revolving-cam driven by suitable geering; this cam acting upon a loose anti-friction pulley, placed at the centre joint of the lever. The saving by the use of this machine is very great, and, what is of no small consequence, the whole operation of riveting is performed in silence; the system of pressure, too, has the advantage of leaving the metal of the rivets in its original state. By the old plan of hammering, the rivets were extremely subject to crystallization, and as a natural consequence, numbers of the heads gave way in the finishing.

We have seen a section of two pieces of boiler-plate riveted together in this manner, the section being taken through the centre of the rivet, and it was remarkable to see how the pressure of the machines had forced, as it were, the metal of the rivet into all the interstices of the plates, incorporating the two so as to be scarcely distinguishable from one piece of solid metal. M. Lemaitre, of Paris, has successfully combined the two operations of riveting and punching, in one machine, which he actuates by the direct pressure of steam, without the intervention of additional geering. We have detailed this machine fully in Fig. 3220, where also is shown M. Lemaitre's arrangement for riveting long and narrow tubes, which is very ingeniously contrived.

Messrs. Schneider, of Creusot, in France, have also applied the direct action of the steam to the purpose of riveting. Their modification closely resembles in principle the plan adopted by Mr. Fairbairn; the piston of the steam cylinder is jointed directly to the central joint of the "knee" combination, and the rise and fall of the former of course gives a lateral traversing motion to the compressing ferrule. Latterly, also, Messrs. Garforth, of Dukinfield, have applied the pressure of steam in a still more direct manner. The shaft carrying the compressing ferrule, for forming the rivet, is at the same time the piston rod, the cylinder of which is placed horizontally in the frame of the machine. It is evident that in this plan, as no mechanical power intervenes between the point of action of the steam, and the point of resistance, a very large cylinder must be used to produce the required pressure, and consequently a large amount of steam must be used at each stroke of the riveter. There is no doubt but that this machine may be arranged to work at a high speed, but we think it must fail to work so economically as the machines worked by a small piston assisted by additional mechanical power.

Mr. Walton, of Leeds, has produced an extremely useful punching and shearing machine, which is capable of being worked either by manual or mechanical power. The framing consists of a single casting, having a stud keyed in the thickness of the metal near its top, for the purpose of carrying the fly-wheel and driving-pinion, which are cast together. These work loose on the stud, the pinion geering with a large spur-wheel keyed on the horizontal eccentric punching-shaft. A slot is cast through the centre of the frame for the reception of this shaft, suitable bearings for carrying it being placed within the slot; the projecting end of the shaft is slightly eccentric, for the purpose of giving motion to the vertical punching and shearing shaft. The latter consists of a heavy piece of metal, having a horizontal slot in the centre, for the purpose of allowing a clear space for the lateral working of the eccentric end of the driving-shaft. Suitable bearings are attached to the front of the frame, in which the punching-shaft is arranged to slide, the top of the latter being the shearing end, and the bottom carrying the punch, the matrix for which is fixed in a projecting piece cast to the frame.

The machine is adapted to punch holes up to $\frac{3}{4}$ inch in diameter in plates $\frac{5}{8}$ inch in thickness, at any distance from the edge not exceeding $7\frac{1}{2}$ inches, the frame being hollowed out to this extent to permit of the entrance of the plates. The shears are capable of cutting plates $\frac{5}{8}$ inch in thickness, and 12 inches breadth, without curling the piece sheared off.

The construction of this machine is exceedingly simple, and being set in an independent framing of its own, may be moved to any part of the workshop with facility. A somewhat similar machine, but much more complete in its details, has been constructed by Messrs. Nasmyth and Gaskell. Here the punching-slide is provided with four punches, by which means the same number of holes are punched at each stroke of the machine. The punching operation is also made self-acting, by an arrangement of a self-moving table for carrying the work. The plates intended to be punched are fixed in the usual manner on a travelling-table, moving on wheels set to run on a pair of triangular rails. A long notched bar is attached by means of brackets to the under side of this table; this is arranged to traverse the table in the following manner:—The large driving-wheel on the eccentric shaft carries a pin fixed in the side of its rim, which, once during each revolution, comes in contact with a lever connected to a ratchet-catch adapted to take into the notches of the bar before mentioned; thus each revolution of the spur-wheel causes the table to advance a distance equal to the length included between each notch in the bar.

In Fig. 3100 we have detailed a machine intended for the bending of wrought-iron plates. This machine, owing to the increase of iron ship-building, has latterly risen to be of great importance to the engineer and ship-builder. The present machine being principally intended for the use of the ship-building yard, where few plates are required to have a regular curve throughout, is not provided with geering for simultaneously altering the positions of the ends of the front roller. This arrangement allows of the setting of one of the ends of the roller at any position with regard to the other, so as to give any required twist to the plate.

In the original application of the bending-rollers to the curving of boiler plates, none of the rollers touch each other, and they are placed so that lines drawn from centre to centre form an equilateral triangle, the upper central roller being made adjustable for the different curvatures required; this arrangement is, however, now entirely superseded by that depicted in Mr. Napier's machine.

We take this occasion to acknowledge our indebtedness to the Engineer and Machinist's Assistant, published by Blackin and Son, Glasgow, for the very valuable articles on Geering, as also this one on Tools. The work mentioned should be in the hands of every engineer and machinist.

TOOLS, TURNING. The process of turning is accomplished with considerably more facility, truth, and expedition, than any other process requiring cutting tools, because in the most simple application of the art, the *guide principle* is always present, namely, that of *rotation*. The expedition of the process is due to its being uninterrupted or continuous, except as regards the progressive changes of the tool, and which is slowly traversed from part to part, so as to be nearly always in action.

To choose the most simple condition, let us suppose the material to be in rotation upon a fixed axis, and that a cutting tool is applied to its surface at fifty places. Provided the tool remain quiescent at *one* place for the period of *one* revolution of the material, the parts acted upon will each become *one* circle; because the space between the tool and the axis is for a period constant, and the revolution of the material converts the distance of the tool from the centre into the radius of one circle, and the same is equally true of the fifty positions.

The fifty circles will be concentric, or parallel with each other, because the same axis, extended or continued as a line, remains constant, or is employed for each of them; and therefore conceiving the fifty circles to be as many parts of the outline of a vase or other object, simple or complex, it will be strictly symmetrical, or equidistant from the central line at corresponding parts.

Each of the fifty circles will also become the margin of a plane at right angles to the axis, and which axis being a straight line, the whole of the circles will be parallel, and therefore the top and bottom of the vase will be also exactly parallel. And yet all these accurate results must inevitably occur, and that without any measurement, provided the material revolve on one fixed axis, and that the tool is for a short period constant or stationary at each part of the surface—conditions inseparable from the turner's art.

The principle of rotation upon a fixed axis removes the necessity for many of the steps and measurements required to produce with accuracy the various angular solids employed in carpentry and many other arts.

The turner's box consists of two pieces, as the bottom and its four sides are resolved into one piece—when of wood, by nature in the forest; when of metal, by man in the crucible. The surfaces are therefore reduced to eight, namely, the inner and outer surfaces of the bottom and lid amounting to four, and the inner and outer sides or margins, amounting to four also, and the revolution of the work upon one axis places the eight in exact and true relation with extreme rapidity.

For example, the ends or terminal planes of the box are, from necessity, at right angles to the axis of rotation, and parallel with each other. In each of these superficies the question of being *in or out of* *winding* ceases; as, if straight, they can only be planes or cones, and which the one straight edge immediately points out.

The principle of rotation insures circularity in the work, and perpendicularity or equality as regards the central line; it only remains, therefore, to attend to the outline or contour. The right line serves to produce the cylinder, which is a common outline for a box; and the employment of mixed, flowing, and arbitrary lines, produces vases and ornaments of all kinds, the beauty of which demands attention alone to one single element, or conception, namely, that of form; and in the choice and production of which a just appreciation of drawing and proportion greatly assist.

In the art of drawing, it is almost essential to the freedom of the result, that the lines should be delineated at once, and almost without after correction; in the art of turning, it is always desirable to copy a drawing or a sketch, but having nearly attained the end, the tool may be continually reapplied, partially to remove any portions which may appear redundant, until the most scrupulous eye is satisfied.

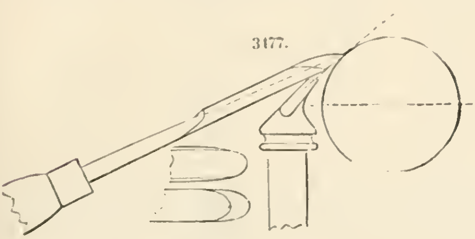
The combining of the several parts of turned objects, as the separate blocks of which a column or other work is composed, is greatly facilitated from the respective parallelism of the ends of the pieces of which turned objects consist; and the circular tenons and mortises, whether plain or screwed, place the different pieces perpendicular and central with very little trouble.

These several and most important facilities in the art of turning, are some amongst the many reasons for its having obtained so extensive and valuable an employment in the more indispensable arts of life, as well as in its elegances.

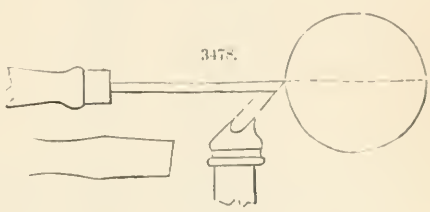
The tools used in turning the woods act much in the manner of the blades of the carpenter's planes; but as we have now, at all times, a *circular guide* in the lathe-mandrel, we do not require the stock or the plane or its *rectilinear guide.* Although if we conceive the sole of the plane applied as the tangent to the circle, the position it would give is nearly retained, but we are no longer encumbered with the stock or guide. In turning-tools for soft woods, the elevation of the tool and the angle of its edge are each of them less than in ordinary planes, and in those for the hard woods both angles are greater.

For example, the softest woods are turned with tools the acute edges of which measure about 20 to 30 degrees, and are applied nearly in coincidence with the tangent, as in Fig. 3477.

3477.



3478.



These tools closely assimilate to the spokeshave, which is the plane of the lowest pitch and keenest edge. On the contrary, the hardest woods may be turned with the above soft-wood tools, applied just as usual; but on the score of economy and general convenience, the edges are thickened to from 60 to 80 degrees, and the face of the tool is applied almost horizontally on the lathe-rest, or as a radius to the circle, as in Fig 3478, thus agreeing with the opposite extreme of the planes, in which the cutter is perpendicular and much less acute, as in the scraping and toothing planes, which are only intended to scrape, and not to cut.

The hard-wood tools may be figured and employed as scrapers in turning the members of the capital or the base of a column, or similar object in hard wood or ivory; but if we try the same tools on deal, ash, and other soft woods, we shall in vain attempt to produce the capital of a column, or even its cylindrical shaft, with a thick horizontal tool as in hard wood; for the fibres would not be cut, but forcibly torn asunder, and the surface would be left coarse and ragged.

But a reference to the planes with which the joiner proceeds *across* the fibres of deal, will convey the particulars suited to the present case; the iron is always thin and sharp, and applied in an oblique manner, so as to attack the fibre from the one end, and virtually to remove it in the direction of its length.

It is proposed now to describe some of the more important of the turning tools, commencing with those employed on the soft grained woods, but it would be both hopeless and unnecessary to attempt the notice of all the varieties which are to be met with in the hands of different individuals; and only so much will be here advanced as, it is hoped, may serve to explain the modifications of the general principles of cutting tools to some of the more usual purposes of turning. To avoid repetition, it may be observed, that in general the position of the tool for turning the cylinder, and secondly, that for the flat surface or plane, will be alone described. For works of intermediate angles, whether curves or flowing lines, the position of the tool slides from that for the cylinder to that for the plane, or the reverse; and these changes will be readily made apparent when the reader gradually moves either a tool, or even a rod of wood, from the one to the other of the described positions.

It may be added that most of the tools for metal are applied direct from the grindstone, the oilstone being used for such tools only as are employed for the more delicate metal works, or for the last finish of those of stronger kinds; all the tools for wood, ivory, and similar materials, are invariably sharpened on the oilstone. It may be desirable to remark, in addition, that the rough exterior faces of all works should be turned with narrow or pointed tools, and only a narrow portion at a time, until the sur faces are perfectly true or concentric; as wide flat tools applied to rough irregular surfaces, especially of metal, would receive a vibratory, or rather an endlong motion, quite incompatible with truth of work.

Turning-tools for soft wood.—*Angle 20° to 30°*—*Figures generally half size.*—The tools most generally used for turning the soft woods are the gouge and chisel, Figs. 3478 to 3479, wherein they are shown of one-fourth their medium size; they vary from one-eighth to two inches wide; and as they are never driven with the mallet, they do not require the shoulders of the carpenter's tools, they are also ground differently. The turning-gouge is ground externally and obliquely, so as to make the edge elliptical, and it is principally the middle portion of the edge which is used; the chisel is ground from both sides, and with an oblique edge, and Figs. 3481 and 3482 represent the full thickness of the chisel and its ordinary angles, namely, about 25 to 30 degrees for soft, and 40 for hard woods. The gouges and chisels wider than one inch are almost invariably fixed in long handles, measuring with the blades from 15 to 24 inches; the smaller tools have short handles, in all from 8 to 12 inches long.

3479. 3479½. 3487. 3480. 3481. 3482.

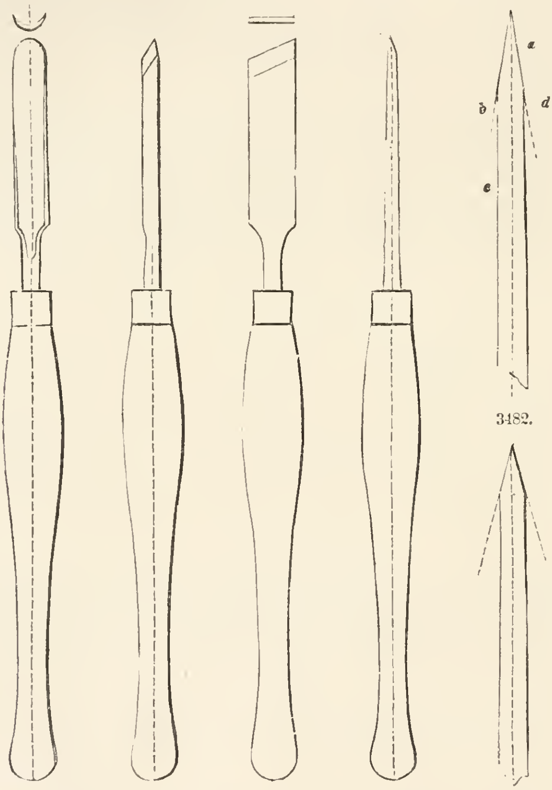


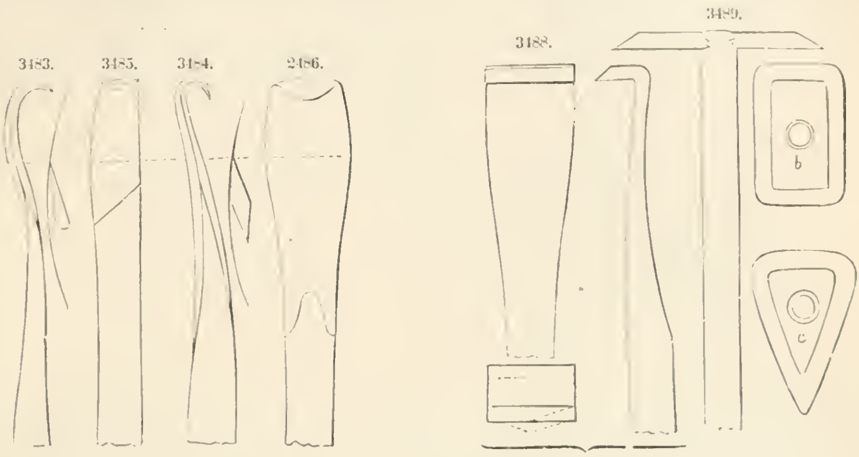
Fig. 3477 shows the position of the gouge in turning the cylinder; the bevel lies at a tangent, and the tool generally rests on the middle of the back, or with the concave side upwards, the extremity of the handle is held in the right hand close to the person, and the left hand grasps the blade, with the fingers folded beneath it, and in this manner the gouge is traversed along the cylinder.

For turning the flat surface the gouge is supported on its edge, that is, with the convex side towards the plane of the work, and with the handle nearly horizontal, to bring the centre of the chamfered edge in near coincidence with the plane; the tool is inclined rather more than the angle at which its chamfer is ground, and it is gradually thrust from the margin to the centre of the work.

The gouge is also used for hollow works, but this application is somewhat more difficult. For the internal plane, the position is almost the same as for the external, except that the blade is more inclined horizontally, that it may be first applied in the centre to bore a shallow hole, after which the tool is traversed across the plane by the depression of the hand which moves the tool as on a fulcrum, and it is also rotated in the hand about the fourth of a circle, so that in completing the margin or the internal cylinder the tool may lie as in Fig. 3477, but with the convex instead of the concave side upwards, as there shown.

In Figs. 3483 and 3484 are represented the plans, and in Figs. 3485 and 3486 the elevations of the *hook-tools* for soft wood, which may be called internal gouges; they differ somewhat in size and form: the blades are from 6 to 12 inches long, the handles 12 to 15. They are sharpened from the point around the hook as far as the dotted lines, mostly on one, sometimes on both sides, as seen by the sections. The hook-tools follow very nearly the motion of the gouge in hollowing, the rest is placed rathe distant and oblique; the tool is moved upon it as a fulcrum, and it is also rotated in the hand, so as always to place the bevel of the tool at a very small inclination to the tangent.

The finishing tools used subsequently to the gouges or hook-tools have straight edges; the chisel, Fig 3487, is the most common; its position closely resembles that of the gouge, subject to the modifications called for by its rectilinear edge. If, for example, the edge of the chisel were just parallel with the axis of the cylinder, it would take too wide a hold; there would be risk of one or other corner digging into the work, and the edge, from its parallelism with the fibres, would be apt to tear them out. All these inconveniences are avoided by placing the edge oblique, as in Fig. 3187, in which the tool may be supposed to be seen in plan, and proceeding from right to left, Fig. 3477 being still true for the other view; the tool is turned over to proceed from left to right, and both corners of the tool are removed from the work, by the obliquity of the edge. The tool may be ground square across, but it must be then held in a more sloping position, which is less convenient.



Turning a flat surface with the chisel is much more difficult. The blade is placed quite on edge, and with the chamfer in agreement with the supposed plane *a b c*, Fig. 3181; the point of the chisel then cuts through the fibres, and removes a thin slice which becomes dished in creeping up *a d*, the bevel of the tool; it then acts something like the scoring-point of the planes, or the point of a penknife. Flat surfaces, especially those sunk beneath the surface, as the insides of boxes, are frequently smoothed with an ordinary firmer chisel, which is ground and sharpened with one bevel, but rather thicker than for carpentry. The edge is then burnished like the scraper, and it is applied horizontally like a hard-wood tool, as in Fig. 3478, but against the face or plane surface. The wire edge then lies in the required position, but it must be frequently renewed.

The *broad*, represented in three views in Fig. 3488, endures much longer, but it requires to be held downwards or *underhand* at about an angle of 40 to 50 degrees from the horizontal, in order to bring its edge into the proper relation to the plane to be turned. Another form of the broad is also represented in Fig. 3489; it is a cylindrical stem, upon the end of which is screwed a triangular disk of steel, sometimes measuring three inches on the sides, and sharpened externally on each edge: this tool requires the same position as the last. Broads of the forms *b c* are also used, but principally for large works the plank way of the grain. Similar tools are also used for turning pewter wares.

For the insides of cylinders the side-tool, Fig. 3490, which is represented in three views, is sometimes used; it is sharpened on both edges, and applied horizontally. The tool Fig. 3491, also shown in three views, serves both for the sides and the bottoms of deep works, but it does not admit of being turned over; and Fig. 3492 is another form of the same tool for shallower works, the cranked form of which is considered to give it a better purchase.

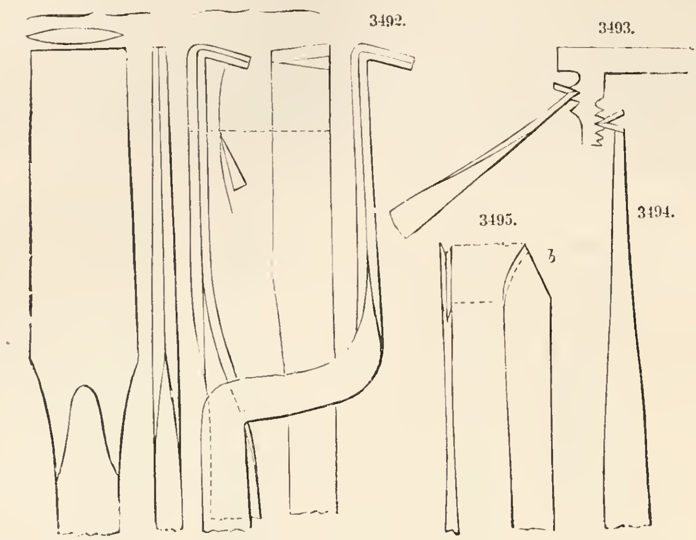
The tools used for cutting screws in soft wood, by aid of the traversing or screw mandrel-lathe, partake of the same general characters as the others, and are represented in their relative positions; Fig 3493 is for the outside, and Fig. 3494 for the inside screw.

To conclude the notice of tools of this class, the parting tool Fig. 3495, has an angular notch or groove on its upper surface, from which it results that when the tool is sharpened on the bevel *b*, the upper face presents two points, which separate the fibres by a double incision. This method wastes only as much wood as equals the thickness of the tool, and it leaves the work smooth and flat; whereas, when the angle of the chisel is used for the same purpose several cuts are required, and the gap must present a greater angle than the bevel of the tool and which consumes both more time and wood.

The various turning tools for soft woods which have been described are, with the exception of the gouge and chisel, nearly restricted to the makers of Tunbridge ware, toys, and common turnery; with them they are exceedingly effective, but to others somewhat difficult. The amateur turner scarcely uses more than the common gouge and chisel, and even these but insufficiently, as much may be done with them. It has been shown, for instance, that moulding tools cannot be used for the soft woods, but they are efficiently replaced by the gouge for the concave, and the chisel for the convex mouldings.

A good fair practice on the soft woods would be found very greatly to facilitate the general manipulation of tools, as all those for the soft woods demand considerably more care as to their positions and management than those next to be described.

3490. 3491. 3492. 3493. 3494. 3495.

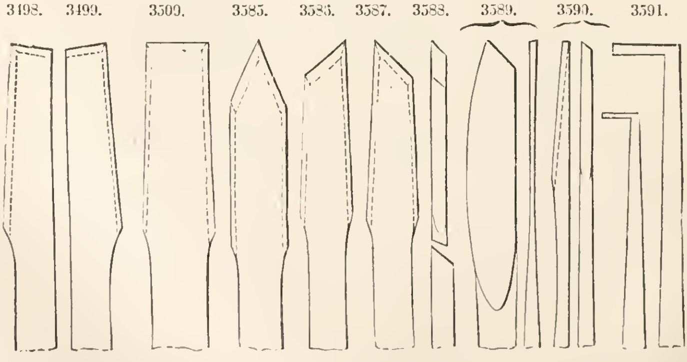


TURNING-TOOLS FOR HARD WOOD AND IVORY.—*Angles* 40° *to* 80°—*Figures generally half size.*—The gouge is the preparatory tool for the hard as well as for the soft woods, but it is then ground less acutely; the soft-wood chisel may indeed be employed upon the hardest woods, but this is seldom done, because the tools with single bevels held in a horizontal position, as in Fig. 3478, are much more manageable, and on account of the different natures of the materials they are thoroughly suitable, notwithstanding that their edges are nearly as thick again as those of soft-wood tools. In general, also, the long handles of the latter are replaced by shorter ones, as in Figs. 3496 and 3497, measuring with the tools from 8 to 12 inches; but these give in general an abundant purchase, as from the nearly horizontal position of the tool, the lathe-rest or support can be placed much nearer to the work.

3496. 3497.

The hard-wood tools are often applied to a considerable extent of the work at one time, and the finishing processes are much facilitated by selecting instruments the most nearly in correspondence with the required shapes. Rectilinear surfaces, such as cylinders, cones, and planes, whether external or internal, necessarily require tools also with rectilinear edges, which are sloped in various ways as regards their shafts; they are made both large and small, and of proportionate degrees of strength to suit works of different magnitudes. The following are some of the most useful kinds.

3498. 3499. 3500. 3585. 3586. 3587. 3588. 3589. 3590. 3591.

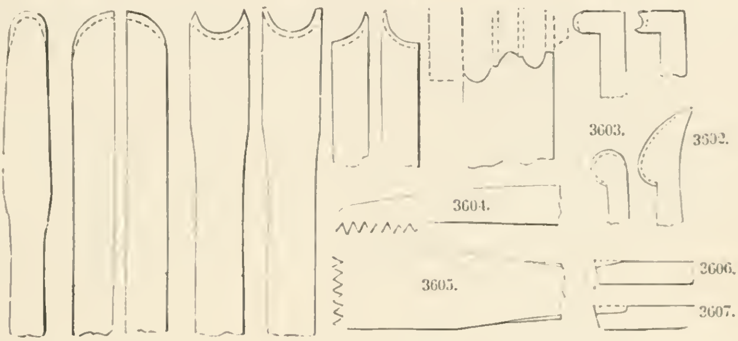


The *right-side tool*, Fig. 3498, cuts on the side and end, the dotted lines being intended to indicate the undercut bevel of the edge—so named because it cuts from the right hand towards the left. The *left-side tool*, Fig 3499, is just the reverse. The *flat-tool*, Fig. 3500, cuts on both sides, and on the end likewise;

and in all three tools the angle seen in plan is less than a right angle, to allow them to be applied in rectangular corners. The *point-tool*, Fig. 3585, is also very convenient; and *bevel-tools*, Figs. 3586 and 3587, the halves of the former, are likewise employed; Figs. 3588 show the general thicknesses of these tools. When any of them are very narrow they are made proportionally deep to give sufficient strength, the extreme case being the *parting-tool*, Fig. 3589, which is no longer required to be fluted, as in the corresponding tool for soft wood; but the side-tools, when used for small and deep holes, necessarily require to be small in both respects, as in Fig. 3590. The *inside parting-tool*, Fig. 3591, is used for the removal of rings of ivory from the interior of solid works, in preference to turning the materials into shavings; it is also useful in some other undercut works.

Some of the curvilinear tools for hard wood are represented in the annexed group of figures; the semicircular or *round tool*, Fig. 3592, is the most general, as concave mouldings cannot be made without it, and it is frequently divided, as in the *quarter round tools*, Figs. 3593 and 3594; it is convenient that these should be exact counterparts of the mouldings, but they may also be used for works larger than themselves, by sweeping the tools around the curves. Convex mouldings are frequently made by rectilinear tools, which are carried round in a similar manner, so as to place the edge as a tangent to the curve, but the *bead*, Fig. 3595, the *astragal*, Fig. 3596, or the *quarter hollows*, Figs. 3597 and 3598, facilitate the processes, and complete the one member of the moulding at one sweep, and enable it to be repeated any number of times with exact uniformity

3592. 3593. 3594. 3595. 3596. 3597. 3598. 3599. 3600. 3601.



Frequently the tools are made to include several members, as the entire base or capital of a column, as in Fig. 3599. Similar figured tools have been applied to turning profiles of about one or one and a half inches high, by employing four different tools, embracing each about a quarter of the profile, and applied at four radial positions, around a ring of some three to five inches diameter; the rings are cut up into radial slices, and turned flat on each face prior to being glued upon tablets. Profiles have been likewise successfully and more skilfully turned, by the ordinary round, point, and flat tools.

Figs. 3600 to 3603 represent some of the various kinds of *inside* tools, which are required for hollowing vases and undercut works; and Fig. 3604 the *inside screw* tool, and Fig. 3605 the *outside screw* tool for hard wood, ivory, and the metals: these tools are made with many points, and are bevelled like the rest of the group.

The hollow tools, Figs. 3595 to 3598, may be sharpened with a narrow slip of oilstone used almost as a file; but their sweeps are more accurately sharpened by conical metal grinders, supplied with emery, as will be explained; most other moulding tools, and the screw tools, are only sharpened upon the face. The ends of these tools may be whetted at a slope, if it be more gradual than in Fig. 3604, this however, increases the angle of the edge; but by nicking in the tools, as in Fig. 3607, by applying them transversely on the grindstone, the original angle is maintained, and which is the better mode for screw tools more especially.

Turning-tools for brass.—*Angles 70° to 90°—Figures generally the same as the tools for hard wood.*—The turning tools for brass are in general simple, and nearly restricted to round, point, flat, right and left side tools, parting-tools, and screw-tools; they closely resemble the hard-wood tools, except that they are generally ground at angles of about 60° or 70°, and when sharpened it is at an angle of 80° or 90°; some few of the finishing or planishing tools are ground exactly at 90°, upon metal laps or emery wheels, so as to present a cutting edge at every angle and on both sides of the tools.

3608. 3609. 3610.

It is not a little curious that the angles which are respectively suitable to brass and to iron, are definitively shown to be about 90 and 60 degrees. For turning brass, a worn out square file is occasionally ground on all sides to deprive it of its teeth: it is used as a side-tool, and is slightly tilted as in Fig. 3608, just to give one of the edges of the prism sufficient penetration; but applied to iron, steel, or copper, it only scrapes with inconsiderable effect. A triangular file, Fig. 3609, similarly ground, cuts iron with great avidity and effect, but is far less suited to brass; it is too penetrative, and is disposed to dig into the work. It appears, indeed, that each different substance requires its own particular angle, from some circumstances of internal arrangement as to fibre or crystallization not easily accounted for.

A stout narrow round tool, Fig. 3592, in a long handle, serves as the gouge or roughing-out tool for brass-work; others prefer the point, Fig. 3585, with its end slightly rounded, which combines, as it were, the two tools with increased strength; a small but strong right side tool, Fig. 3582, is also used in rough-turning; the *graver*, Figs. 3611 and 3612, although occasionally employed for brass, is more proper for iron, described hereafter.

The wide finishing tools should not be resorted to under any circumstances until the work is roughed-out nearly to the shape, and reduced to perfect concentricity or truth, with narrow tools which only embrace a very small extent of the work.

It is the general impression that in taking the finishing cuts on brass it is impolitic, either to employ wide tools, or to support them in a rigid solid manner upon the rest, as it is apt to make the work full of fine lines or striæ. This effect is perhaps jointly attributable to the facility of vibration which exists in brass and similar alloys, to the circumstance of their being frequently used in thin pieces on the score of economy, and to their being rotated more rapidly in the lathe than iron and steel, to expedite the progress of the work.

When a wide flat tool is laid close down on the rest, and made to cut with equal effect throughout its width, lines are very likely to appear on the metal, and which if thin, rings like a bell from the vibration into which it is put; but if the one corner of the tool penetrate the work to the extent of the thickness of the shaving, whilst the other is just flush with the surface, or out of work, the vibration is lessened, and that whether the penetrating angle or the other move in advance.

The brass-turner frequently supports the smoothing-tool upon the *one edge only*, and keeps the other slightly elevated from the rest by the twist of the hand, which thus appears to serve as a cushion or spring to annul the vibrations: Fig. 3610 shows about the greatest inclination of the tool. Some workmen with the same view interpose the finger between the tool and the rest, in taking very light finishing cuts. The general practice, however, is to give the tool a constant rotative shuffling motion upon the supported edge, never allowing it to remain strictly quiet, by which the direction of the edge of the tool is continually changed, so as not to meet in parallelism any former striæ which may have been formed, as that would tend to keep up the exciting cause, namely, the vibration of the metal. The more the inclination of the tool, the greater is the disposition to turn the cylinder into small hollows.

Some workmen burnish the edges of the finishing tools for brass, like the joiners' scraper, or the firmer chisel used in soft-wood turning. On account of the greater hardness and thickness of the edge of the tool, it cannot be supposed that in these cases any very sensible amount of burr or wire edge is thrown up. The act appears chiefly to impart to the tool the smoothness and gloss of the burnisher, and to cause it, in its turn, to burnish rather than cut the work; the gas-fitters call it a planishing tool, but such tools should never be used for accurate works until the surface is perfectly true and smooth.

The hard-wood and brass-turners avoid the continual necessity for twisting the lathe-rest in its socket to various angular positions, as they mostly retain it parallel with the mandrel, and in turning hollow works they support the tool upon an arm-rest; this is a straight bar of iron, which resembles a long-handled tool, but it has a rectangular stud at the end, to prevent the cutting-tool from sliding off.

The position of the arm-rest and tool, as seen in plan, are therefore nearly that of a right angle; the former is held under the left arm, the latter in the right hand of the workman, the fore-fingers of each hand being stretched out to meet near the end of the tool. This may appear a difficult method, but it is in all respects exceedingly commodious, and gives considerable freedom and choice of position in managing the tool, the advantage of which is particularly felt in guiding the first entry of the drill, or the path of the screw-tool; and in brass-work it likewise renders the additional service of associating the tool with the elastic frame of the man. But when particular firmness and accuracy are required the tool should be supported upon the solid rest as usual.

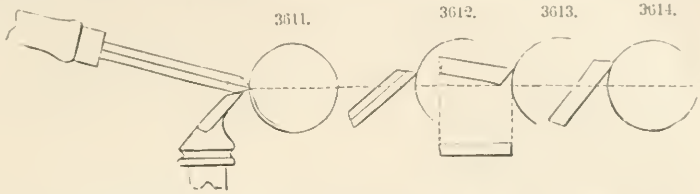
Turning-tools for iron, steel, etc.—*Angles* 60° *to* 90°—*Figures generally one-sixth the full size.*—The *triangular* tool is one of the most effective in turning these metals, as was adverted to above; the triangular tool is also used by the engravers and others for scraping the surfaces of the metals, and it is then applied nearly perpendicular, or as a penknife in erasing; but when the triangular tool is placed nearly as a tangent against the inner or outer edge of a ring or cylinder, as in Fig. 3609, it seems almost to devour the metal, and instead of scratching, it brings off coarse long shavings. In turning the flat sides of the ring, the face of the tool is placed almost in agreement with the plane to be turned.

The *graver*, which is also an exceedingly general tool, is a square bar of steel ground off at the end, diagonally and obliquely, generally at an angle of from 30 to 50 degrees. The parts principally used are the two last portions of the edge close to the point, and to strengthen the end of the tool a minute facet is sometimes ground off, nearly at right angles to the broad chamfer, or principal face.

The proper position of the tool in turning a cylinder, will be most readily pointed out by laying the chamfer of the tool in exact contact with the flat end of such cylinder; it will be then found that one of the lateral angles of the tool will touch the rest, and the obliquity in the shaft of the tool would be the angle, at which the graver is ground, instead of which it is held square and slightly elevated above the horizontal position, as shown in Fig. 3611. The graver is rotated upon the supporting angle, which sticks into the rest, much the same as the edge of the triangular tool; in fact, the two tools, although different in form, remove the shaving in a very similar manner.

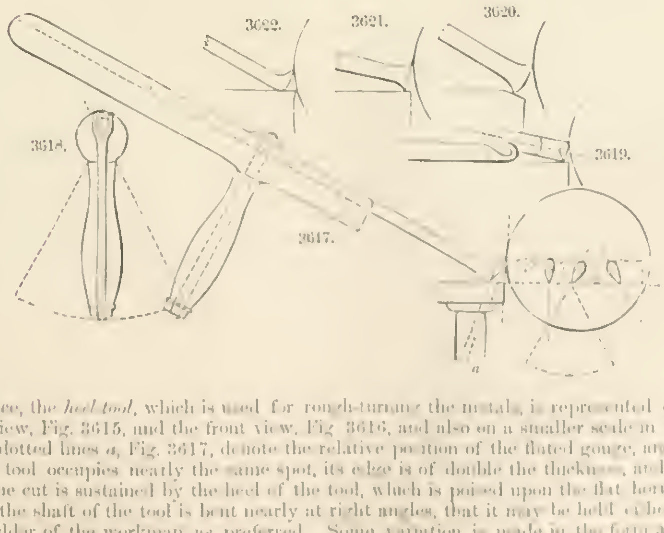
In using the graver and other tools for the metals, it is the aim to avoid exposing the end of the tool to the rough gritty surface of the material. This is done by cleaning the surface, especially the extreme edge, with an old file, and beginning at that edge, the work is at one sweep reduced nearly to its required diameter by a wide thin cut, which may be compared with a chamfer, or a conical fillet, con necting the rough external surface with the smooth reduced cylinder. Therefore after the first entry, the point of the tool is buried in the clean metal below the crust, and works laterally, which is indeed the general path of pointed tools for metal.

When the graver is used in the turn-bench with intermittent motion, as for the pivots of watches, the axes for sextants, and other delicate works, it is applied *overhand*, or inverted, as in Fig. 3612; but it is then necessary to withdraw the tool during each back stroke of the bow, to avoid the destruction of the acute point, and which alone is used. The graver, when thus applied in lathes with continuous motion, is only moved on the rest as on a fulcrum, and in the plane in which it lies, rather as a test of work done, than as an active instrument.



The edge of the graver is afterwards used for smoothing the stronger kinds of work; it is then necessary to incline the tool horizontally, to near the angle at which it is ground, in order to bring the sloping edge parallel with the surface. But the smoothing is better done by a thick narrow flat tool, ground at about sixty degrees, the handle of which is raised slightly above the horizontal, as in Fig. 3613, in order that its edge may approach the tangential position; here also the tool is rotated on one edge, after the manner of the brass tools or the graver.

For many slight purposes requiring rather delicacy than strength, as in finishing the rounded edge of a washer, the flat tool is inverted or placed bevel upwards, as in Fig. 3614; the lower side then becomes the tangent, and the edge the axis of rotation of the tool, the same as in turning convex mouldings with the soft-wood chisel. Indeed, many analogies may be traced between the tools respectively used for soft woods and iron, except that the latter are ground at about twice the angle to meet the increased resistance of the hard metal, and the tools are mostly sustained by the direct support of the rest, instead of resting in great measure against the hands of the individual.



For instance, the *heel tool*, which is used for rough-turning the metals, is represented of the full size in the side view, Fig. 3615, and the front view, Fig. 3616, and also on a smaller scale in Figs. 3617 and 3618. The dotted lines *a*, Fig. 3617, denote the relative position of the fluted gouge, and although the heel or hook tool occupies nearly the same spot, its edge is of double the thickness, and the entire resistance of the cut is sustained by the heel of the tool, which is poised upon the flat horizontal surface of the rest; the shaft of the tool is bent nearly at right angles, that it may be held either above or below the shoulder of the workman, as preferred. Some variation is made in the form and size of the heel tools, and they are occasionally pointed instead of round upon the cutting edge.

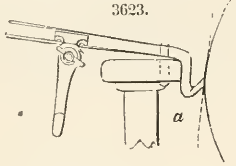
The heel tool is slightly rotated upon its heel in its course along the work, so that, as seen at *b*, its edge travels in short arcs, and when its position becomes too inclined, a fresh footing is taken; on this account the straight handle, employed in ordinary tools, is exchanged for the transverse handle represented. In the best form of heel-tools the square shaft lies in a groove in the long handle, and is fixed by an eye-bolt and nut, passing through the transverse handle, as seen in the section, Fig. 3618. Notwithstanding the great difference the materials upon which the gouge and heel-tool are employed, their management is equally easy, as in the latter the rest sustains the great pressure, leaving the guidance alone to the individual.

Fig. 3619 represents another kind of *hook-tool* for iron, which is curiously, like the tools Figs. 3483 to 3484, p. 707, used for soft wood, the common differences being here also observable, namely, the increased strength of edge, and that the one edge is placed upon the rest to secure a firm footing or hold.

Nail-head tools are made much on the same principle: one of these, Fig. 3620, is like a cylinder, terminating in a chamfered overhanging disk, to be rolled along so as to follow the course of the work, but it is rather a theoretical than practical instrument. When, however, the tool is made of a square or rectangular bar, and with two edges, as at Fig. 3621, it is excellent, and its flat termination greatly assists in imparting the rectilinear form to the work. Occasionally the bar is simply bent up at the end to present only one edge, as in Fig. 3622; it is then necessary the curved part should be jagged as a file to cause it to dig into the rest like the others of its class, and which present some analogy to the soft-wood tools, Figs. 3488 and 3489, p. 707.

The *cranked*, or *hanging* tools, Fig. 3623, are made to embrace the rest, by which they are prevented from sliding away, without the necessity for the points and edges of the heel-tools; the escape of the cranked-tool sideways is prevented by the pin inserted in one of the several holes of the rest. The direct penetration is caused by the depression of the hand; the sideway motion by rotating the tool by its transverse handle, which is frequently a hand-vice temporarily screwed upon the shaft. To save the trouble of continually shifting the lathe-rest, an iron wedge (not represented) is generally introduced at *a*, between the rest and the back of the tool; when the wedge is advanced at intervals it sets the tool deeper into the work, when it is withdrawn it allows more room for the removal of the tool.

3623.



3624.

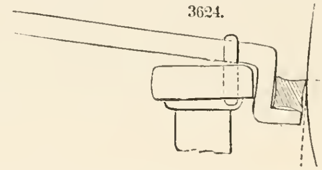


Fig. 3624 represents a tool of nearly similar kind; the stock is of iron, and it carries a piece of steel, about three or four inches long, and one inch square, which is forged hollow on the faces by means of the fuller, to leave less to be ground away on the stone. The rectilinear edges of this tool are used for smoothing iron rollers, iron ordnance, and other works turned by hand, and to preserve the edge of the tool, thin spills of hard wood are sometimes placed between the cutter and the bar. Under favorable arrangements these tools also are managed with great facility; indeed, it occasionally happens that the weight of the handle just supplies the necessary pressure to advance the tool, so that they will rest in proper action without being touched by the hand; a tolerable proof of the trifling muscular effort occasionally required, when the tools are judiciously moulded and well applied.

These hand-tools, and various others of the same kinds, although formerly much used by the millwrights, are now in a great measure replaced by the fixed tools applied in the sliding-rest.

Fixed or machine tools for turning and planing.—*Angles as in the hand-tools—Figures generally one-fourth to one-eighth the full size.*—The performance of fixed tools is, in general, much more effective than that of hand-tools; as the rigid guides and slides now employed do not suffer the muscular fatigue of the man, nor do they experience those fluctuations of position to which his hand is liable. Therefore, as the tool pursues one constant undeviating course, the corresponding results are obtained both more economically and more accurately by the intervention of the *guide-principle*, or the *slide-rest*, from which we derive the *side-lathe*, and thence the *planing machine*, and many other most invaluable tools.

The cutting edges of machine-tools mostly follow the same circumstances as those of hand-tools, but additional care is required in forming them upon principle; because the shafts of the fixed tools are generally placed, with little power of deviation, either at right angles to, or parallel with, the surfaces to be wrought; the tools are then held in the iron grasp of screws and clamps, in mortises, staples, and grooves. The tools do not, therefore, admit of the same accommodation of position, to compensate for erroneous construction, or subsequent deterioration from wear, as when they are held in the hand of the workman, and directed by his judgment.

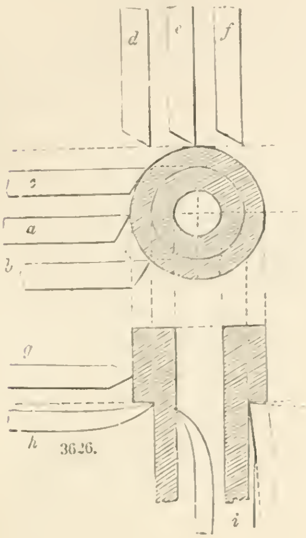
It must also be additionally borne in mind that, however ponderous, elaborate, or costly the *machine* may be, its effectiveness *entirely depends* upon the proper adaptation and endurance of the *cutting-tool*, through the agency of which it produces its results.

The usual position of the fixed turning-tools is the horizontal line, as at *a*, Fig. 3625; and unless the tools always lie on the radius, (or any other predetermined line,) various interferences occur. For instance, the tool proceeding in either of the lines *b* or *c*, could not reach the centre of the work, and a portion would then escape being wrought; the curvature of the circle at *b* would sacrifice the proper angle, and expose the tool to fracture from the obliquity of the strain; and at *c*, the edge would be altogether out of contact, and the tool could only rub and not cut. These evils increase with the diminution of the circle; and although the diagram is greatly exaggerated for illustration, the want of centrality is in truth an evil of such magnitude that various contrivances are resorted to, by which either the entire slide-rest, or the cutter alone, may be exactly adjusted for height of centre.

The planing tools for metals are in general fixed vertically, and the path of the work being, in the majority of planing-machines, rectilinear and horizontal, the tool may be placed at *d*, *e*, or *f*, indifferently, there being no interference from curvature as in turning.

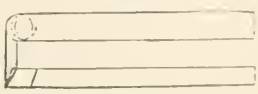
In those modifications of the planing-machine in which, as in Brunel's mortising-engine, the cutter travels perpendicularly, and is also fixed perpendicularly, as in the key-groove or slotting-engines, and the paring-engines, the general form of the tool *f*, or that of a strong paring chisel, is retained, but the blade is slightly inclined in its length as at *j*, Fig. 3626, to avoid touching the surface to be wrought except with its cutting edge, and the length of the tool supplies a little elasticity to relieve the friction of the back stroke.

3625.



3626.

3627.



3628.

Although all the various forms of hand-turning tools are more or less employed as fixed tools, still the greater part of the work is done with the point-tool, (such as *g*, in the plan Fig. 3626,) the angle of which should be slightly rounded; but for working into an angle, the point of the tool is thrown off as at *h*, so that its shaft may avoid either side of the angle, and it is then called a side-tool. For internal works, and in small apertures especially, the abrupt curvature requires particular attention to the central position of the tool *i*, and a frequent sacrifice of the most proper form of the chamfer or edge. We will now describe a few of the slide-rest tools in the previous order, namely, those for soft wood, for hard wood, for brass, and for iron.

The fixed tools for soft wood require the same acute edges and nearly tangential positions as those used by hand; and if these conditions exist, it is quite immaterial whether the tool touch the work above or below the centre; but the central line, or *a*, Fig. 3625, is the most usual. The soft wood gouge, or hook-tool, is successfully imitated by making an oblique hole in the end of a bar of steel, as seen in two views in Fig. 3627, but it is not very lasting; or a bar of steel may be bent to the form of Fig. 3628, and sharpened internally, either rounded to serve as a gouge, or straight and inclined as a chisel, but neither of these tools admits in itself of adjustment for centre.

The difficulty of centre is combated by the use of a tool exactly like a common gouge or chisel, but only an inch or two long, and with a cylindrical stem also an inch or two long, by which it may be retained at any height, in the end of a bar of iron, having a nearly perpendicular hole and an appropriate side-screw for fixing the tool; this construction is abundantly strong for wood.

The fixed tools for hard wood and ivory follow the several forms of the hand tools, Figs. 3198 to 3605, except in having parallel stems; they are always placed horizontally, and are treated in all respects just as before. Care should be taken, however, that the *end* of the tool is its widest part; in order that, if it be sent in below the surface of the work, as in cutting a groove, it may clear well and not rub against the sides.

In sharpening the tools intended for hard wood and ivory, the oil stone should be applied principally at the end, or on the chamfer of the tool, as this will not reduce the height of centre, which it is always important to retain. If, however, the tools should eventually become chamfered off, after the manner of Fig. 3606, they may be annealed, and thrown up to place the chamfered part in the line of the general face; they are then rehardened, and ground up as at first. But as most of the slide-rests for wood turning are fitted into pedestals by means of a cylindrical stem with a vertical screw adjustment, the tools may be at all times accurately centered when particular care is required; and this provision is of still greater importance, with the several revolving cutters applied to the slide-rest, which will be hereafter adverted to.

The fixed tools for brass and for iron, whether used in the lathe or the planing machine, will be considered in one group; the principal difference is, that the tools for brass present an angle of nearly 90 degrees, the tools for iron an angle of 60, to the superficies to be wrought. Indeed, the angles or edges of the cube may be considered as the generic forms of the tools for brass, and the angles or edges of the tetrahedron, as the generic forms of the tools for iron; that is, supposing the edges or planes of these solids to be laid almost in contact with the line of motion or of the cut, in order that they may fulfil the constant conditions of the paring tools.

The fixed tools for brass and similar alloys resemble, as in hand-turning, the more simple of the hard wood tools, except that they are sharpened a trifle thicker on the edge; they are, however, nearly re stricted to the point-tool, the narrow round tool, and to the side-tool, which is represented at *j*, Fig. 3626 It is ground so that the two cutting edges meet at an angle not exceeding about 80 degrees, that in proceeding into rectangular corners it may clear each face by about five degrees, and it will then cut in either direction, so as to proceed into the angle upon the cylindrical line, and to leave it upon the plane surface, or it may be applied just in the reverse manner without intermission.

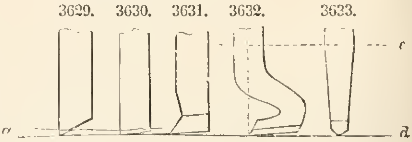
When the tool is used for rough work the corner is slightly rounded, but in finishing it is usually quite sharp; and as it differs only some ten degrees from the solid angle of a cube, it is abundantly strong. If the tools acted upon a considerable extent or width of the brass, they would be liable to be set in vibration; but as the paths of the cutters are determined by the guide principle employed, the point fulfils all that can be desired.

The fixed tools for iron present more difficulties than the generality of the foregoing kinds; first, the edges of the tools are thinner and more interfered with in the act of grinding, as the vertical height of the cutting edge is reduced when either face of the wedge is ground; and secondly, they are exposed to far more severe strains from the greater hardness of the material, and the less sparing manner in which it is reduced or wrought, owing to its smaller price and other circumstances; and therefore, the most proper and economic forms of the tools for iron are highly deserving of attention.

The fracture of a tool when it is overloaded commonly points out the line of greatest resistance or strain. The tool, Fig. 3629, although apparently keen, is very weak, and it is besides disposed to pursue the line at which its wedge-formed extremity meets the work, or to penetrate at an angle of some 30 degrees. Fig. 3629 would probably break through a line drawn nearly parallel with the face *a b* of the work under formation; that portion should therefore be made very nearly parallel with *a b*, the line of resistance, in order to impart to the tool the strength of the entire section of the steel; so that should it now break it will have a much longer line of fracture. The tool thus altered is very proper for brass, an alloy upon which acute tools cannot be favorably employed.

But with the obtuse edge of Fig. 3630 other metals will be only removed with considerable labor, as it must be remembered the tool is a wedge, and must insinuate itself as such amongst the fibres of the material. To give the strengthened tool the proper degree of penetration, the upper face is next sloped, as in Fig. 3631, to that angle in which the minimum of friction and the maximum of durability of the edge most nearly meet; and which, for iron, is shown to be about 60 degrees, as in the triangular tool, Fig. 3609. The three planes of pointed tools for iron, meeting at 60 degrees, constitute the angle of the tetrahedron, or the solid with four equilateral planes, like a triangular pyramid, the base and sides of which are exactly alike.

3629. 3630. 3631. 3632. 3633.



But the form of Fig. 3631 would be soon lost in the act of grinding; therefore, to conclude, the tool is made in the bent form of Fig. 3632, in which the angles of Fig. 3631 are retained, and the tool may be many times ground without departing from its most proper form. This is in effect extending the angle of the tetrahedron into the triangular prism ground off obliquely, or rather, as seen in the front view, Fig. 3633, into a prism of five sides, the front angle of which varies from 60 degrees to 120 degrees, and is slightly rounded, the latter being most suitable for rough work; sometimes the front of the prism is half-round, at other times quite flat: these forms are shown in Fig. 3639.

The extremities of Figs. 3631 and 3632 approach very closely to the form of the graver used for engraving on steel and copper-plates, than which no instrument works more perfectly. The slender graver, whether square or lozenge, is slightly bent, and has a flattened handle, so that the ridge behind the point may lie so nearly parallel with, and so completely buried in, the line or groove under formation, as to be prevented or checked by the surface contact from digging into the work. This is another confirmation of the fact that the line of penetration is that of the lower face of the cutter or wedge, or that touching the work.

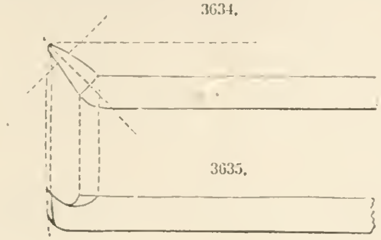
In adopting the crank-formed tools, Fig. 3632, the principle must not be carried into excess, as it must be remembered we can never expunge *elasticity* from our materials, whether viewed in relation to the machine, the tool, or the work.

The tool should be always grasped as near the end as practicable, therefore the hook or crank should occupy but little length; as the distance from the supposed line of the fixing-screw *c* to the edge of the tool being doubled, the flexure of the instrument will be four-fold; when trebled, nine-fold; in fact, as the square. And also as the flexure may be supposed to occur from near the centre of the bar, (that is, neglecting the crook,) the point of the tool should not extend beyond the central line *o*; otherwise when the tool bends, its point would dig still deeper into the work from its rotation on the intersection of *c* and *o*; the point situated behind the central line would spring *away from*, or *out of*, instead of *into* the work. To extend the wear of the cranked tools they are commonly forged so that the point is nearly level with the upper surface of the shaft, as in Fig. 3638; they then admit of being many times ground before they reach the central line, and they are ultimately ground (always at the end of the prism and obliquely) until the hook is entirely lost. This avoids such frequent recurrence to the forge fire, but it is a departure from the right principle to allow the point to extend beyond the centre line *o*.

The works of the lathe and planing-machine frequently present angles or rebates, chamfers, grooves, and under-cut lines, which require that the tool should be bent about in various ways, in order that their edges may retain as nearly as possible the same relations to all these surfaces, as the ordinary surfacing tools, Figs. 3631 and 3632, have to the plane *a b*. For instance, the shaft of the tool Fig 3631, when bent at about the angle of 45 degrees, becomes a side cutting and facing tool, as shown in plan in Fig. 3634, in elevation in Fig. 3635, and in perspective in Fig. 3636; and in like manner the cranked tool, Fig. 3632, when also bent as in Fig. 3634, becomes Fig. 3637, and is also adapted to working into angular corners upon either face.

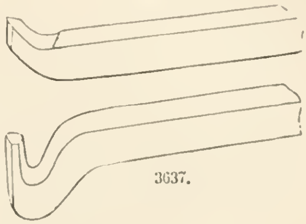
3634.

3635.



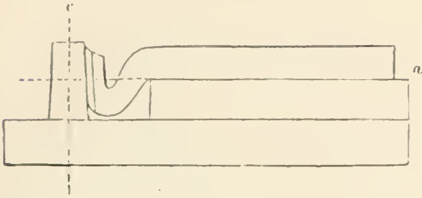
3636.

3637.

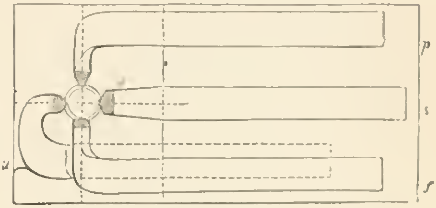


Mr. Nasmyth's tool-gage, shown in elevation in Fig. 3638, and in plan in Fig. 3639, entirely removes the uncertainty of the angles given to these irregular bent tools; for instance, when the shaft of the tool is laid upon the flat surface and applied to the iron cone *c*, whose side measures about 3° with the perpendicular, it serves with equal truth for *s*, the tool for surfaces; *p* and *f*, the side-cutting tools, used also for perpendicular cuts and fillets; and *u* for under-cut works.

3638.

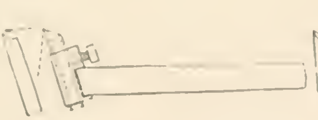


3639.

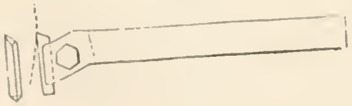


In applying tools to lathe works of small diameters, it is necessary to be very exact, and not to place them *above* the centre, or they immediately rub; and as this soon occurs with tools having so small an angle, it appears desirable to make the cone-gage for small lathe works of about twice the given angle, and to mark upon the cone a circle exactly indicative of the height of centre; the tool can be then packed up to the centre line, with one or two slips of sheet-iron, to be afterwards placed beneath the tool when it is fixed in the lathe-rest. In small hollow works, the most lasting or the crank-formed tools are entirely inapplicable; indeed, so much attention is required to prevent the tool from rubbing against the interior surfaces, that the ordinary angles cannot be employed, and the cone-gage ceases to be useful, but in every other case it should be constantly resorted to; the additional thickness *a* is required to make it applicable to the crank-formed tools.

3640.



3641.



3643.

3642.

Fig. 3640 represents a cutter introduced in the block machinery at Portsmouth, England, to lessen the difficulty of making and restoring the tools for turning the wrought iron pins for the sheaves; it consists of a cylindrical wire which, from being ground off obliquely, presents an elliptical edge; the tool is fixed in a stock of iron, terminating in an oblique hole, with a binding screw. The tool, when used for iron, in the "pin turning lathes," was made solid; when used for turning the surfaces of the wooden shells, in the "shaping engine," it was pierced with a central hole; the latter could only facili tate the process of sharpening without altering the character of the edge, which continued under the same circumstances as when solid.

About sixteen years back the author made for his own use a tool such as Fig. 3640, but found that with rough usage the cutter was shivered away, on account of its breadth, and he was soon led to substitute for the solid cylinder a triangular cutter, the final edge of which was slightly rounded, and placed more nearly perpendicular, in a split socket with a side screw, as in Fig. 3641. The strength of the edge was greatly increased, and it became, in fact, an exact copy of the most favorable kind of tool for the lathe or planing-machine, retaining the advantage that the original form could be always kept with the smallest expenditure of time, and without continually reforging the blade, to the manifest deterioration of the steel from passing so frequently through the fire; it being only requisite to grind its extremity like a common graver, and to place it so much higher in the stock as to keep the edge at all times true to the centre.

A right and a left hand side-tool for angles, the former seen in Figs. 3642 and 3643, were also made; the blade and set-screw were placed at about 45°, and at a sufficient vertical angle to clear both the inside of a cylinder of three inches diameter and also to face the bottom or surface. These side-tools answered very well for cast-iron; but Fig. 3641, the ordinary surfacing tool, is excellent for all purposes, and has been employed in many extensive establishments.

The prismatic cutters admit of the usual variations of shape: sometimes two binding screws are used, and occasionally a tail screw, to receive the direct strain of the cut. When the blades are only used for cutting in the one direction, say from right to left, they may, with advantage, be ground with a double inclination; for as all these pointed tools work *laterally*, the true inclination of some 60° to the narrow facet or fillet operated upon is then more strictly attained.

Considerable economy results from this and several other applications, in which the cutter and its shaft are distinct parts. The small blades of steel admit of being formed with considerable ease and accuracy, and of being hardened in the most perfect manner. And when the cutters are fixed in strong bars or shafts of iron, they receive any required degree of strength, and the one shaft or carriage will serve for any successive number of blades.

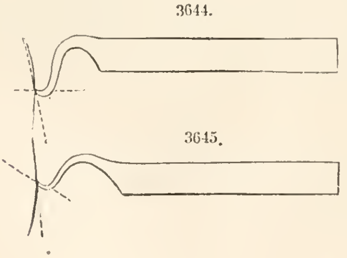
The blades are sometimes made flat, or convex in the front, and ground much thinner, to serve for soft wood; the tools for hard wood and ivory, being more easily ground, do not call for this application of detached blades.

In turning heavy works to their respective forms, a slow motion and strong pointed tools are employed; but in finishing these works with a quicker rate of motion, there is risk of putting the lathe in a slight tremor, more particularly from the small periodic shocks of the toothed wheels, which in light finishing cuts are no longer kept in close bearing as in stronger cuts.

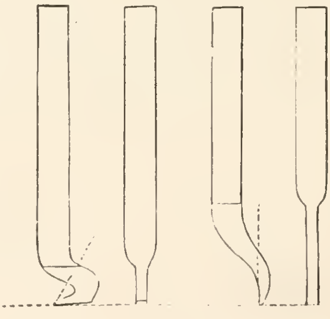
Under these circumstances, were the tools rigid and penetrative, each vibration would produce a line or scratch upon the surface, but the *finishing* or *hanging* tools, Figs. 3644 and 3645, called also *springing* tools, which are made of various curves and degrees of strength, yield to these small accidental motions. The first resembles in its angles the rest of the tools used for brass, the second those for iron; their edges are rectilinear, and sometimes an inch wide. The width and elasticity of these finishing tools prevent their acting otherwise than as scrapers for removing the slight superficial roughness without detracting from the accuracy of form previously given. In a somewhat similar manner the broad hand flat tool, rendered elastic by its partial support, as in Fig. 3610, is frequently used for smoothing brass works, and others turned with the slide-rest.

3644.

3645.



3646. 3647. 3648. 3649.



Figs. 3646 and 3647 represent a very excellent finishing tool, introduced by Mr. Clement, for planing cast and wrought iron and steel; it resembles the cranked tools generally, but is slighter; it is made smooth and flat upon the extremity, or rather in a very minute degree rounded. This tool is sharpened very keenly upon the oil-stone, and is used for extremely thin cuts, generally one-quarter of an inch wide, and when the corners just escape touching the work is left beautifully smooth; the edge should on no account stand in advance of the centre line. But to avoid the chatters so liable to occur in brass works, Mr. Clement prefers for that material the elastic planing-tool, Figs. 3648 and 3649; its edge is situated considerably behind the centre.

In concluding the notice of the turning tools it may be necessary to add a few words on those used for lead, tin, zinc, copper, and their ordinary alloys. The softest of these metals, such as lead, tin, and soft pewter, may be turned with the ordinary tools for soft wood; but for the harder metals, such as zinc, and hard alloys containing much antimony, the tools resemble those used for the hard woods, and they are mostly employed dry.

Copper, which is much harder and tougher, is turned with tools similar to those for wrought-iron, but in general they are sharpened a little more keenly, and water is allowed to drop upon the work to lessen the risk of *dragging* or tearing up the face of the copper, a metal that neither admits of being turned or filed with the ordinary facility of most others. Silver and gold, having the tenacious character of copper, require similar turning tools, and they are generally lubricated with milk.

In the above, and nearly all the metals except iron and those of equal or superior hardness, there seems a disposition to adhere, when by accident the recently removed shaving gets forcibly pressed against a recently exposed surface, (the metals at the time being chemically clean;) this disposition to unite is nearly prevented when water or other fluid is used.

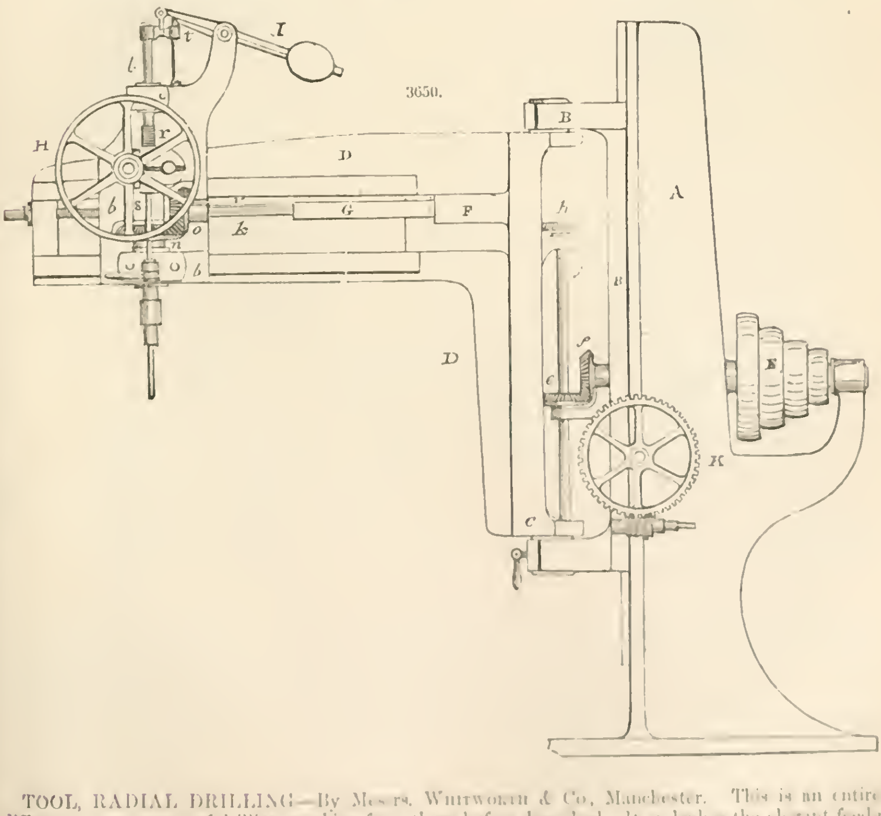
Water is occasionally resorted to in turning wrought-iron and steel; this causes the work to be left somewhat smoother, but it is not generally used, except in heavy work, as it is apt to rust the machinery; oil fulfils the same end, but it is too expensive for general purposes.

Cast-iron, having a crystalline structure, the shavings soon break without causing so much friction as the hard ductile metals; cast-iron is therefore always worked dry, even when the acute edges of 60 degrees are thickened to those of 80 or 90, either from necessity, as in some of the small boring tools, or from choice on the score of durability, as in the largest boring tools and others. Brass and gun-metal are also worked dry, although the turning tools are nearly rectangular, as the copper becomes so far modified by the zinc or tin, that the alloys, although much less crystalline than cast-iron, and less ductile than copper, yield to the turning tools very cleanly without water.

But when tools with rectangular edges are used for wrought-iron and steel, on account of the greater cohesion of these materials, they must be lubricated with oil, greese, soap and water, or other matter, to prevent the metals from being torn. And the screw-cutting tools, many of which present much surface friction, and also rectangular or still more obtuse edges, almost invariably require oil or other unctuous fluids for all the metals.

In the practice of metal turning the diamond point *a b*, Fig. 2845, is occasionally used in turning *hardened* steel and other substances; *i l*, Fig. 2845, are constantly used in engraving by machinery, and in graduating mathematical instruments.

3650.

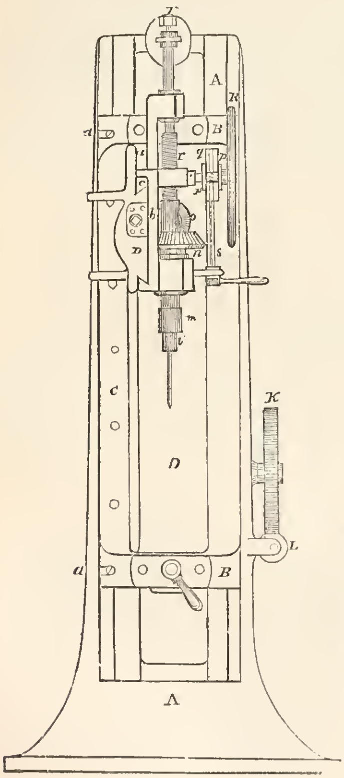


TOOL, RADIAL DRILLING.—By Messrs. Whitworth & Co., Manchester. This is an entirely different arrangement of drilling machine from those before described. It embodies the elegant feeding apparatus introduced by the same makers, and described in the account already given of their vertical drilling machine, p. 387; but in that form of the machine the drilling spindle does not admit of any lateral motion; it is strictly confined to the same vertical position, and in that can rise and fall at the wil of the operator; but in this the drill-spindle has not only the same vertical and revolving motions as in that form of the machine, but admits also of a lateral motion whereby it can be brought over the work into any required position within the limits of the radial arm D, on which the whole drilling apparatus is carried.

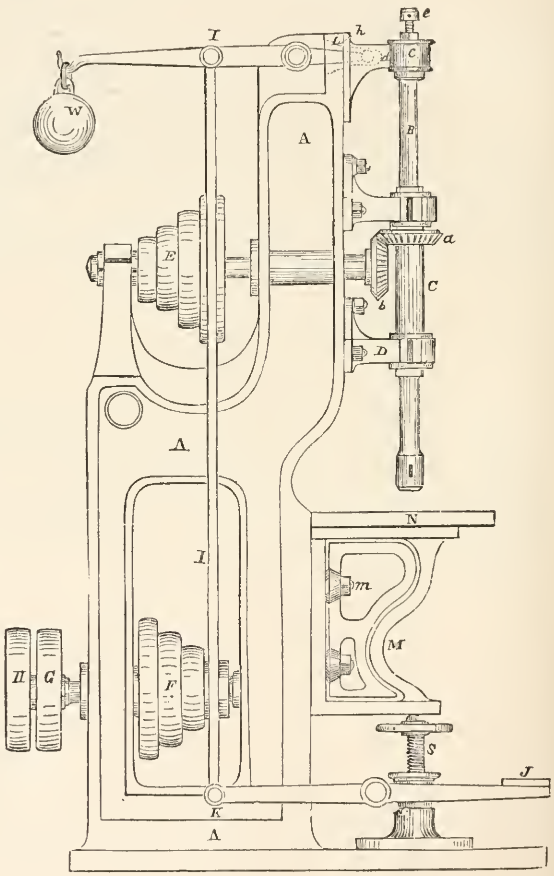
The arrangement consists of a strong upright framing A A, Fig. 3650, with a sole by which it can be bolted to a stone foundation. To this is attached a vertical sliding bracket B B B, attached by dovetailed guides. This bracket is raised and lowered at pleasure, according to the height required for the work, by means of a handle which fits on the end of the tangent-screw L; this screw works into the tangent-wheel K, on the spindle of which is a small pinion which geers with a rack on the back of the bracket B B. The bracket is secured, when raised to its proper position, by the pinching-screw *w*, on the outer end of which a handle is fixed.

C C is the sole of the radial arm D D. It is supported in bearings at its extremities in the vertical slide B B, and by this means can swing through an arc of 180 degrees. On this arm D D is carried movable slide, to which all the drilling apparatus is attached.

3651.



3652.



E is the pulley-cone by which motion is communicated to the machine. On the spindle of this cone is keyed the bevel-wheel *f*, which geers with the similar wheel marked *e* on the vertical spindle *g*. This spindle is provided with a sunk-feather to allow it to slide through the eye of the wheel *e* when the bracket is moved vertically. On the upper end of the spindle *g* is keyed the bevel-wheel *h*, which works into another similar wheel on the end of the horizontal and hollow shaft G, which has its bearing in the boss F. This hollow shaft G has a groove-cut inside of it to receive a feather inserted into the spindle *k*, which passes into it, and with which it must of necessity turn by virtue of the connecting feather or key projecting from the surface of *k*. The other end of the spindle *k* has its extreme bearings in the slide, and has the bevel-wheel *o* keyed upon it; this wheel geers with that marked *n* on the drill-spindle. It is therefore clear that motion being communicated to the driving pulley-cone E, it will be transferred to the bevel-pair *f* and *e*, then to the similar bevel-pair at *h*, and from that point through *g* and *k* to the bevel-pair *o* and *n*, the last of which is placed on the drill-spindle *l* with a sliding feather or key, as before explained.

We have described the wheel which geers with that marked *h*, as being directly keyed on the hollow piece G; this, however, is not the case: the wheel is keyed on an independent short spindle of its own, which enters G in F, and connects itself also by a sunk key, so that the piece G is nothing more than a coupling for this spindle with that marked *k*, and can moreover be slid considerably further into the boss F than is represented in the drawing, Fig. 3652.

The slide is moved along the radial arm D by a crank-handle placed on the squared end of the screw *v v*, which passes through a nut fixed on the back of the slide in the usual manner.

The slide moves along the arm in dovetail guides, as shown in the front view, Fig. 3653; on the upper side are the adjusting piece *c* and setting-screws *d*.

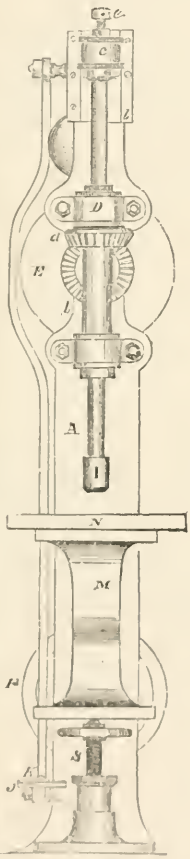
As already stated, the feeding apparatus, and in fact all the drilling tackle, is identical in arrangement with that described on p. 387: *p p* are the friction-pulleys on the same axes as the screw-wheels which geer with the screwed part *r* of the drill-spindle. *q q* are the friction-clips upon the pulleys *p p*, and *s* is the screwed rod by which the clips are brought into action.

For some special purposes the radial drill affords great convenience, but where much accuracy is required it cannot be so well depended upon as the ordinary form, as it rarely possesses the requisite degree of rigidity.

It may be here observed, that the merit of first introducing this description of drilling machine is due to Messrs. Benjamin Hick & Son, of Bolton.

3654.

3653.



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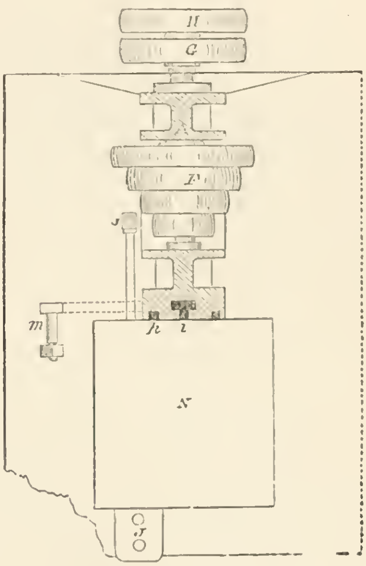
3655.



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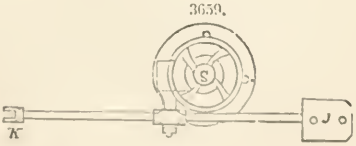

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TOOL, PORTABLE DRILLING—By Nasmyth, Gaskell & Co., Manchester. Fig. 3652 is a side elevation of the machine; Fig. 3653, a front view.

Fig. 3654 is a partial section through the axis of the drill spindle.

Fig. 3655, a cross-section above the table N, showing the form of the frame A A.

This frame is formed of one casting, and is bolted to a large sole plate, which serves as a foundation without other fixing.

B B, the drill-spindle, passes through a long tube marked C C, and which serves as a guide to the spindle, in ascending and descending. The spindle is attached by a sunk feather to the interior of the tube, so that the spindle can slide in it vertically, but cannot turn round within it.

D D, the two fixed brackets in which are the bearings of the guide table C C, the plan of which is shown separately by Fig. 3658.

E, a set of driving cone-pulleys corresponding to the lower set of cone-pulleys F. On these two sets of pulleys is placed the belt, which directly gives motion to the drill-spindle by means of the bevel-pair *a* and *b*, of which the wheel marked *a* is keyed on the guide-tube C C of the drill-spindle, and that marked *b* is fast on the rod of the same spindle on which are the cone-pulleys E.

G and H, a pair of pulleys, one fast and the other loose, by which the machine is driven. They are upon the same spindle as the lower cone-pulleys F, by which the motion is conveyed through a belt to the pulley E.

I, a link connecting the foot-lever J with the weighted lever L, one end of which enters a recess *d* of the sliding bracket *h h*, the sole of which is guided in dovetail grooves, formed by the pieces *b b b b*, seen in Fig. 3653. From this arrangement it is easy to perceive that when the foot is pressed upon the foot-board at J, the link I will cause the weighted end of the lever L to ascend, and the other to descend; and at the same time the sliding bracket, into which is fitted the top of the drill-spindle.

The manner of attaching the drill-spindle to the sliding bracket is rendered obvious by Fig. 3654: the top is formed with a ruff upon it, which is kept in the screwed recess formed in *c* to receive it, by the hollow screw which bears against the under side of the ruff. The spindle is at the same time met above by a screwed steel pin. The end of this pin sustains the downward pressure when the foot is placed on the treddle J.

M is the bracket of the table N. The table is simply a plank of wood resting upon the top plate of the bracket.

As the travel of the drill-spindle is very limited, the table-bracket can be raised and lowered at pleasure, through the required range, by means of the screw S. Its sole is guided vertically by grooves *k k* in the frame; this has also grooves formed in it to receive the heads of the setting-bolts *m m*, the nuts of which, being screwed tight, keep the bracket in its place. The bolt-heads are entered through the openings *n*, and slide down the grooves *l l*; the arrangement of the table-screw S, with the hand-wheel for working it, also its socket with the treddle-lever attached, are shown in plan, Fig. 3659.

Fig. 3656 is a plan of the sliding bracket for feeding the drill-spindle; and Fig. 3657 is a plan of the lever by which it is worked by means of the treddle and link I.

TORSION in mechanics is the twisting or wrenching of a body by the exertion of a lateral force. If a slender rod of metal suspended vertically, and having its upper end fixed, be twisted through a certain angle by a force acting in a plane perpendicular to its axis, it will, on the removal of the force, untwist itself, or return in the opposite direction with a greater or less velocity, and, after a series of oscillations, will come to rest in its original position. The limits of torsion within which the body will return to its original state depend upon its elasticity. A fine wire of a few feet in length may be twisted through several revolutions without imparing its elasticity; and within those limits the force evolved is found to be perfectly regular, and directly proportional to the angular displacement from the position of rest. If the angular displacement exceeds a certain limit, the particles of the body will be wrenched asunder; or if the elasticity is not perfect, (as in a wire of lead, for example, before disruption takes place,) the particles will assume a new arrangement, or *take a set*, and will not return to their original position on the withdrawal of the disturbing force.

The resistance which cylinders or prisms formed of different substances oppose to torsion, furnishes one of the usual methods of determining the elasticity and strength of materials; and the property which a metallic wire or thread stretched by a small weight possesses of becoming twisted and untwisted in a series of isochronous and perfectly regular oscillations, has been ingeniously applied in the torsion balance to the measurement of very minute forces, and thereby to the establishment of the fundamental laws of electricity and magnetism, and to the determination of the mean density of the earth. See BALANCE OF TORSION.

The laws of torsion have been experimentally investigated by Coulomb in a variety of substances; as metallic wires, hairs, fibres of silk, &c. The method which he employed consisted in attaching a body of given form and dimensions to the extremity of the wire, and, after twisting it through a certain angle, to abandon it to the action of the force evolved, and observe the time of the oscillations. The following general laws were found to hold good:

1. On loading a wire or thread with different weights, it will settle in different positions of stability; that is to say, an index attached to the weight will point in different directions if the weight be varied, and the angular deviation may amount even to a whole circumference.
2. The oscillations are isochronous.
3. The time of oscillation is proportional to the square root of the weight which stretches the wire.
4. The time of oscillation is as the square root of the length of the wire.
5. The time of oscillation is inversely as the square of the diameter of the wire.

From the second of these laws it follows that when the wire is twisted round from the position of rest, the force with which it tends to return to that position is proportional to the angle to be described in order to attain it. For it is a general result of mechanics that all motions produced by forces acting according to this law have the property of tautochronism; that is to say, the oscillations are performed in equal times, whatever be the length of the arc. This fundamental property is usually enunciated by saying that the force of torsion is proportional to the angle of torsion.

Let F denote the force of torsion, measured by the weight which it would be necessary to apply by means of a pulley to a point *p*, situated at the unit of distance (one inch) from the axis of the wire, and invariably connected with it, to cause the point *p* to describe an arc of a circle equal in length to the unit of distance; then, by the property enunciated, the force which must be applied at *p* in order that the point may describe any arc ϕ is expressed by $F' \phi$. If the arc of torsion is expressed in degrees instead of parts of the radius, we have $\phi = \pi \phi^\circ \div 180^\circ$ (π being the semicircumference to radius 1, or $= 3 \cdot 14159$;) whence the expression of the force becomes $F + \pi \phi^\circ \div 180^\circ$.

On this principle of the proportionality of the impelling force to the angle or deviation the problem of determining the time of an oscillation is solved. Suppose a body of any form attached to the extremity of a slender wire, whose weight in comparison to that of the body may be neglected, and let

dm be an element of the mass, r the distance of dm from the axis of the wire, and T the time of ar oscillation; the solution of the problem gives

$$T = \pi \sqrt{\left(\int \frac{r^2\, dm}{F}\right)}, \text{ or } T^2 = \pi^2 \int \frac{r^2\, dm}{F}.$$

The integral $\int r^2\, dm$ is the *moment of inertia* of the attached body. If the body be a cylinder whose axis coincides with that of the wire, and if a denote its radius and M its mass, then $\int r^2\, dm = \frac{1}{2} M a^2$; or, substituting the weight for the mass, and observing that if the weight be denoted by P, and the accelerating force of gravity by g (= 32·1908 feet or 386.2894 inches in a second,) we have P = M g, $\int r^2\, dm = P a^2 \div 2g$. Hence the expression for the time becomes $T = \pi a \sqrt{\frac{P}{2 g F}}$.

If the attached body were a slender cylindrical needle suspended horizontally by its middle to the wire, we should, on denoting its length by l, have $\int r^2\, dm = \frac{1}{3} M l^2$; whence $T = \pi l \sqrt{\frac{P}{3 g F}}$.

The following results are deduced from the formula: 1. The force of torsion is independent of the weight which stretches the wire, or F remains constant while P is varied. For suppose P to become P′, and let T′ be the corresponding time of oscillation, and F′ the corresponding force, we have then

$$T^2 = \frac{\pi^2 a^2 P}{2 g F},\ T'^2 = \frac{\pi^2 a^2 P'}{2 g F'};$$

whence $T^2 : T'^2 :: P F' : P' F$. But, by the third experimental law, $T^2 : T'^2 :: P : P'$; therefore $F' = F$.

2. The force is inversely as the length of the wire. For, supposing P to remain constant, we have $T^2 : T'^2 :: F : F$. But, by the fourth experimental law, $T^2 : T'^2 :: l : l'$; whence $F' : F :: l : l'$.

3. The force is proportional to the fourth power of the diameter of the wire. Let there be two wires of the same substance, but of different diameters, D and D′, and stretched by the same weight P; and let T and T′ be the corresponding times. By the fifth experimental law, we have $T : T' :: D'^2 : D^2$. But it has been shown that $T^2 : T'^2 :: F' : F$; therefore $F : F' :: D^4 : D'^4$.

To show the method of applying the formulæ, we shall compute one of the experiments of Coulomb. An iron wire was stretched by a vertical cylinder of ·8 of an inch radius and weighing 2 lbs., and it was observed to make 20 oscillations in 242 seconds, or one in 12·1 seconds. It is proposed to determine the force F. From the formula for the time of an oscillation we have, by transposition, $F = \frac{\pi^2 a^2 P}{2 g T^2}$. Substituting numbers in this formula, we have $\pi^2 = 9{\cdot}8696$, $a^2 = {\cdot}64$, $P = 2$, $g = 386{\cdot}2894$, $T^2 = (12{\cdot}1)^2 = 146{\cdot}41$; consequently $F = \frac{12{\cdot}633}{113113} = {\cdot}0001117$ of a pound, or about ·78 of a grain. Hence the weight applied at the distance of one inch from the axis of the wire that would be required to twist the wire through a complete revolution, or 360°, is 6·283 times this quantity, or nearly five grains.

For the demonstration of the fundamental formula, namely, $T^2 F = \pi^2 \int r^2\, dm$, see Coulomb, *Théorie des Machines Timples;* or Biot, *Traité de Physique*, tom. i.

TRANSIT INSTRUMENT *for the correction of time-keepers.* Mr. Dent had long felt persuaded that the interest of Horology would be promoted if the public were more generally possessed of a cheap, simple, and correct transit instrument, requiring little or no scientific knowledge for its right use, and not readily susceptible of injury or derangement. To this end he had devoted much time and thought; and, in 1840, he considered that he had succeeded in inventing an apparatus which, by means of *shadows*, would produce the desired result. This idea he communicated to J. M. Bloxam, Esq., who thereupon informed him that his own attention had for some years been devoted to the same object, and that he had contrived an optical arrangement, which, by the agency of a single and double reflection, determined the sun's passage over the meridian with great exactness. Convinced of the superiority of Mr. Bloxam's contrivance, Mr. Dent, in conjunction with that gentleman, after two years of great labor and expense, produced the instrument in its present simple and accurate form. It has been made the subject of a patent, and may be had, with complete instructions for its use, from the maker and proprietor, Mr. Dent.

Fig. 3660 gives a general outline of the instrument, in readiness for taking observations.

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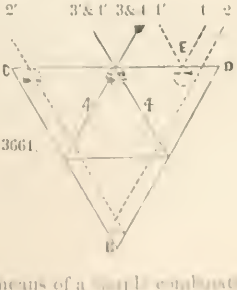

The Dipleidoscope operates by reflecting the sun's rays by means of a simple combination of reflecting surfaces. Bearing this in mind, and remembering also that the angle of the incident rays of light falling upon a plane is equal to the angle of the reflected rays, the nature and action of the instrument will be obvious from the figure.

The instrument consists of three reflecting planes D C, D B, and B C, Fig. 3661. D C represents the exterior plate of glass, which covers in the other two opaque glass surfaces D B and B C, set in the interior of the instrument. Suppose D C to be so divided that the ray No. 1 falling on D C, at E, will be reflected to the eye at 1′, and the image of the sun will appear to advance in the direction from D towards C. The ray No. 2 passing through D C, is reflected from C B, impinges on D B, and reaches the eye in the direction 2′. The image of the sun thus formed will appear to move from C towards D, because it has been *twice* reflected, and thus the two images will *approach* each other. Suppose the ray No. 1 to have advanced to the position No. 3, and the ray No. 2 to the position No. 4; it will then be evident that their reflected rays will be in the same direction 3′ and 4′, and, therefore, that the two images of the sun coincide, as shown by the arrows being in the position of crossing each other, and indicating the instant of apparent noon; as the rays continue to advance, the images, having passed over each other, will, of course, be seen to separate.

The following familiar illustration is introduced to further explain the optical construction. When the sun is about setting, it is not uncommon to see the rays so reflected from the windows of a whole range of houses, as to convey the idea of a public illumination. While some portions of the sun's rays are thus reflected, other portions pass through the glass into the rooms. The rays thus transmitted (the rays of *incidence*, as they were styled above) may be thrown at pleasure in any direction consistent with the range of the sun, by a person within the room, having a looking-glass in his hand: exactly as children produce what they call a *Jack-o'-Lantern.* Now if, instead of throwing the rays upon a non-reflecting object, (such as the wall, &c.,) he were to transfer them to another looking-glass, they would be again reflected from this latter glass. Supposing these two looking-glasses to be placed at an angle of less than 90°, in a manner corresponding with the position of the two silvered planes seen in the instrument, and also shown in the figure at D B, B C, he can reflect the sun's rays again out of the window. Now, if we imagine the window to represent the outer reflector of the meridian instrument, its construction is, by this process, completely exemplified. To proceed a little further; it is evident, that the angle and situation of the two looking-glasses could be so arranged as to direct the rays of the sun through any particular pane of the window; so that a person standing without, in a proper position, would see, in addition to the sun's rays reflected from the *outer* surface of the pane, the rays of incidence that had passed through the window, and were thus reflected from the double mirror. One of the luminous objects (the flash or glare of the sun) so produced, would be reflected from the surface of the window, and would be a *single* reflection; while the rays of incidence, which had passed through the window, and undergone a *double* reflection by means of the *two* mirrors would, on being thrown back by the mirrors through the window, move in a direction contrary to that taken by the single reflection from the surface of the window-pane. Hence, any one of the heavenly bodies, subjected to the eye by a process of the above description, would not only appear as two distinct objects, but those objects would be seen to approximate and cross each other in an *opposite* course: a desideratum being hereby secured which increases the power of the instrument in a double ratio, and renders it proportionably preferable to any other that has been hitherto employed.

The Dipleidoscope, or new patent meridian instrument, will enable any person to obtain correct time with the greatest facility, by an observation either of the transit of the sun over the meridian by day, or of the transit of the stars by night. It possesses great advantages over any other of similar correctness; it is exceedingly simple, it is not liable to get out of adjustment or repair, and it does not require any attention beyond that which is, of course, necessary in the first instance, viz., that it be placed on a level surface, and in the meridian. The observations to be taken afterwards can be made by any one, although previously unacquainted either with astronomical apparatus or practical astronomy; the instrument being as simple as a sun-dial, while it is infinitely more correct, since it gives the time to within a fraction of a second. The utility of possessing an indicator of this kind in addition to the most perfect time-keeper, must be evident: for, however excellent a clock or watch may be, experience shows how difficult it is to obtain exact time, *for lengthened periods*, by any mere mechanical contrivance. To remedy the defect of mechanism, it has been already remarked, that actual observation of the heavenly bodies becomes indispensable; as, without it, the best time-keeper cannot be implicitly depended upon for any considerable interval.

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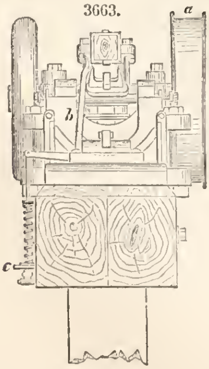

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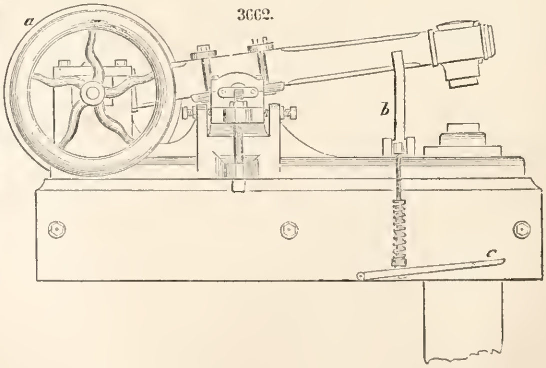

TRIP-HAMMER. Fig. 3662 is a side elevation of a small trip-hammer, such as is commonly used for forging spindles and bolts, and for swaging various other kinds of small work

Fig. 3663 is an end elevation of the same. A is the driving-pulley, with a flanch on each side to guide the belt while running loose. This pulley is attached to the cam-shaft, upon the other end of which is the balance-wheel E. C a foot-lever, connected with the catch *b*, by a rod and spring, and by means of which the hammer can be stopped or started without shipping the belt. F, bed of timbers bolted together to support hammer. G, post in which the hammer-block is placed—usually extending into the ground four or five feet. *f* is the husk-supporter or rocker, adjusted by screws and bolts, so that the hammer can be set at any taper. S is a heavy cast-iron bed-plate to which all other parts are connected. This plate is bolted firmly to the timbers below.

TRIP or TILTING HAMMER. From the Lowell Machine Shop. Figs. 3664 and 3665 are side and end elevations of a tilting hammer, with a head weighing 250 lbs.

a is the driving-pulley. As the belt runs loose around the pulley when the hammer is not in use, here is a flanch on each side to keep the belt in its place.

B, large timbers on which the heavy iron-work rests.

P, timbers disconnected with B, which support the block S in which the lower die is fastened.

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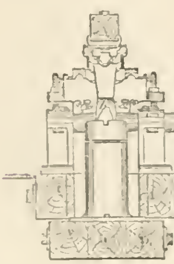

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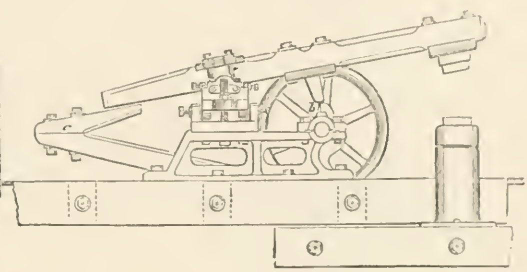


c, a spring of the best kind of timber, which serves as a stop for the hammer when raised, and gives force to the blow.

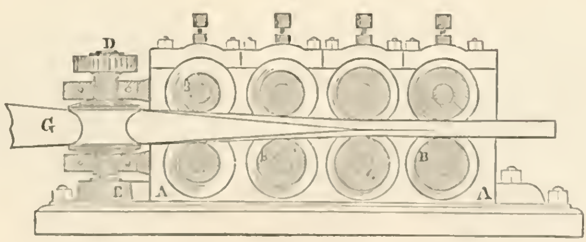
b is the cam, which raises the hammer twice in one revolution.

The bush of this hammer is hung in a rocking stand, adjusted by set-screws and bolts, so that it can be set at any taper for drawing tapering work.

This hammer is well adapted to swaging car-axles, &c.

TUBE-MAKING MACHINERY—Deakin's improvements, 1850. The patentee's invention relates to rolling machinery for the manufacture of metallic cylindrical, taper, and other tubes and solids

3666.



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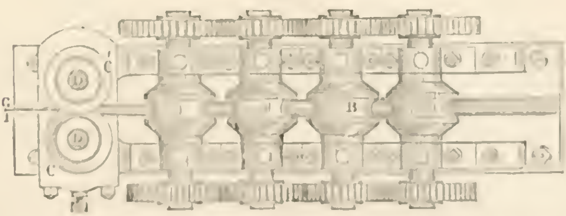
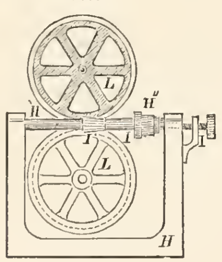


Fig. 3666 represents a longitudinal vertical section of the machinery for making tubes, taken centrically through the rollers at the line 1, 1; Fig. 3667 is a plan view. A A, the side frames of the apparatus, upon which are mounted the four pairs of rollers, B B B B. The patentee does not, however, confine himself to the employment of this number of rollers in each apparatus, as a greater or less number may be used, but he prefers this number generally, as most advantageous. These rollers are connected together by means of spur wheels, so that the surface velocities of the rollers acting immediately upon the metal passing between shall be equal, although the diameters of such rollers may be unequal or equal, as most convenient. Immediately in front of the first pair of these rollers B B are placed the pair of rollers C C^1, the centres of the shafts of these rollers being in a direction at or near right angles to those of the rollers B B, and therefore revolving at right angles to them. The peripheries of the rollers B B are all concave, the concavity of the first pair from the rollers C C^1 being greater than the concavity of the other pairs, and this concavity decreases in each pair of rollers until the last, in which the two concavities of the rollers form together a circle. The peripheries of the two rollers C C^1 are different from each other; that is, one of them, as C, is convex, and the other, C^1, is concave. The lower ends of the vertical shafts D D, carrying the rollers C C^1, revolve in steps, E^1, E^2, upon the bed-plate F, which thereby supports the weight of them and the rollers. The rollers are geered together by spur-wheels, and the requisite rotary motion is given to them and to the rollers B B by any well known and convenient means. G represents the plate or skelp of metal in the process of being bent and formed into a tube. The flat skelp is previously heated in a suitable furnace, and then passed through the machine, first between the convex and concave rollers C C^1, by which it is bent from its previous flat form, and assumes that of the peripheries of the rollers, being about semi-cylindrical, of considerably larger diameter or radius than that of the intended tube, and then passes on to the first pair of the horizontal rollers B B, by which the edges of the skelp become further bent round, and begin to approach each other, and this rounding gradually goes on in the passage between the remaining pairs of rollers. In passing between the second pair of rollers, the edges are caused to approach nearer together; the action of the third pair brings the edges into contact, and the last pair effects the closing or welding of the joint. When the whole formation of the tube is intended to be effected at one operation of the machine, it is necessary that the skelp should be at a welding heat when passed into the machine. Thus it will be seen, that at one operation of the machine, the flat plate or skelp will be bent up to the cylindrical form, the joint welded up, and the perfect tube produced at one heat of metal. This result, however, cannot always be obtained, as when very thin plates or skelps are used for the manufacture of tubes. In this case the metal cannot be retained at a welding heat sufficiently long to insure a perfect junction of the edges of the skelp at the last pair of rollers, therefore the skelp is bent up to the tubular form, and the edges brought together at the first operation, preparatory to the welding process, which the patentee then effects by passing it, at a welding heat, between the rollers of a second machine of similar construction to that previously described, but not having any rollers similar to these, C C^1. The rollers B B are sometimes arranged in vertical positions, instead of horizontal, as described; the rollers C C^1 will likewise be reversed in their position, but their action on the skelp and the result will be precisely the same as by the first arrangements.

The next improvement consists in the means of manufacturing taper tubes. The machinery employed for this purpose is the same as that previously described for manufacturing cylindrical tubes, except that one or more of the pairs of rollers employed, instead of having their grooves regular, and of equal size throughout the whole of their peripheries, are formed of varying sizes, either increasing or decreasing, according as the tube to be manufactured is required to be produced of increasing or decreasing diameter. One of the rollers is represented in section, Fig. 3668, which shows the form of the

3668.



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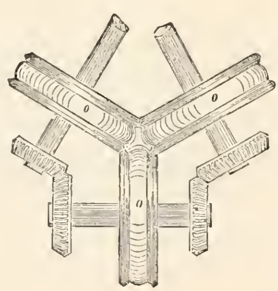


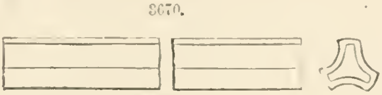
groove. It will be seen that proceeding from the cutter I^2, Fig. 3668, in one direction round the roller, the size of the groove is gradually increased until it arrives at the same point, which is the junction of the greatest and smallest portions of the groove; proceeding in the other direction from the same point the reverse obtains, the corresponding roller working with the one shown in section, both being grooved in a similar manner, so that when working together they present a circular passage of gradually varying diameter, and thereby produce a tube, the taper of which corresponds with the varying size of the grooves; the variation in the sizes of the grooves will of course depend upon the degree of taper the manufactured tube is required to have. The patentee sometimes employs taper plates or skelps of metal in the manufacture of taper tubes, by means of the above-described machinery; and when he requires to manufacture tubes with the interior cylindrical, and taper upon the exterior, he then employs skelps of metal of unequal thickness. The means adopted for forming and making the varying grooves in the rollers, so that they shall present a smooth surface, and also that their variations shall be perfectly regular and uniform throughout the circumference, is this:—It consists of a frame or head-stock H, Fig 3668, fitted in bearings, in the top of the uprights of which is mounted the shaft or mandril H^1, upon which is fixed the driving cone of pulleys or wheels, H^2, by which the requisite rotary motion is given to the mandril H: the mandril is hollow, and slotted upon opposite sides. A rod I passes into the hollow of the mandril from one end. The inner end of the rod is pointed or wedge shaped, and passes into, and bears against a corresponding recess in the end of the cutter I^1, which is of two or more parts, the cutting-edges of which pass through the slots in the sides of the mandril, and project beyond it

The rod I is caused to traverse along the mandril by means of the screw I², passing through a bracket fixed to the back of the upright carrying the open end of the mandril, the end of the screw bearing against the end of the slotting-rod I, so that as the screw is screwed up, it causes the cutter to expand by acting on the rod. The cutter is, of course, carried round with the mandril. A spur-pinion is fixed upon the screw I², by which a slow but regular rotary motion is given to it, by which the expansion of the cutter is effected at a regular and uniform rate. The rollers L L are mounted upon shafts in a carrying-frame, in position shown, the groove to be cut off, one being above and one beneath the cutter. A slow rotary motion is given to the rollers, both moving at equal velocities, at the same time that a rapid motion is given to the mandril and cutters; when the cutter is in the position shown in the drawings, the largest part of the groove required will be cut, because the largest part of the cutter is then in the plane passing through the two centres of the rollers; but as the cutting progresses, the size of the groove cut will gradually decrease, by reason of the cutter being caused to traverse along the mandril, when the small part of the cutter comes gradually into action, until the rollers have made one revolution, when the cutter will have traversed so far that only the small end of the cutter will be in action, in cutting the smallest part of the groove, where the junction with the largest part of it takes place. The degree of variation of the grooves cut in the peripheries of the rollers will depend upon the form and length of the cutter, and amount and rate of traverse given to it, in relation to that of the rollers upon their axis. In manufacturing other forms of tube, the patentee employs the cylindrical tubes in the manner before described, which are reheated and passed between rollers, the peripheries of which are of such a form as to cause the tubes to assume the exterior form desired. A pair of rollers, the forms or shapes of the peripheries of which are such as to compress the cylindrical tubes between them, and into the form of a hollow railway rail, are shown in Fig. 3671.

Fig. 3669 shows an arrangement of these rollers, O O O, placed triangularly, for compressing and rolling cylindrical tubes into hollow trilateral forms, suitable likewise for railway rails, the peripheries of the rollers being of such shapes as to produce the forms required.

Fig. 3670 shows the hollow trilateral rail produced, and rolled by the arrangement of rollers, as shown in Fig. 3669.

3670.



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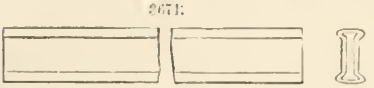

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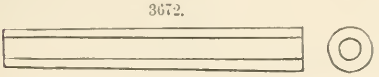
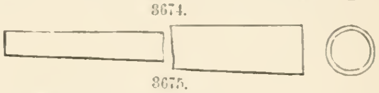


3673.

3674.



3675.

Fig. 3675 is another form of hollow trilateral rail, slightly differing from the preceding.

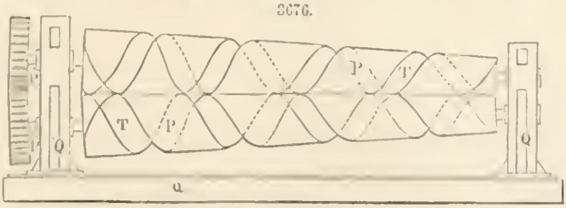
Fig. 3673 represents a cylindrical tube.

Fig. 3674 is a taper tube, the interior and exterior being of uniform taper, and of equal thickness of metal throughout.

Fig. 3672 represents a tube tapered exteriorly, and cylindrical interiorly, and of an equal thickness of metal. Mandrils may be employed or not in the above modes of manufacturing tubes, as convenient.

The next improvement relates to the manufacture of spiral or helical metal tubes. This improvement is illustrated in Fig. 3676, which represents an elevation of the apparatus. The apparatus con-

3676.



sists of a pair of rollers P P, mounted one above the other in the framing Q Q, the bearings in which the rollers revolve being in the uprights Q¹ Q¹ of the framing, and the mode of attachment to the bearings being such that the rollers may be removed or replaced with facility, as it is necessary to remove the rollers from the frame before the spiral or helical tubes can be removed from the rollers. These rollers are geered together at one end by the geering wheels P¹ P¹, so that they revolve in unison. The peripheries of the rollers are formed with spiral grooves T T, around which the direction of the spiral of one is in one direction, and that of the other is in another direction, so that as the rollers revolve, the grooves of one always coincide with the grooves of the other, and the two together form the exterior of the spiral tube, as is the case with grooved rollers generally. The grooves may be of any form so as to manufacture the spiral or helical tubes of any form of cross-section desired. Motion is given to the rollers by any convenient means. When a spiral tube is to be formed, the tube is previously manufactured cylindrical, or of other shape suitable for the purpose, and as the rollers P P revolve, one end of the tube is applied to the grooves in the rollers at or near the smaller ends of them, or the reverse, a catch being provided to secure it, and as the rollers revolve, the tube will be drawn between them, and coiled along the spiral grooves T T, thus forming the spiral tube required, and when the tube has been formed, the machinery is stopped and the rollers removed from their bearings, when the spiral tube may be drawn off. The rollers are then replaced in their bearings preparatory to another operation. The rollers may be formed with any required degree of taper, so as to manufacture tubes of corresponding forms, and the spiral grooves may be made so as to produce spiral tubes either regular or irregular in the pitch of the spirals, increasing or decreasing, as required. When it is required to manufacture helical tubes, the patentee employs cylindrical instead of taper rollers, and proceeds as before described, with respect to spiral tubes. By this improved machine the patentee is enabled to manufacture spiral or helical tubes, in which the direction of the spiral or helix shall be either right-handed or left-handed. This is effected simply by causing the straight tube to be coiled during the process, and wrapped around either one or the other of the two rollers, the grooves of one being right-handed, and the other left-handed, and therefore a correspondingly formed tube is produced.

TUNNELS. From an examination of James Hayward, Esq., C. E., before a Committee of the Massachusetts Legislature.

Mr. Hayward visited Europe and examined as many as thirty tunnels. The Marseilles Tunnel is located at Nerthe near Marseilles, is three miles (15,153 feet) long, and has twenty-four shafts. The material in this tunnel is a very hard limestone. The height of the ground over it is a little over 600 feet. The aggregate length of all the shafts is 7,589 feet; the deepest shaft is 610 feet. The cost per yard down, for excavation, was $43. The shafts are nine feet in diameter, and are lined with masonry, at a cost of $19 40 per yard down.

The deepest shaft cost $73 per yard down, entirely completed. The entire cost of all the shafts for the masonry amounted to $47,000; and $150,000 for the whole cost of the tunnel. The entire cost of the tunnel for the contractor was $125 for the lineal yard; this includes shafts. The tunnel was lined with masonry of different thicknesses, and cost $423,000. The entire cost of the tunnel, exclusive of masonry, was $705,000.

Woodhead Tunnel between Manchester and Sheffield, is a little over three miles long, and the hill over it 600 feet high. It has five shafts, 10 feet in diameter, which vary from 400 to 600 feet in depth. The character of the rock is granite, not so hard as our granite; it is called there "Mill-stone rock." The tunnel was about five years in construction, and its whole cost was $1,026,705.

There are various ways of ventilating the tunnel while the miners are at work, and it is easily done. It was supposed that the shafts would be necessary for ventilation in the Woodhead Tunnel, as the cars passed through it, but they are now closed. Mr. H. gave an explanation of the various modes that are adopted for ventilation. In the mines in Cornwall, there are excavations extending 30 miles under ground. There are tunnels in the Duke of Bridgewater's Canal, which make, in the aggregate, thirty miles. On the Thames and Medway Canal, there is a tunnel about two miles long. The shafts by which it was originally constructed, except one in the centre, are closed. The tunnel is used both for a railway and canal, and trains pass through it every half hour daily. Gen. Paisley, the superintendent of public works, passed nearly a day in the tunnel, and he says that the smoke and steam from the trains passed almost immediately away. There was a constant current of air through it.

The Box tunnel, on the Great Western Railway, about 100 miles from London, is the largest and most expensive tunnel ever constructed; it is 39 feet high, and over 30 feet wide. The shafts were 25 feet in diameter, its length is 9579 feet. Over one-third of it is through the solid rock.

Upingham Tunnel, 1320 feet in length, cost £25 per lineal yard. Pulpit Rock Tunnel, Pennsylvania, a difficult tunnel on the Reading Road, cost $66 20 per lineal foot. Gen. Barnard gave to Mr. Baldwin, in answer to some inquiries, the cost of five tunnels, the highest of which was $4 36 per cubic yard.

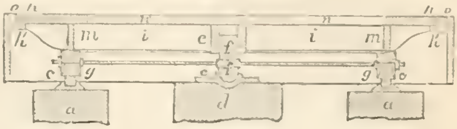
TURBINE. See Water Wheel.

TURN-TABLE. A contrivance on railroads by means of which the engine or cars may be turned round. This is effected by excavating a pit under a portion of the track, and laying in the bottom of this pit a circular track, upon which a platform, supported by friction-wheels, is made to revolve. A great many plans have been devised to effect this object. The following is the method of constructing the iron turning platform used in England.

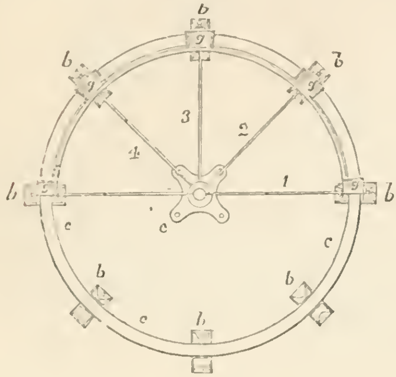
These tables are thus constructed: *o o*, Fig. 3680, is the surface of the ground whereon the rails of the railway are laid, a circular hole being dug of sufficient depth to receive the table; around this, large stone blocks *a a*, similar to the railway blocks, are placed; upon these blocks eight cast-iron chairs, represented at *b b b*, &c., Fig. 3681, are placed, and pinned down; a circular ring of cast-iron *c c* is laid within these chairs, about two inches and a half broad at top, and a little bevelled; this ring is laid perfectly horizontal, and upon it the small bevelled rollers *g g g*, &c., revolve, the arms 1, 2, 3, 4 acting as axles to them, and around the ends of which they turn freely. These arms pass through a ring of iron near the extremity, which keeps the rollers constantly in their proper position; the arms are fastened in the centre to a ring of iron *f*, which turns freely round the spindle *f′*, Fig. 3680. The turn-table rests upon these rollers, which are for the purpose of causing it to turn round as freely as possible. Fig. 3682 shows the framework of the table; *h h h*, &c, are the outer rim; *i i i* the arms; and *m m* the inner rim, which is of the same diameter as the ring of iron *c c c*, and which rests on, and turns round upon, the periphery of the rollers *g g g*. The table is kept in its place by the vertical spindle *f′* fixed upon the table at *e*, and turning with it upon the rest *c′*.

The table, it will therefore be seen, turns round this rest as a centre, and revolving upon the periphery of the rollers, it moves round with very little friction. It is not intended that the spindle *f′* should support any part of the weight of the table, the use of it being solely to prevent any side motion. The outer ring *h* of the table projects above the level of the arms *i i* and the inner part of the ring *h′ h′*. Within this outer ring a platform of timber is laid, resting upon and fastened to the arms *k k*, the bolt holes being shown in the figure; upon this platform the rails of the road are placed *n n*. Fig. 3680 shows the timber, the upper side of which is level with the top of the outer ring *h h*. A circular ring *o o* of cast-iron, or of mason-work, is laid around the outer circle of the table, upon which the rails rest and which abut against the ends of the rails laid upon the turn-table.

3680.



3681.



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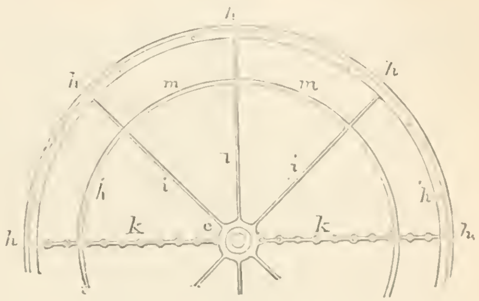
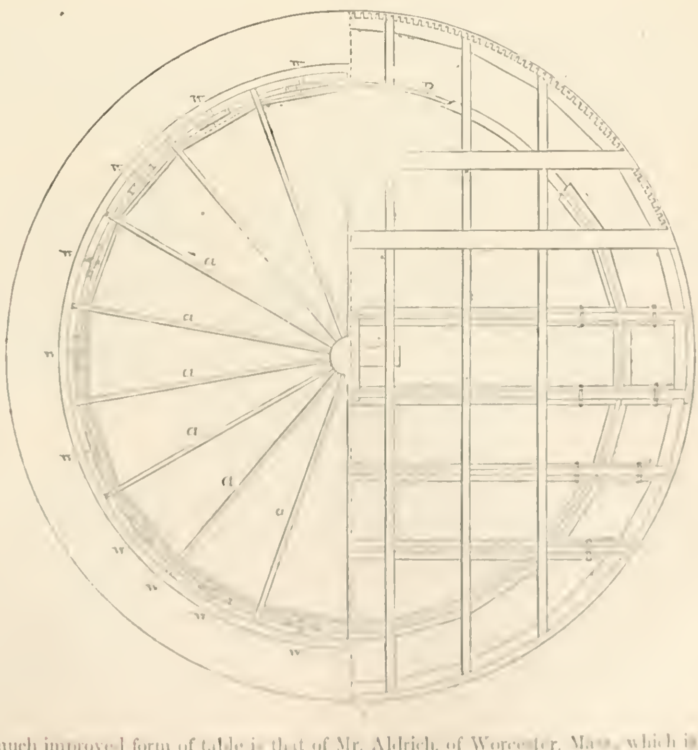


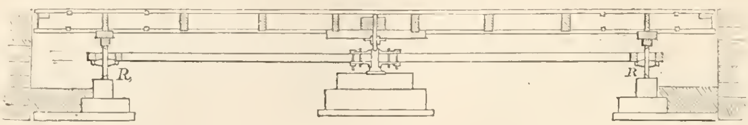
We have said that the top of the turn-table is covered with timber, on which the rails forming the railway is laid; in many cases the top is formed of cast-iron, the rails being raised a little above the surface of the cast-iron plate.

3683.



A very much improved form of table is that of Mr. Aldrich, of Worcester, Mass., which is extensively used in New England, sometimes as large as 18 feet in diameter. A plan and section is shown in Figs. 3683 and 3684. It will be seen that in this table the wheels are fixed to a framing independently of the table; in fact, the principle being the same in many respects as the one above described, the number of friction-rollers is however much greater, and on the whole the arrangement is superior to the English tables. This wheel is turned by means of a pinion working into the toothed segment shown in plan Fig. 3683. These tables are of wood, and were originally patented. The arrangement is shown in the figures so clearly as to require no further description.

3684.



TWISTING MACHINE FOR IRON—Melling's. The great advantages of obtaining perfect homogeneity of matter in metal surfaces over which heavy loads are passed, either with an abrading or rolling movement, is obvious; and by a very simple process a vast increase in permanency may be conferred upon articles of this class as well as upon various others, as axles, shafts, connecting-rods, and piston-rods. In shafts, for instance, where the mass is built up out of a series of bars, flaws are of frequent occurrence, through imperfect welds; and where the weld is good, a deficiency in strength and durability is generally the resulting effect of the parallelism of the fibre.

To overcome this practical mechanical difficulty, Mr. Melling, of the Rainhill Iron Works, Liverpool, has proposed to twist together the bundles of constituent bars which go to form a shaft, or other forging of large size, and for this end he has devised and introduced the machine which forms the subject of our figures. This machine has now been in operation for a considerable period; it is not, therefore, held up simply as a novelty, but as a valuable workshop accessory.

Fig. 3685 is a complete longitudinal elevation of the machine in working order, having the front heavy driving geering removed to avoid obscuring the twisting details. In the same view are also shown the carriages on which the bars under treatment are conveyed to and from the machine.

Fig. 3686 is a corresponding plan, partly in section, showing the driving geering. In this view a bar is represented as in the act of passing through the twisting rollers.

Fig. 3687 is an end view, looking upon the delivering rollers.

3685.

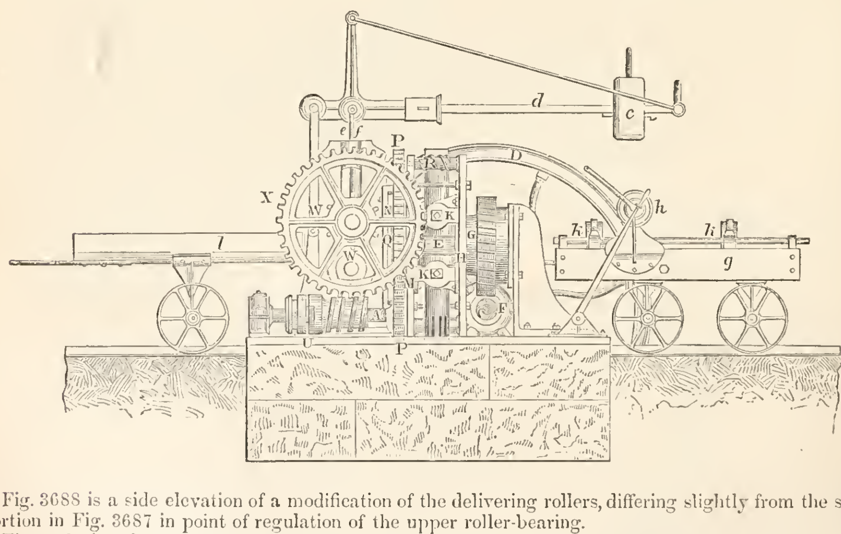


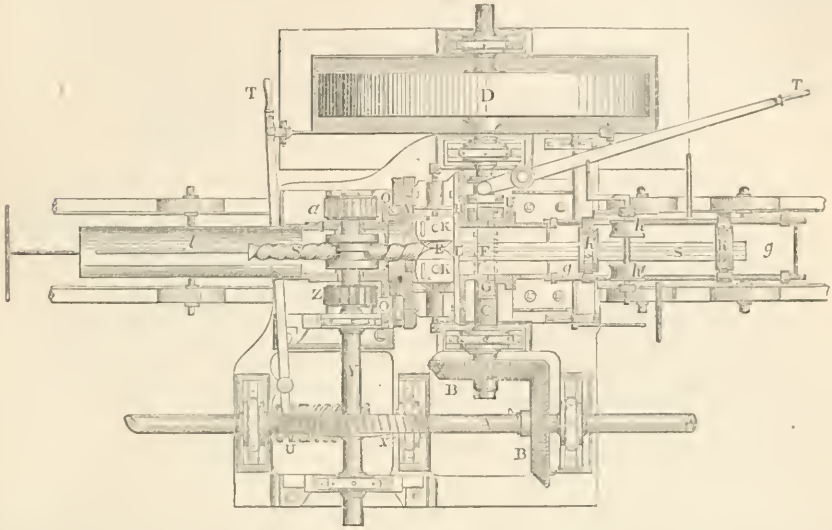
Fig. 3688 is a side elevation of a modification of the delivering rollers, differing slightly from the same portion in Fig. 3687 in point of regulation of the upper roller-bearing.

Fig. 3689 is a front elevation of the first or revolving set of rollers, exhibiting the actuating mechanism whence the revolving movement round the axis of the twisting bar is obtained.

Figs. 3690, 3691, 3692, 3693, 3694, and 3695 represent various kinds of work, as finished from the original pile of bars.

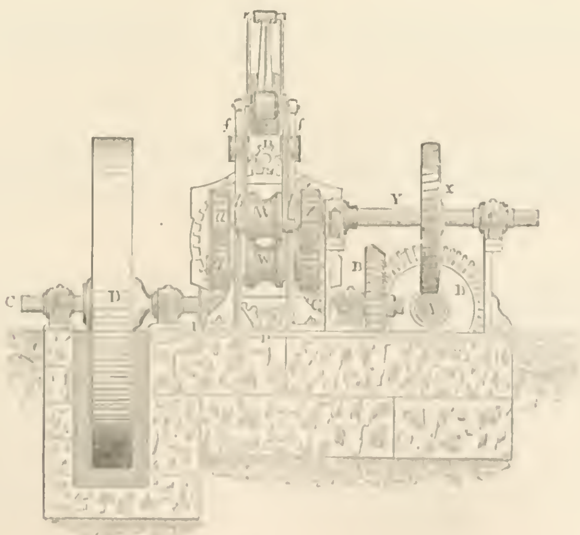
The machine stands upon a massive foundation of masonry, to the surface of which the cast-iron bed-plate is bolted. The driving power is communicated to the shaft A, from which motion is communicated through the pair of wheels B B to the transverse shaft C C, passing right across the machine, and having a heavy fly-wheel D at its opposite end. From this shaft the first pair of rollers E E, from their peculiar movement distinguished as the *revolving rollers*, are worked by the worm F, which geers with the large worm-wheel G, cast in one piece with the back of the plate H, and bored out at the back to work upon a fixed carrier bolted to an upright bracket fixed to the back part of the bed-plate. The shafts T T carrying these rollers are supported in four bearings K K, fitted into a pair of transverse cheeks L L, bolted and keyed between the two plates H M. The latter is supported by a corresponding plate N, into which is fitted a turned ring cast on the front of the plate M, and this plate N is again bolted to flanges O O on the upright cheeks of the delivering rollers. It is easy to see how by this arrangement the revolution of the main shaft C communicates a revolving movement to the frame-work carrying the rollers E E; but in addition to this movement they revolve also round their own axes, and this is obtained by means of the two plates H and M, which carry round with them two small spur-pinions P P, geering with the fixed toothed rim Q. This motion is then transmitted from these pinions to the rollers, through the two worms R R upon their shafts, to the two worm-wheels cut upon the roller-shafts.

3686.



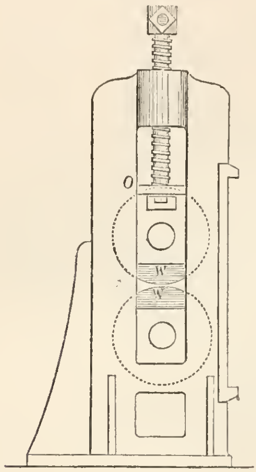
In the plan, Fig. 3686, the machine is shown as thrown out of geer with the driving-shaft, whilst a bar S S is passing through. This disengagement is effected by the two lever-handles T T acting each one upon a clutch-box, corresponding with similar clutches on the worms v and v, the latter being that through which motion is communicated to the front delivering rollers, which latter may be thrown in or out of geer by the attendant, when on the opposite side of the machine, by means of a short handle at v.

3687.

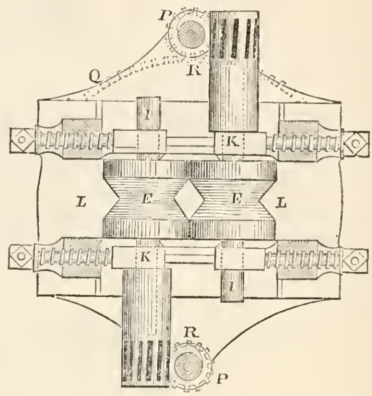


The lower of the two delivering rollers W W, which simply revolve round their own axes, receives its motion from the main shaft, through the worm geering with the worm wheel X on the second transverse shaft Y, carrying a pinion Z geering with a similar one on the lower roller-shaft. The object in giving motion to the lower roller first being to admit of the raising and lowering of the upper one a may be required to suit the work, the upper being driven from the lower one by the pair of pinions *a a* on the opposite side of the roller-standards *b b*. In the combined views of the machine, the pressure upon the upper delivering roller is represented as obtained from the weight *c*, adjustable on the long lever *d* having its fulcrum at *e*, and pressing upon the journals of the upper roller by the two spindles *f f*. Crane-power may be applied to raise or lower this weighted lever, by attaching a chain to either of the two loops formed for the purpose, both on the weight and on the lever. In Fig. 3685 the office of this weighted lever is represented as supplied by a pair of adjusting screws pressing upon the upper roller-bearings.

3688.

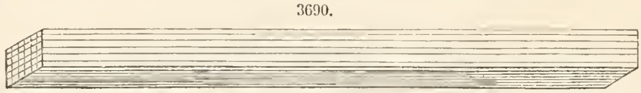


3689.

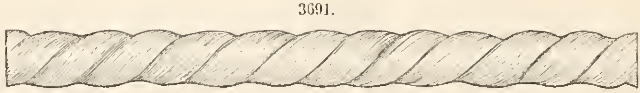


The bars to be operated upon are brought from the furnace in the carriage *g g*, running upon four wheels on a tramway. The body of this carriage carries two brackets supporting a cross-shaft, on which are two pulleys *h h*, employed for the withdrawal of the bars from the furnace. The pulley-shaft is worked by a short winch-handle, as in Fig. 3686, and the ends of the two chains, coiled on the pulleys, are attached to a box which is slipped over the bar whilst in the furnace. Guides are attached to the carriage at *k k* for the support of the bar or pile of bars to be twisted; and to admit of their free revolution they are turned on the outside and fitted into the cast-iron rings, bored to correspond. These

3690.



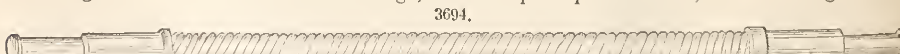
3691.



3692.

bearing-rings are put together in halves, and are carried upon a pair of parallel longitudinal rods connected with the body of the carriage, or they may be simply suspended from a crane. The carriage for receiving the twisted bar, as delivered from the machine, is at *l* on the opposite or delivering end. It is nothing more than a semicircular iron trough, mounted upon a pair of wheels, with a drawing handle.

3694.



3695.

The bar or pile of bars being entered between the revolving rollers, and passed through until the end reaches the delivering pair, the upper one of this latter pair is pressed hard down upon it, so as to prevent it from turning. Being thus firmly held at this end whilst the after portion is carried round by the revolvers, it is clear that a twist must take place, and so the simultaneous revolutions of each pair upon their own axes carry forward the bar; it is preserved perfectly straight, and an even and regular twist is given to it. Fig. 3690 is the original pile of rectangular bars; fig. 3691 represents these bars as twisted together previous to the subsequent finish under the hammer. In fig. 3692 the twisted metal is shown under the form of a double-T rail. 3693 is an axle formed out of round bars twisted together, and welded only at each end for the wheels and journals; and fig. 3694 is a tire-bar exhibiting the striated texture, as in fig. 3692.

TYPE FOUNDING. There are two kinds of fonts which are used respectively for book printing and job printing, the latter including such work as hand and posting bills, etc. Book types include eleven or twelve regular bodies, from Great Primer, which is the largest, to Diamond, which is the smallest type used for printing books. The following are specimens of book types:

Great Primer,
English,
Pica,
Small Pica,

Long Primer,
Bourgeois,
Brevier,
Minion,
Nonpariel,
Pearl,
Diamond.

Each of the above fonts of type consist of five alphabets, viz.: A, ᴀ, a, *A*, *a*, together with many other characters, about 200 in all, and these must all be exactly alike, except in device and width. The greatest width is for the W and M, and the least for the i and !.

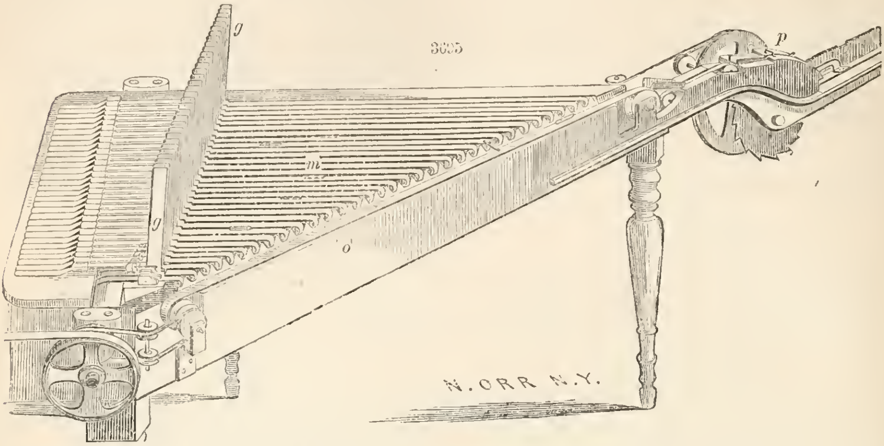
Every one of these numerous characters requires for its formation a punch, a matrix, a mould, and type metal in a fused state. The punch is a piece of steel with a single letter at one end. It is formed by hammering down the hollows and filing up the edges of the metal in a softened state. Each letter must harmonize with all the others in the font with regard to height, breadth of stroke whether heavy or fine.

The matrix is a small piece of copper about $1\frac{1}{4}$ inch long, $\frac{1}{4}$ inch deep, and wide in proportion to the size of the type: into this the hardened punch is struck. This must be managed with care, so as to allow the faces of the types, when composed or set up, to be in a perfect plane. Hence the depth of the impression in the matrix is of great importance, and it is usual to adjust this depth by filing down the surface of the copper. The matrix having thus received a sunken impression from the raised letter on the punch, all that is required is to pour a quantity of fluid metal into the matrix in order to reproduce the letter as it is engraven on the punch. But in addition to this the cast letter will require a support, or body, an appropriate width, and certain nicks or notches, which enable the compositor to place the letter in the proper position in his composing-stick without having to examine every letter by eye. The measure of the type with regard to height, width, and body, is determined by the type mould. The mould is made in two parts, so contrived that on being put together, the two halves form in the centre a space or mould, in which the type is formed: the matrix is placed at the bottom of the mould, and is retained in its place by a spring. By sliding one part upon the other, the square cavity in the centre, while retaining the same height, would have its width diminished to any extent required. The extent to which the two parts of the mould slide upon each other is determined by the width of the matrix. The metal is poured in at the orifice formed by closing the upper parts.

These details being understood, a few words will suffice to explain the operation of casting. The caster stands by the side of a furnace containing the melting-pot and the fused type-metal (see METALS AND ALLOYS). He holds the mould in his left hand, and taking up a portion of the metal, in a very small ladle, held in the right, he pours a sufficient quantity of it into the mould, and immediately jerks it up for the purpose of expelling the air from the cavity and driving the metal into the finest strokes of the matrix. Then, by means of one finger, he releases the spring, separates the mould, and hooks out the letter. The small and the large sizes require more time: the former, on account of the increased care, and the latter, to allow the metal to set.

The types are removed from the caster's table by a boy, who, seizing the type by the edges, breaks or bends off the superfluous metal at the bottom; he then conveys them to a man seated at a table, who, with his finger protected by a piece of tarred leather, rubs the side of every letter on a slab of gritty stone for the purpose of removing knobs or globules. The letters are next set up by a boy, in lines, in a long stick, or shallow frame, with the face uppermost, and the nicks outwards. With the assistance of other frames, a man called the dresser polishes the types on each edge, and turning them with the face downwards, planes the bottom, and planes the groove which brings the types to the required height, and enables them to stand steadily; the letters are carefully inspected with a lens, and the font being proportioned, i. e. the proper proportion of each letter, together with the spaces, quadrats, etc., being counted out, each letter, &c., is tied up in lines of convenient length for the printer.

TYPE SETTING MACHINE, or COMPOSING APPARATUS. For a series of years it has been attempted to supersede manual labor in composing by machinery. The most successful thus far is the invention of William H. Mitchel, of Brooklyn, which has now been for some two or three years in practical operation, in John F. Trow's establishment. Fig. 3695 represents a perspective view of the machine: *g g* are conductors placed in a range, and each conductor allowed to a particular letter or character, and a range of finger keys marked with corresponding character are so arranged that upon striking one of said keys, the bottom type in the conductor with which it is connected, drops on to a corresponding endless belt *m*, of a series of belts of successively increasing length, or speed, towards the delivering or composing part of the machine, which belt delivers the types on to a diagonal belt *e*, in such manner, that they reach the composing wheel *p* in the order in which the keys are struck. The types are delivered upon the composing wheel by an inclined conductor. The composing wheel delivers the type in an upright position to the composing slide, from which they are taken and justified by the workman.



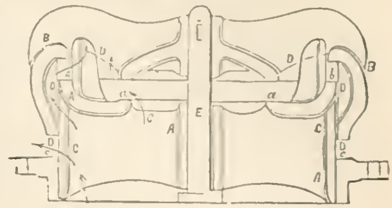
TYPE DISTRIBUTOR. Mr. Mitchel has also invented a simple and efficient distributing machine, of which the following is his description.

"Before the types are made use of or composed, each letter of the font is prepared, by cutting or otherwise forming (as the assorted letters are set up in line) one or more grooves or notches in the body of the type at a certain distance or distances from its bottom or lower end, each respective character having its notch or notches differently located relatively to the lower end of the body from those of any other varieties of letters or types, and around the edge of the wheel pins are inserted near the bottom of each groove therein, which pins, by the notches before mentioned, sustain the types in different positions, according to the position of the notch or notches in the types; hence, as said types are carried along on said pins, each respective letter is dropped into a groove or receptacle provided for it when it arrives opposite to said receptacle, by its lower end taking an off-set or incline, which removes the type from its pin; or any suitable means may be made use of to deposit the type in the receptacle adapted to its peculiar position on the revolving wheel; and by a peculiar arrangement of double notches, a very great number of separate characters of types may be distributed to their respective receptacles by a very simple arrangement of inclines and off-sets. The lines of types in the receptacles or grooves are successively pushed along to give room for the succeeding types, and a stop motion is used, by which any misplaced type arrests the rotation of the machine.

TYPE DISTRIBUTING MACHINE, *Beaumont's Patent.* This machine is automatic and distributes with perfect accuracy every thing but two-em and three-em quadrats, without any attendance except to supply the matter at short intervals. The types are carefully picked apart and are left standing in lines suitable for a type-setting machine, or tumbled unceremoniously into boxes, as may be desired, the latter being easier as requiring less labor and care in their removal by the attendants. The principle on which the machine is able to discriminate and put each type in its appropriate place, is that of feeling, not the face, but the sides of the body. Each type is prepared expressly for the purpose by cutting three nicks on its edges, differently arranged for each letter. The letter *a*, for example, is manufactured with three nicks, called one, two and three, counting from the highest; *c* has one, two and four; *b* has two, three and five, etc. The channel leading to each box is provided with a mouth of the same form, carefully executed in hardened steel to withstand the wear, and the lines of type are pressed up successively against all these channels until the right one is presented, when the first type in the line pops in, leaving the next to commence a similar round. The receiving channels are arranged in a circle, faces inward, and the lines of type to be distributed are ranged radially in a horizontal wheel of somewhat less diameter. This wheel is properly geared and rolls around within the enclosure, presenting each type rapidly, but gently, to every aperture. The lines are thrust outward in the wheel by suitable springs, which are simultaneously compressed by a simple movement when it is desired to supply more matter. In working out the details of this machine the most beautiful simplicity has been arrived at, and every type is seized, on entering its proper channel, by a spring lever of sufficient force to tear it from its fellows, however adhesive may be its alkaline and inky bond. A similar lever guards the exit of each type from the wheel, and the hold is slackened only during the instant it presses fairly against the steel mouth of a channel for its reception. Thirty lines are received at once in the wheel, and the machine has been for several months in operation without appearing to wear, or otherwise injure the sides of the type. The nicks cause a slight annoyance by catching the rule in setting, but this evil will probably be overcome by practice. Each machine will distribute but one size of type; but the inventor states that they may be so constructed as to be easily adapted to the different sizes of small type. If worked by hand, one man or boy can distribute 12,000 ems per hour, and with scarcely a possibility of an error of a single type; whereas by the usual process of hand distribution, 3,000 ems are about the average. The machines can be worked by steam, and one man can then attend to three of them, making the total distribution in one hour 36,000 ems.

URANIUM. A metal discovered by Klaproth in 1789. The oxides of uranium are used in painting upon porcelain, yielding a fine orange color in the enamelling fire, and a black one in that in which the porcelain itself is baked.

3696.

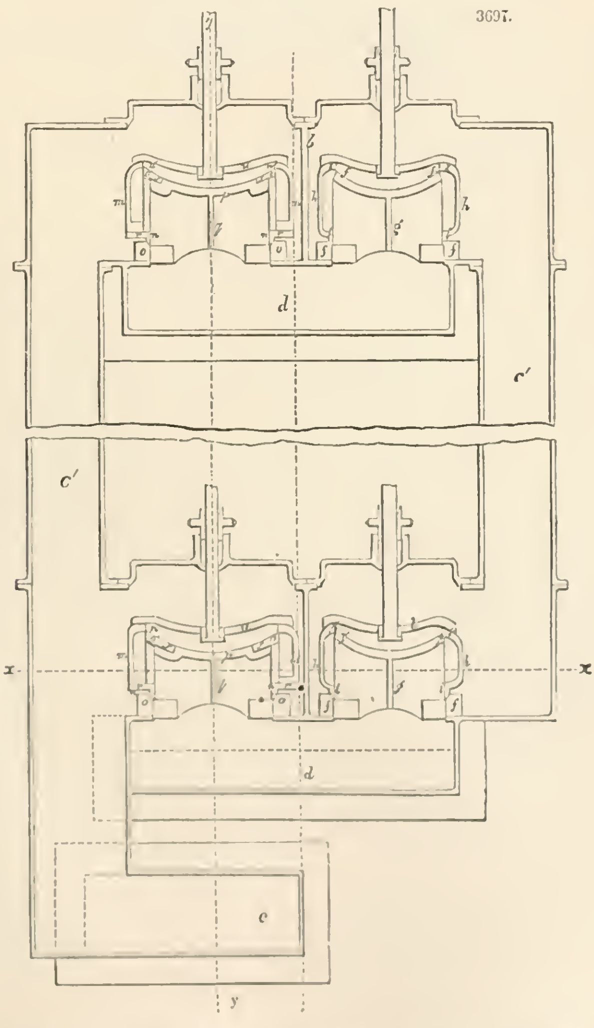


VALVES. (See ENGINES, VARIETIES AND DETAILS OF.)

Carnell and Hosking's Treble Beat Hydraulic Valves. A is the valve seat; B, the valve; C C, the passages through the seat, and D D, passages through and around the valve; E is the guard or stop to prevent the valve from being thrown out of its seat by any sudden or unusual action of the engine. In fig. 3696 the valve is shown in its open position, and the arrows indicate the course taken by the water in passing through it; *a a*, *b b*, *c c*, are the seats or bearing surfaces. The most prominent advantage offered by these valves, is the larger opening for the passage of the water than is afforded by the valves of the forms hitherto in use, while at the same time the lift is reduced, and consequently the concussion very considerably lessened.

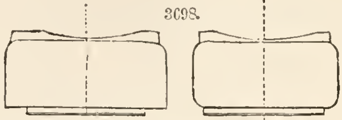
VALVES, BALANCED—STEVENS' *Improvements*, 1851. The patentee's object is a convenient adaptation to the double-acting steam-engines of balanced valves, commonly known as the Cornish double-beat valves. For the balanced spindle valve, as commonly constructed, is liable to two objec-

3697.



tions: in the first place, the valve being formed by two disks connected by a spindle, the force of the steam acting against the disks in opposite directions puts a great strain on the spindle, so that should it be slightly eccentric, the valve will be sprung from the seat and will leak; and in the second place, the difference of expansion between the valve spindle, which is completely surrounded by steam, and the steam-chests holding the valves, which is on the outside, exposed to the atmosphere, will also cause the valves to leak. The valves commonly known as the Cornish double-beat valves are obviously superior in principle to the spindle valves just described, and having been invented nearly a century ago, and been in constant use ever since, it may be presumed that their general introduction in the double-acting steam-engine, where balanced valves are used, has been prevented or retarded by the difficulties presented for their adaptation to that purpose. These difficulties might be of the space occupied, or of the expense, or of such an adaptation as would alter but little the arrangements of the existing parts of the engine. The object is to endeavor to arrange these valves in such manner that

3698.



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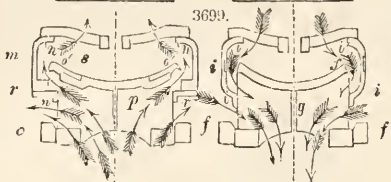
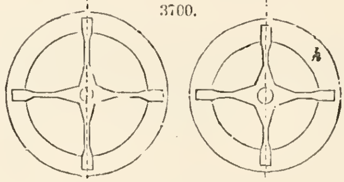
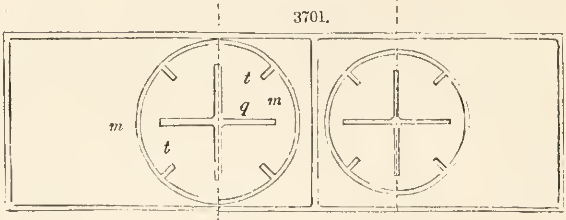


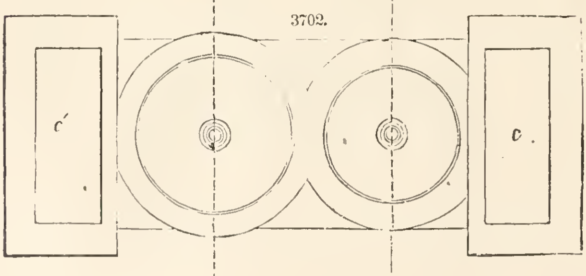
3700.



3701.



3702.



the advantages gained by their superiority in principle may not be so counterbalanced by the difficulties above named, as to prevent their general introduction. To effect this, the valves are arranged on the same level, as this is the arrangement most generally adopted in engines having balanced valves; and for the same purpose certain peculiarities are introduced in the construction of the valve, that render it different from any hitherto in use.

Fig. 3698 represents a side view of one of each of the steam and exhaust valves; the steam-valve being the Cornish valve, and the exhaust-valve having Stevens' improvement.

Fig. 3699 represents a vertical section of the same valves both raised off their seats, which are also shown in section.

Fig. 3700 represents a horizontal view of the same valves.

Fig 3697 represents a vertical section of the side-pipes, steam-chests, valves, and valve-seats.

Fig. 3701 represents a horizontal cross-section of the lower steam-chest valves and valve-seats, taken through the dotted line *x x* of Fig. 3697.

Fig. 3702 represents a horizontal view of the lower steam-chest.

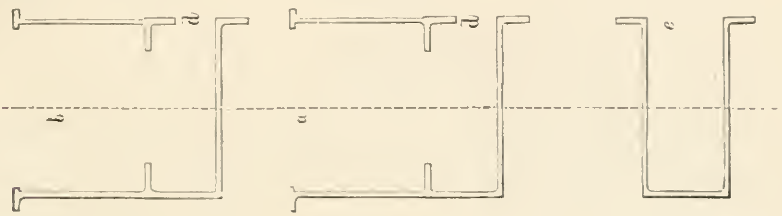
Fig. 3703 represents a vertical section of the side-pipes, taken through the dotted line *y y* of Fig. 4082.

In the drawings, *a* is the lower steam-chest; *b* is the upper steam-chest; *c* and *c* are the side-pipes, leading respectively to the boiler and condenser; *d* and *d* are the openings from the side-pipes into the cylinder nozzles; *e* is the opening into the condenser.

h h represents the two steam-valves, differing but little, if any, from the Cornish valve; *m* and *m* represents the two exhaust-valves, showing the alterations made to adapt them to the position in which they are placed relatively to the steam-passages. In the first place we will describe the different parts of the Cornish valve.

f and *f* are respectively the lower and upper seats, the upper seat being formed on the circumference of a disk supported by a cross; *g g*, cast in the centre of the ring, forming the lower seat; the valve *h* is formed by a hollow cylinder, the lower part of which being turned in, as shown, forms the valve-face *i*; that rests on the seat *f*, and the upper part also turned in, forms the valve-face *i*; that rests on the seat *f*; *k k* are ribs cast on the inside of the valve to guide it; *l* is a cross by which the valve is lifted by the valve-stem.

3703.



The steam-valve *h*, thus drawn and described, does not differ materially, if in any respect, from a Cornish double-beat valve; and we have been thus particular in describing it in order to explain the manner in which to alter it, the alteration constituting the material part of the invention.

It will be observed by a reference to the drawings that the position of the exhaust-valve with respect to the steam-passages, and also with regard to the direction in which it is opened, is such that if it were made similar to the valve just described, the pressure of the steam would force it from its seat. It is necessary, therefore, in order that the valve shall be retained on its seat by the pressure of the steam, that the seat formed on the disk supported by the ribs shall be larger in diameter than the seat that forms the circular opening through which the steam passes. In order to effect this, a ring is attached to the valve, forming the bearing for the smaller seat, this ring being smaller in diameter than the disk; there is also a ring attached to this disk, forming the larger seat. We are thus enabled to put the valve together by slipping the smaller ring over the disk, and then by attaching the larger ring to the disk, and finally by slipping the valve over the disk and attaching it to the smaller ring.

The faces of this valve having respectively the smaller and larger diameter are represented respectively by *n* and *n*, resting on the seats *o* and *o'*; *p* is the disk supported by the cross *q*. The valve is formed in two pieces by bolting it to the ring *r*, on the edge of which the smaller valve-face *n* is shown; the disk is also formed into two pieces, by bolting to the disk *p* the ring *s*, on the edge of which the larger valve-seat *o'* is shown. To put the valve in its place, the ring *r* must be slipped over the disk *p*, then the ring *s* must be bolted to the disk *p*, and finally the remainder of the valve must be slipped over the disk *p* and ring *s*, and bolted to the ring *r*; *u* is a cross by which the valve is lifted by the valve-stem, *t t* are ribs to guide the valve. From the position in which this valve *m* is shown in reference to the steam-passages, it will be seen that when the valve is closed the pressure of steam will be below the valve, and the vacuum will be above the valve; it will also be seen from the construction of the valve that it will be held down on its seat by the pressure of the steam acting from below.

VELOCIMETER. An apparatus for measuring the rate of speed of machinery. When the velocity is uniform, the instrument is merely a measurer of distance; but this is not the case with a variable velocity, which requires a much more elaborate contrivance for its estimation. Such a velocity measurer was constructed by Breguet, of Paris, under the direction of M. Morin, the principle of which may be briefly explained as follows: A circular disc, covered with card or paper, is made to revolve with an uniform motion by means of clock-work, regulated by air-vanes; upon this disc a revolving pencil, whose motion is caused by and corresponds with that of the body whose variable velocity is to be measured, describes a curved line; and from this curve, which results from a combination of the variable with the uniform motion, the velocity may be easily ascertained by processes and formulæ adapted to the purpose.

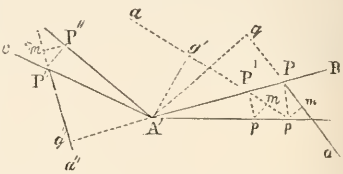
VELOCITY, VIRTUAL. Virtual velocity, in mechanics, is the velocity which a body in equilibrium would actually acquire during the first instant of its motion in case of the equilibrium being disturbed.

The general principles on which the laws of equilibrium in machines are established may be reduced to three; namely, the principle of the *lever*, the principle of the *composition of forces*, and the principle of *virtual velocities*. The last consists in this, that forces are in equilibrium when they are in the inverse ratio of the virtual velocities of the points to which they are applied, estimated in the direction in which they respectively act. Thus, let F and F′ be two forces applied to the points p and p' of a body which is in equilibrium between their joint actions, and let s and s' be the spaces which the points p and p' would describe in the first instant of time, in case of the equilibrium being disturbed; then $F : F' :: s' : s$, or $F s = F' s'$. The principle is thus enunciated generally by Lagrange, (*Méc. Analytique*, p. 22:)

"If any system of bodies or material points, urged each by any forces whatever, be in equilibrium, and there be given to the system any small motion, by virtue of which each point describes an infinitely small space, which space will represent the virtual velocity of the point; then the sum of the forces, multiplied each by the space which the point to which it is applied describes in the direction of that force, will be always equal to zero or nothing, regarding as positive the small spaces described in the direction of the forces, and as negative those described in the opposite direction."

In order to illustrate this principle we may take as an example the case of the bent lever, Fig. 3700. Let P P′ P″ be the points of application of the three forces F F′ F″, acting on the lever B A C, in the directions P Q, P′ Q′, P″ Q″, which are all supposed to be comprised in the same plane. Suppose the lever to describe an infinitely small angle about the fulcrum A, so that the points P P′ P″ come into the positions $p\, p'\, p''$. According to the definition given above, the infinitely small arcs $P p$, $P' p'$, $P'' p''$, which may be considered as straight lines, will be the virtual velocities of the points of application P P′ P″, of the three forces F F′ F″. From the points $p\, p'\, p''$ let there be drawn $p\, m$, $p'\, m'$, $p''\, m''$, respectively perpendicular to the lines P Q, P′ Q′, P″ Q″; then $P\, m$ will be the virtual velocity of the point P reduced to the direction P Q of the force F, and $P'\, m'$, $P''\, m''$ will in like manner represent the virtual velocities of the points P′ and P″ reduced to the directions in which the forces F′ and F″ respectively act. Let $P\, m = s$, $P'\, m' = s'$, and $P''\, m'' = s''$; and as the force F acting in the direction P Q tends to turn the lever in the direction in which the motion has been supposed to take place, while F′ and F″ tend to turn it in the contrary direction, the space s must be regarded as positive, and s' and s'' as negative.

3700.



Now, according to the principle of virtual velocities the sum of the given forces, each multiplied by the velocity of its point of application reduced to the direction of that force, is zero in the case of equilibrium; and, reciprocally, when this sum is zero the system is in equilibrium; hence the equation of the equilibrium of the lever is

$$F s + F' s' + F'' s'' = 0.$$

It is easy to verify this equation by showing that it may be derived from the equation of equilibrium deduced from the principle of the lever. From A let $A\, q$, $A\, q'$, $A\, q''$, be drawn respectively perpendicular to the directions P Q, P′ Q′, P″ Q″, and let the angle $P A p = \theta$; then, since the angle $A P p$ may be regarded as a right angle, $m\, P p = P A q$; whence the two triangles $m\, P\, p$, $q\, A\, P$, are similar, and $m\, P : A\, q :: P p : P A :: \tan.\ \theta : 1$; therefore $m\, P = A\, q \tan.\ \theta$, that is, $s = A\, q \tan.\ \theta$. In like manner we have $s' = A\, q' \tan.\ \theta$, $s'' = A\, q'' \tan.\ \theta$; whence, by substituting in the above equation, and leaving out the common multiplier $\tan.\ \theta$, we find

$$F \cdot A\, q + F' \cdot A\, q' + F'' \cdot A\, q'' = 0,$$

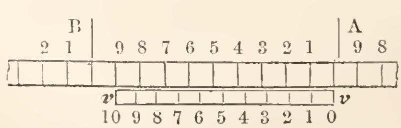
which is the well-known equation of equilibrium.

The equation $F s + F' s' + F'' s'' = 0$ may be extended to a solid body of any form, or to any machine whatever. Let $d\, m$ be an element of the body, F an accelerating force applied to $d\, m$, v the velocity of that element, z the angle comprised between the direction of the force F and that in which the element $d\, m$ moves; then the moving force of the element will be $F\, d\, m$, and $v \cos.\ z$, its velocity estimated in the direction of this force; and consequently, by the principle of virtual velocities, the equation of equilibrium will be $\int F\, v \cos.\ z\, d\, m = 0$.

The principle of virtual velocities is easily verified by experiment with respect to all the simple machines; namely, the lever, the pulley, the wheel and axle, the inclined plane, and the screw. Its importance as a fundamental principle in rational mechanics was first recognized by John Bernoulli, (see the *Nouvelle Mecanique* of Varignon, tom. ii.;) and Lagrange has derived from it the whole theories of statics and dynamics in his celebrated work, the *Mecanique Analytique*. Fourier (*Journal de l' Ecole Polytechnique*, cahier v.) has demonstrated the principle from the property of the lever.

VENTILATION. See Warming.

VERNIER. A contrivance for measuring intervals between the divisions of graduated scales or circular instruments. The name is given from that of the inventor, Peter Vernier, who published an account of the contrivance in a work printed at Brussels in 1631. It consists of a small movable scale, which slides along the graduated scale; the divisions on the one scale being to those on the other in the proportion of two numbers which differ from each other by unity. The theory of the instrument, and the manner in which it is used, may be explained as follows:

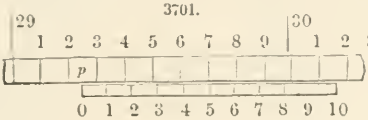


Let $A B = a$ be a distance on the scale containing n of its divisions. Let $v\, v$ be another scale equal in length to $n - 1$ of the divisions on A B; and let $v\, v$ be divided into n equal parts. Since the distance

A B $= a$, and contains n equal parts, each division on the scale $= \frac{a}{n}$. Hence the length of the vernier $v\,v = a - \frac{a}{n}$; and, as it is divided into n equal parts, each division on the vernier $= \frac{1}{n}\left(a - \frac{a}{n}\right) = \frac{a}{n} - \frac{a}{n^2}$; and therefore the difference between a division on the scale and one on the vernier $= \frac{a}{n^2}$. Suppose the zero of the vernier to coincide with the division marked A on the scale; then the first division on the vernier will not coincide with the first after A on the scale, but fall behind it by a quantity equal to their difference, or equal to $\frac{a}{n^2}$. In like manner, the next line on the vernier will fall behind the next on the scale by a quantity equal to twice the difference of the divisions, or equal to $\frac{2\,a}{n^2}$. The third on the vernier will fall behind the third on the scale by $\frac{3\,a}{n^2}$; and so on to the nth division on the vernier, which will fall behind the nth on the scale by $\frac{n\,a}{n^2} = \frac{a}{n}$, that is, by a whole division; and therefore the nth on the vernier coincides with the division $n - 1$ on the scale. Conceive the scale to be a scale of inches, and suppose it divided into tenths; then $a = 1$ inch, $n = 10$, $\frac{a}{n} = \frac{1}{10}$ of an in., and $\frac{a}{n^2}$ (the difference between a division on the scale and on the vernier) $= \frac{1}{100}$; so that the $\frac{1}{100}$th of an inch is exhibited on the scale, though its divisions are only to tenths.

The vernier is connected with the scale in such a way that it can be moved along it by means of a rack and pinion, or a tangent-screw, or some similar contrivance, and its zero be brought to coincide with any point on the scale. If, when the vernier is thus adjusted, its zero coincides exactly with a division on the scale, the measure is read off at once; but if (as must generally happen the zero falls between two of the divisions on the scale, then some one of the lines on the vernier will coincide, or very nearly coincide, with one of the divisions on the scale, and the distance of the zero beyond the last division on the scale behind it is expressed in hundredths by the number of the division on the vernier which is coincident with a division on the scale. Suppose, for example, the position of the vernier with respect to the scale be as represented in Fig. 3701, where the zero of the vernier is brought to coincide with a certain point p on the scale.

3701.



The point p is read on the scale 29 inches, 2-10ths, and a fraction, which is to be measured by the vernier. Here the division 5 on the vernier coincides with that which is marked 7 on the scale; therefore the distance of the zero of the vernier from the last division (2) behind it on the scale is 5-100ths of an inch; for as 5 on the vernier coincides with 7 on the scale, the distance of 4 from 6 is 1-100ths; of 3 from 5, 2-100ths; of 2 from 4, 3-100ths; of 1 from 3, 4-100ths; and of 0 from 2, 5-100ths. In like manner, if the vernier were pushed along till the division 8 coincided with 30 inches on the scale, then the reading of the zero point would be 29 inches, 2-10ths, and 8-100ths. If, when the zero is brought to coincide with p, none of the divisions on the vernier coincide exactly with a division on the scale; for example, if the 5 on the vernier should be a little past the 7 on the scale, and the 6 not up to the 8, the reading would be between 5-100ths and 6-100ths; but its precise amount could only be stated by estimation. If the line 5 appeared nearer 7 than 6 to 8, the distance measured would be greater than 5-100ths, or 10-200ths, but less than 11-200ths; and if the line 6 appeared nearer to 8 than 5 to 7, the distance would be greater than 11-200ths, but less than 12-200ths, or 6-100ths. Thus in any case the limits of the uncertainty must be confined within a distance = 1-200ths of an inch. In order that the coincidences may be observed with greater certainty, the divisions are generally read with a lens.

The vernier is equally applicable to circular scales as astronomical circles; it is then circular also, and must move concentric with the limb of the circle. Suppose the limb divided into intervals of $10'$; and let $n = 10$. We have then 10 divisions on the limb $= 100' = a$; and the length of the vernier $\left(= a - \frac{a}{n}\right) = 100' - 10' = 90'$; which, divided into 10 equal parts, gives $9'$ for the length of a division on the vernier, and consequently the difference of the length of a division on the scale and on the vernier $= 1'$. The arc, therefore, can be read to minutes. But the reading may be carried to much more minute quantities by increasing the length and the number of divisions on the vernier. Instead of embracing 9 intervals of $10'$ on the scale, let the vernier embrace 59 such intervals, and be divided into 60 equal parts. We have then $a = 10' \times 60 = 600'$, $n = 60$, $n^2 = 3600$; therefore, $\frac{a}{n^2} = \frac{600'}{3600} = \frac{1'}{6} = 10''$; that is to say, the arc may be read to $10''$.

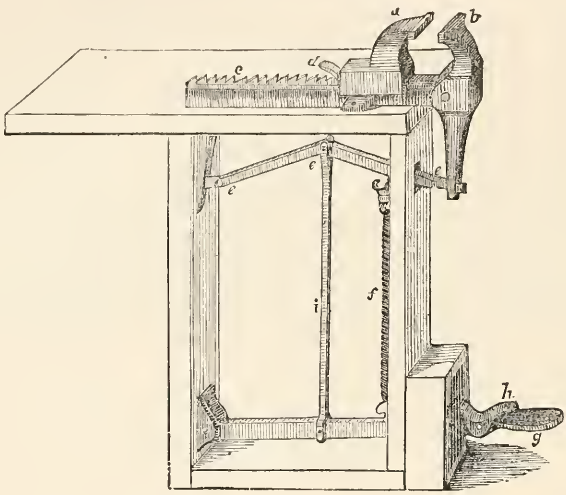
In barometers, where a considerable degree of accuracy is required, the inch is divided into 20 equal parts; the vernier is made equal in length to 24 of these, and divided into 25 equal parts. In this case we have $a = \frac{25}{20} = 1{\cdot}25$ inch, $n = 25$; therefore $\frac{a}{n^2} = \frac{1{\cdot}25}{625} = {\cdot}002$; so that the vernier gives the reading to 1-500th of an inch

Instead of making the vernier equal to $n-1$ divisions of the scale, it is sometimes made equal to $n+1$ divisions, and the object will still be accomplished in precisely the same manner. For in this case the length of a division on the scale being as before, $\frac{a}{n}$, and that of a division on the vernier $\frac{1}{n}\left(a+\frac{a}{n}\right)=\frac{a}{n}+\frac{a}{n^2}$, the difference is still $\frac{a}{n^2}$. The principle is the same in both cases.

The vernier is often called a *nonius*, but improperly, the contrivance invented by Nonius or Nunnez being on a quite different principle.

VICE, LEVER. This is an engraving of a vice invented by Mr. J. PECK, and improved by Mr. L. PARDEE, of New Haven, Conn. It possesses great strength and great power. It is made of wrought-iron, and is claimed to have better qualities than any now in use. It is worked entirely by the foot without laying down a tool for that purpose, and it can be changed to receive work from 1-16th to 8 or 10 inches in width, as quickly as any other vice can be moved one-fourth of an inch.

3702.



Description.—*a*, Fig. 3702, sliding-jaw; *b*, jointed or swing jaw; *c*, rail on which the sliding-jaw moves; *d*, click which catches in ratchet on rail *c*, and holds the sliding-jaw firmly where placed. E, jointed lever (elbow-joint) which turns on pins *e e*, and is attached to prong of rail *c* and the lower end of the swinging-jaw. *g*, foot-lever with joint attached to leg of bench, and connected by rod *i* with jointed lever. *h*, click which catches in ratchet at the foot of the forward bench-leg, and holds the jaws firmly as forced up by the combined levers; it is easily tripped with the foot. *f* is a spiral spring which lifts the foot-lever and throws open the jaw.

It will be recollected that when this vice is forced up it becomes very firmly attached to the bench, and very solid for chipping and other heavy work that is required to be put into a vice, and heavy work requiring both hands to lift can be very easily placed in it. It is certainly much easier for the mechanic, for the strain upon the breast in turning the screw is avoided. This vice has been tested and found to be a useful invention, and one of them weighing fifty pounds has been found to possess as much power as an English vice weighing seventy pounds.

WARMING AND VENTILATION. Heat is given off from bodies by two distinct processes—*radiation* and *conduction*. In radiation, rays of heat diverge in straight lines from every part of a heated surface, and also from extremely minute depths below such surface. These rays, like rays of light, are subject to the laws of refraction and reflection, and their intensity decreases as the square of the distance. When we approach an open fire, or the surface of a stove, we feel its heat by radiation, and it has been ascertained that, at the ordinary temperature of hot-water pipes, about one-fourth of the total cooling effect is due to radiation.

But the amount of radiation of a body heated above the temperature of the surrounding atmosphere depends greatly upon the nature of its surface. If a vessel of hot water, coated with lamp-black, radiate 100 parts of heat within a given time, a similar vessel, containing water of the same temperature, coated with writing-paper, will radiate 98 parts of heat; resin, 96; China ink, 88; red lead, or isinglass, 80; plumbago, 75; tarnished lead, 45; tin, scratched with sand-paper, 22; mercury, 20; clean lead, 19; polished iron, 15; tin-plate, 12.

In order to ascertain the velocity of cooling from a surface of a cast-iron pipe 30 inches long, $2\frac{1}{2}$ inches diameter internally, and 3 inches diameter externally, the rates of cooling were tried with different states of the surface: first, when covered with the usual brown surface of protoxide of iron; next it was varnished black, and finally the varnish was scraped off, and the pipe painted white with two coats of lead paint. The ratios of cooling 1° were found to be for the black varnished surface 1·21 minutes for the iron surface, 1·25 minutes, and for the white painted surface, 1·28 minutes. "These ratios are in the proportion of 100, 103·3, and 105·7; but, as the relative heating effect is the inverse of the time of cooling, we shall find that 100 feet of varnished pipe, 103¼ feet of plain iron pipe, or 105¾ feet of iron pipe, painted white, will each produce an equal effect."

Tarnished surfaces, or such as are roughened by emery, by the file, or by drawing streaks or lines with a graving tool, have their radiating power considerably increased. But, according to Melloni, the roughness of the surface merely acts by altering the superficial density which varies according as the body is of a greater or less density, previous to the alteration of its surface by roughening. The following experiment gives the data for this conclusion: Melloni took four plates of silver, two of which, when cast, were left in their natural state, without hammering, and the other two were planished to a high degree under the hammer. All four plates were then finely polished with pumice-stone and charcoal, and after this one of each of the pairs of plates was roughened by rubbing with coarse emery paper in one direction. The quantity of heat radiated from these plates was as follows:

Hammered and polished plate	10°	Cast and polished plate	13·7°
Hammered and roughened plate	18°	Cast and roughened plate	11·3°

Thus it appears that the hard hammered plate was increased in radiating power four-fifths by roughening its surface, while the soft cast plate lost nearly one-fifth of its power by the same process.

When a body is exposed to a source of heat, a portion of it is absorbed, and it has been proved, experimentally, that the absorptive power of bodies for heat is precisely equal to their radiative power. It was long supposed that color had great influence on radiation and absorption. By exposing variously colored surfaces to the heat of the sun, their absorbing power was in the following order: black, blue, green, red, yellow, and white. Hence it would naturally be expected that the radiating powers of differently colored bodies would be in this order, and that by painting a body of a dark color we should increase its radiating power. Such, however, is not the case, for the absorption and radiation of *simple heat*, or *heat without light*, depend on the nature of the surface rather than on color.

The numbers which represent the radiating powers of different bodies for invisible or non-luminous heat, or heat of low temperature, evidently bear no relation to color, for lamp-black and writing-paper are nearly equal; Indian ink is much less, and plumbago still less. A thermometer bulb, coated with a paste of chalk, is affected by invisible heat even more than a similar one coated with Indian ink; but this result does not occur when the heat is from a luminous source. Thus it was found that when two spirit thermometers, one containing colored, and the other colorless alcohol, were exposed to the sun, the colored liquid rose much more rapidly than the colorless, but when they were both plunged into a vessel containing hot water, they rose equally in equal times.

The propagation of heat by conduction is a very different process from that of radiation. By conduction, the heat travels through or among the particles of solid matter, until the temperature of the body in contact with the source of heat is raised more or less above the temperature of the air. When heat is communicated to a fluid body, the process is different. In consequence of the great mobility of its particles, those which first come under the action of the source of heat, being raised in temperature, escape from its influence, and ascend through the fluid mass, distributing a portion of their acquired heat among other particles on its way; other particles immediately take its place, and being heated, ascend in like manner and distribute their heat. By this process of *convection*, as it is called, the whole of the particles in a confined mass of fluid come under the action of the heating body; those first heated escape as far as possible from the source of heat, and becoming cooled, descend again to be heated, and again to ascend and descend. In this way a circulation is maintained in the whole mass of fluid.

It is only by this process of convection that air may be said to be a conducting body, for if a mass of air be confined in such a way as to prevent the free motion of its particles, it ceases almost entirely to conduct heat, and may be usefully employed to retain heat; as in the case of double windows, the inclosed mass of air prevents the heat from escaping from the apartment, and shields the glass which is in contact with the warm air of the room from the cooling action of the external air. According to some experiments each square foot of glass will cool 1·279 cubic feet of air 1° per minute, when the temperature of the glass is 1° above that of the external air. This, however, is in a still atmosphere. Glass is a very bad conductor of heat, and the cooling effect of wind upon it is not so great as is generally supposed.

Solids differ greatly in their heat-conducting powers. If gold conduct 100 parts of heat, platina will conduct 98·10 parts; silver, 97·30; copper, 89·82; iron, 37·13; zinc, 36·20; tin, 30·39; lead, 17·96; marble, 23·60; porcelain, 12·20; fire brick, 11·10. The slow conducting power of such bodies as porcelain, brick, and glass, may be contrasted with the rapid conducting power of some of the metals by holding one end of a piece of each substance in a flame; the metal will soon become too hot for the hand, while the porcelain may be heated to redness in the flame without its being felt to be much warmer at the other end. A practical application of this property is also to be found in the materials of close stoves for heating apartments; for while those in which the outer case consists of copper or iron receive their heat quickly and part with it quickly, those which are lined with brick and covered with porcelain receive their heat slowly, and communicate it slowly to the air of the apartment. Much, however, depends on the thickness of the metal casing; for, by increasing this, it will, of course, retain its heat longer.

When a heated body cools under ordinary circumstances, it is by the united effects of radiation and conduction, and the rate of cooling increases considerably in proportion as the temperature of the heated body is greater than that of the surrounding medium. We have seen that the cooling effect of radiation depends greatly on the nature of the surface; but it is a remarkable fact that the cooling effect of the air by conduction has no reference to the nature of the surface; it is the same on all substances, and in all states of the surface of those substances. The air in contact with such surfaces robs them of a portion of heat, and immediately ascends to make way for other portions of air, which repeat the process. By these two processes the body cools down to the temperature of the surrounding air, the conductive power of which varies with its elasticity, or barometric pressure; the greater the pressure the greater also the cooling power. It has also been shown by Dulong and Petit that the ratio of heat lost by contact of the air alone, is constant at all temperatures; that is, whatever is the ratio between 40° and 80° is also the ratio between 80° and 160°, or between 100° and 200°.

It was long supposed that a certain relation existed between the radiating and conducting powers of heated bodies. This does, to a certain extent, apply where low temperatures are concerned, but does not hold at high temperatures. Thus, in a set of experiments by Dulong and Petit, the total cooling at 60° and 120° (Centigrade) was found to be about as 3 to 7; at 60° and 180°, as 3 to 13; and at 60° and 240°, as 3 to 21; whereas, according to the old theory, these numbers would have been as 3 to 6, 3 to 9, and 3 to 12. When the excess of temperature of the heated body above the surrounding air is as high as 240° Cent., or 432° Fahr., the real velocity of cooling is nearly double what it would have been by the old theory, varying, however, with the surface.

Since the heat lost by contact of the air is the same for all bodies, while those which radiate most, or are the worst conductors, give out more heat in the same time than those bodies which radiate least, or are good conductors, it might be supposed that those metals which are the worst conductors would be best adapted for vessels or pipes for warming rooms by radiation. "Such would be the case if the vessels were *infinitely* thin; but as this is not possible, the slow conducting power of the metal (iron) opposes an insuperable obstacle to the rapid cooling of any liquid contained within it, by preventing the exterior surface from reaching so high a temperature as would that of a more perfectly conducting metal under similar circumstances; thus preventing the loss of heat both by contact of the air and by radiation, the effect of both being proportional to the excess of heat of the *exterior* surface of the heated body. If a leaden vessel were *infinitely* thin, the liquid contained in it would cool sooner than in a similar vessel of copper, brass, or iron; but the greater the thickness of the metal, the more apparent becomes the deviation from this rule; and as the vessels for containing water must always have some considerable thickness, those metals which are the worst conductors will oppose the greatest resistance to the cooling of the contained liquid."

The reflective power of different substances for heat is inversely as their radiating power. If a surface of brass reflect 100 parts of heat, a similar surface of silver will reflect 90 parts; tin-foil, 85; block-tin, 80; steel, 70; lead, 60; tin-foil, softened by mercury, 10; glass, 10; glass, coated with wax, 5.

When similar substances are exposed to the same temperature they all become heated to the same degree, as measured by the thermometer; but if the temperatures of dissimilar substances have to be raised to the same degree, the quantities of heat required for the purpose will be very different for different substances. Thus, if we place side by side, upon a hot plate, two equal and similar vessels, one containing a certain weight of water, and the other an equal weight of mercury, the mercury will soon become much hotter than the water. So also, on lowering the temperature of dissimilar substances to an equal degree, some will give out more and others less heat. Different bodies, therefore, display different degrees of susceptibility for receiving free heat within their molecules; this is called their *capacity for heat*, and the quantity required to raise equal masses or equal weights 1°, is termed their *specific heat*. The theory of specific heat is of great importance in a practical point of view, for on it depend many of the calculations for ascertaining the proportions of the various kinds of apparatus employed in warming buildings.

The specific heat of different substances can be ascertained by mixing together, with certain precautions, ascertained quantities of the substances under consideration, when their mutual capacities for heat are determined by the decrease in the temperature of the hotter body, and by its increase in the cooler. Thus, if 1 lb. of mercury at 32°, and 1 lb. of water at 62°, be mixed together, the common temperature will be 61°. The temperature of the metal has, therefore, risen 30°, while that of the water has fallen 1°. If the mercury had been at 62°, and the water at 32°, the common temperature of the mixture would have been 33°. In this case the water would have gained 1° of temperature, and the mercury would have lost 30°. Thus it appears that the capacity of water for heat exceeds that of mercury 30 times. If the water be taken as unity, the specific heat of the mercury will be $\frac{1}{30}$, or 0·033.

Again, if 1 lb. of iron filings at 68° be mixed with 1 lb. of water at 32°, the temperature of the mixture will be 36°. That quantity of heat, therefore, the loss of which lowers the temperature of iron 32°, raises the temperature of water only 4°; so that eight times as much heat is required to raise or depress the temperature of the water 1°, as would raise or depress the temperature of an equal weight of iron 1°. Hence the specific heat of iron is $\frac{1}{8}$, or 0·125.

The capacity of substances for heat may also be found by observing the quantity of ice which the body under investigation is capable of thawing. Thus, if equal weights of iron and lead be operated on, it will be found that the iron requires a greater quantity of heat than the lead to produce the same change of temperature, in the proportion of nearly 11 to 3. If a bar of iron, in falling from 100° to 95°, melt 11 grains of ice, then a bar of lead of equal weight, under similar circumstances, would melt rather less than 3 grains; heat is, therefore, more effective in warming lead than iron. Again, an ounce of mercury and an ounce of water, in falling from 60° to 55°, will melt quantities of ice, in the proportion of 33 to 1000, or very nearly 1 to 30; that is, to raise water from 55° to 60°, requires a greater quantity of heat than to raise an equal weight of mercury through the same range of temperature, in the proportion of 30 to 1. The quantity of ice melted by different kinds of fuel affords a convenient method of estimating their relative values. Thus it has been found that

1 lb. of coal, of good quality	melts 90 lbs. of ice.	
" coke, " "	" 84	"
" wood, " "	" 32	"
" wood charcoal, "	" 95	"
" peat, " "	" 19	"

One method of estimating how much of the heat of a common fire is radiated around it, and how much combines with the smoke, is to allow all the radiant heat to melt a quantity of ice contained in a vessel surrounding the fire, and all the heat of the smoke to melt the ice in another vessel surrounding the chimney. By comparing the two quantities of water thus obtained with the quantities of ice melted, it will be found, according to Dr. Arnott, that the radiant portion of the heat is, in ordinary cases, rather less than the combined, or less than half the whole heat produced.

The specific heat of bodies has been determined not only for equal weights, but also for equal volumes, and this is called their *relative heat*, which is to the specific heat of any substance directly as its specific gravity. It may be found by multiplying the specific heat into the specific gravity; and conversely, the specific heat may be found by dividing the relative heat by the specific gravity. Now as the quantity of heat required to raise the temperature of 1 lb. of water 1° is sufficient to raise 1 lb. of mercury 30°, we say that the specific heat of mercury is $\frac{1}{30}$, taking water as unity; and since the specific gravity of mercury is about 13·6, it follows that the relative heat of an equal volume of this metal is $\frac{1}{30} \times 13{\cdot}6 = 0{\cdot}453$.

With respect to gaseous bodies, it has been found that their specific heat is inversely as their specific gravity or density; and, consequently, equal weights of such gases contain a larger quantity of heat, less their specific gravity. The capacity of atmospheric air is taken as the unit by which to estimate the specific heat of gaseous bodies; but sometimes that of water is assumed as the unit, and then the capacities of gases are comparable with those of solids and liquids. The latter values are obtained by multiplying the former into 0·2669, which is the index of the specific heat of atmospheric air compared with that of water.

The following table shows the specific heat of various substances referred to water as the standard, and are supposed to represent the quantity of heat contained in equal weights of the several substances:

Water	1·0000	Carbonic acid	0·2210
Aqueous vapor	0·8470	Carbonic oxide	0·2884
Alcohol	0·7000	Charcoal	0·2631
Ether	0·6600	Sulphur	0·1850
Oil	0·5200	Wrought-iron	0·1100
Air	0·2669	Mercury	0·0330
Hydrogen	3·2936	Platinum	0·0314
Nitrogen	0·2754	Gold	0·0298
Oxygen	0·2361		

The method of ascertaining the specific heat of gases is as follows:—The gas to be examined is well dried, and then brought from a vessel, surrounded with water at 212°, gradually through a spiral tube, surrounded by cold water, the gas escaping through the opposite end of the spiral. In the course of its passage, the gas parts with a portion of its heat to the cold water which surrounds the spiral, and the temperature of the water gradually rises, until after some time it becomes stationary. The equilibrium thus established between the water and the gas is measured by a thermometer, so as to find both the rise in the temperature of the water, and the fall in that of the gas. If the experiment be made with some other gas, and the result should give a higher temperature to the water, then this second gas must have imparted to the fluid a greater amount of heat than the former one did. If, on the contrary, the temperature of water be less this time than before, it will have given out less heat, and the respective capacities for heat of these two gases will be proportional to the temperatures of the water through which they have been admitted. The capacity of atmospheric air being taken as the unit, the specific heat of other gases may be expressed by proportionate numbers. To raise 1 lb. of water from 32° to 212°, requires the same quantity of heat as will raise 4 lbs. of atmospheric air the same number of degrees. The specific heat of air is therefore $\frac{1}{4}$, or, more exactly, 0·2669 that of water, as stated in the above table.

When heat is added to a solid body, the first effect which marks the increase of temperature is *expansion*. At a certain point, however, the temperature, as marked by the thermometer, becomes stationary; and although the heat be continually applied, the temperature does not rise. The solid is now undergoing a change of state; it is passing from the solid into the liquid state; and no rise in temperature will be observed until the whole of the solid has become liquid. The point at which a body begins to fuse or melt, is called its *fusing point* or *point of liquefaction*, and is different in different substances. The quantity of heat absorbed by the body, and unaccounted for, as far as the thermometer is concerned, is called *latent heat*. When the body is liquefied, the temperature again begins to rise, until another point is attained, when it again becomes stationary, and the liquid begins to pass off in the form of vapor or steam. This point is called the *boiling point*, and is different in different substances. The heat absorbed during the process of boiling or vaporization is also called latent.

In the following table, the melting points of a few substances are noted, together with the quantity of heat rendered latent by each in passing from the solid into the liquid state. From these and other results, it may be seen that, in general, the higher the point of fusion, the greater will be the quantity of heat absorbed in liquefaction. There is, however, no proportion between these effects, for ice and spermaceti melt at 32° and 112°, and yet the quantities of heat rendered latent are nearly the same.

	Melting Point.	Latent Heat.
Water	32 degrees.	140 degrees
Sulphur	213 "	143·7 "
Spermaceti	112 "	145 "
Lead	612 "	162 "
Bees'-wax	150 "	175 "

	Melting Point.	Latent Heat.
Zinc	773 degrees.	493 degrees.
Tin	442 "	500 "
Bismuth	476 "	550 "

In the following table, the boiling points of a few substances are given, together with the quantity of heat rendered latent by each in passing from the liquid into the aeriform state:

	Boiling Point.	Latent Heat.
Water	212 degrees.	1000 degrees.
Alcohol (sp. gr. 0·7947)	173 " (bar. 29·5)	457 "
Ether	98 "	312·9 "
Oil of Turpentine	314 "	183·8 "
Nitric Acid (sp. gr. 1·50)	210 "	550 "
Ammonia		865·9 "
Vinegar		903 "
Petroleum		183·8 "

These details respecting latent heat will enable the reader to compare the merits of the two systems of heating buildings by pipes filled with hot water, and by similar pipes filled with steam.

In the former system, it is not desirable to raise the water to the boiling point (212°), because, in such case, steam would be formed, and this escaping by the safety-pipe, would abstract much useful heat from the apparatus. In the latter system, it is desirable to maintain the pipes at 212°, because, at a lower temperature, the steam would condense, and also absorb much useful heat from the apparatus. From the necessity of maintaining the temperature of 212° in steam-pipes, it is evident that a given length of steam-pipe will afford more heat than the same quantity of hot-water pipe; but the following remarks by Mr. Hood, on the relative permanence of temperature of the two methods, will show an advantage in favor of the hot-water system:

"The weight of steam, at the temperature of 212°, compared with the weight of water at 212°, is about as 1 to 1694; so that a pipe which is filled with water at 212° contains 1694 times as much matter as one of equal size filled with steam. If the source of heat be withdrawn from the steam-pipes, the temperature will soon fall below 212°, and the steam immediately in contact with the pipes will condense; but in condensing, the steam parts with its latent heat; and this heat, in passing from the latent to the sensible state, will again raise the temperature of the pipes. But as soon as they are a second time cooled down below 212°, a further portion of steam will condense, and a further quantity of latent heat will pass into the state of heat of temperature; and so on, until the whole quantity of latent heat has been abstracted, and the whole of the steam condensed, in which state it will possess just as much heating power as a similar bulk of water at the like temperature; that is, the same as a quantity of water occupying $\frac{1}{1694}$ part of the space which the steam originally did.

"The specific heat of uncondensed steam, compared with water, is for equal weights as ·8470 to 1; but the latent heat of steam being estimated at 1000°, we shall find that the relative heat obtainable from equal weights of condensed steam and of water, reducing both from the temperature of 212° to 60°, to be as 7·425 to 1; but for equal bulks, it will be as 1 to 228, that is, bulk for bulk, water will give out 228 times as much heat as steam, on reducing both from the temperature of 212° to 60°. A given bulk of steam will, therefore, lose as much of its heat in one minute, as the same bulk of water will lose in three hours and three quarters."

But when the water and the steam are both contained in iron pipes of the same dimensions, the rate of cooling will differ from this ratio, in consequence of the greater quantity of heat contained in the metal than in the steam. The specific heat of iron being nearly the same as that of water, the pipe filled with water will contain 4·68 times as much heat as that which is filled with steam; and if the latter cools down to 60° in one hour, the other will require about four hours and a half to do the same. There are other circumstances to be noticed hereafter, which cause the hot water apparatus to be six or eight times (instead of 4½) more efficient as a source of warmth than steam.

The process of boiling is by no means indispensable to the formation and escape of steam or vapor; for at all temperatures below the boiling point, vapor is formed at the surface of liquids, and escapes therefrom by a process called *spontaneous evaporation.* The difference between this process and ebullition is chiefly this:—When a liquid boils, the vapor which escapes therefrom constantly maintains the same temperature, provided the pressure remain the same; but evaporation may go on at all temperatures and pressures, the quantity of liquid evaporated depending on the temperature and the amount of surface exposed.

We have seen that the pressure or elasticity of vapor at 212° is sufficient to support a column of mercury 30 inches high. The force of vapor at lower temperatures is also measured by the length of the mercurial column which it will support. Vapor at 200° will support 23·64 inches of mercury; at 150°, 7·42 inches; at 100°, 1·86 inches; at 80°, 1 inch; at 60°, ·524 inch; at 50°, ·375 inch; at 32°, ·2 inch.

The amount of evaporation, however, is greatly influenced by the motion of the air, which carries off the vapor from the surface of a liquid as fast as it is formed. A strong wind will cause twice as much vapor to be discharged as a still atmosphere. Dalton ascertained the number of grains' weight of water evaporated per minute from a vessel, six inches in diameter, for all temperatures between 20° and 212°, when the air was still, or in gentle or brisk motion. When the water was at 212°, the quantity evaporated was 120 grains per minute in a still atmosphere; 154 grains per minute with a gentle motion of the air; and 189 grains per minute with a brisk motion of the air. The following is an extract from his table between the temperatures of 40° and 60°:

Temperature. Fahrenheit.	Force of vapor in inches of mercury.	Evaporating force in grains of water.		
		Still.	Gentle.	Brisk.
40 degrees.	0·263 degrees.	1·05 degrees.	1·35 degrees.	1·65 degrees.
42 "	·283 "	1·13 "	1·45 "	1·78 "
44 "	·305 "	1·22 "	1·57 "	1·92 "
46 "	·327 "	1·31 "	1·68 "	2·06 "
48 "	·351 "	1·40 "	1·80 "	2·20 "
50 "	·375 "	1·50 "	1·92 "	2·36 "
52 "	·401 "	1·60 "	2·06 "	2·51 "
54 "	·429 "	1·71 "	2·20 "	2·69 "
56 "	·458 "	1·83 "	2·35 "	2·88 "
58 "	·490 "	1·96 "	2·52 "	3·08 "
60 "	·524 "	2·10 "	2.70 "	3·30 "

The amount of spontaneous evaporation is also greatly influenced by the quantity of vapor already existing in the air. In order to find this, we must ascertain the *dew-point* of the air, or the temperature at which the vapor in the air begins to condense, and then, by referring to the table, the quantity of vapor in the air at the time can be found; and this, deducted from the quantity shown by the table to be given off at the ascertained temperature of the evaporating liquid, will give the quantity of water that will be evaporated per minute. In finding the dew-point, we must bring some colder body into the air, or have the means of cooling some body to such a point as shall just condense the vapor of the air upon its surface. Dr. Dalton used a very thin glass vessel, into which he poured cold water from a well, or cooled down the water by adding a small portion of a freezing mixture. If the vapor was instantly condensed, he poured out the cold water and used some a little warmer, and so on, until he could just perceive a slight dew upon the surface. The temperature at which this took place was the dew-point. In Daniell's hygrometer, the cold is produced by the evaporation of ether. Now suppose the dew-point of the air to be 40°, and the temperature of the air and of the evaporating liquid to be 60°, with a still atmosphere, the vapor in the air, as shown by the table at 40°, is 1·05 grains, which, subtracted from that at 60°, or 2·10, gives 1·5 grains per minute as the quantity of vapor given off from a surface six inches in diameter.

During the spontaneous evaporation of wet surfaces, a considerable degree of cold is produced by the quantity of heat rendered latent by the formation of the vapor; and the heat is mostly derived from the liquid itself, or the surface containing it. By proper contrivances, water may be frozen, in consequence of the abstraction of heat during the rapid formation of vapor. When a person takes cold from wearing wet clothes, the vapor from the wet clothes obtains its heat from his body, and the chilling sensation is often the greater the warmer the air. A person with damp clothes, entering a room filled with hot dry air, is very likely to take cold, on account of the powerful effect of warm air in abstracting moisture.

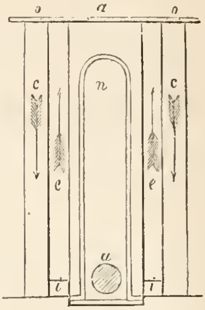
In a badly ventilated room, the moisture from the breath of the inmates, and from the combustion of lamps and candles, accumulates nearly to the point of saturation. This is well shown by an experiment of the late Professor Daniell. The temperature of a room being 45°, the dew-point was 39°; a fire was then lighted in it, the door and window shut, and no air was allowed to enter. The thermometer rose to 55°, but the point of condensation remained the same. A party of eight persons afterwards occupied the room for several hours, and the fire was kept up; the temperature rose to 58°, and the point of condensation rose to 52°. Now, if this room had been properly ventilated, the vapor would have been removed as it was formed, and with it the effluvia and impure air.

On the warming of buildings by means of steam and hot water.—The method of warming buildings by steam, depends on the rapid condensation of steam into water when admitted into any vessel which is not so hot as itself. At the moment of condensation, the latent heat of the steam is given out to the vessel containing it, and this diffuses the heat into the surrounding space.

The first practical application of this principle was made by James Watt, in the winter of 1784-5, who fitted up an apparatus for warming his study. The room was 18 feet long, 14 feet wide, and 8½ feet high. The apparatus consisted of a box, or heater, made of two side plates of tinned iron, about 3½ feet long, by 2½ feet wide, separated about an inch by stays, and jointed round the edges by tin-plate. This heater was placed on its edge, near the floor of the room. It was furnished with a cock to let out the air, and was supplied with steam by a pipe from a boiler, entering at its lower edge; and by this pipe the condensed water also returned to the boiler. The heating effect of this apparatus was not so great as was anticipated, in consequence, perhaps, of the bright metallic surfaces of the box not being favorable to radiation.

About the end of the year 1799, Mr. Lee, of Manchester, under the direction of Boulton and Watt, erected a heating apparatus of cast iron pipes, which served also as supports to the floor. This answered perfectly, and was, in point of materials and construction, the earliest of its kind. Mr. Lee afterwards had his house heated by steam; and the staircase, hall, and passages were warmed by the apparatus shown in Fig. 3703. It was placed in the underground story, and consisted of a vertical cast iron cylinder *a*, surrounded by a casing of brick-work, leaving a space *c c* of two and a half inches all round, and having openings *i* below, to admit the air. This casing was surrounded, at the distance of three or four inches, by another wall, forming a sort of well *e*. The colder and heavier air falling to the bottom of this well, entered by the holes *i* into the space *c* where it came in contact with the cylinder *a*, and, being heated, ascended. The entrance of the steam into the cylinder was regulated by a valve, the air being allowed to escape by a stop-cock, while the steam was entering, the condensed water escaping by a pipe not shown in the figure. The transmission of the heated air was regulated by a valve at *a*, on the top of the brick-work. This apparatus was so effective, and heated the staircase to such a degree, that after it had been in operation a short time, it was necessary to suspend its action by closing the valve at *a*, or by closing the valve which admitted steam into the cylinder.

3703.



In establishments where a steam-engine is in daily use, the steam-pipes may be supplied from the engine-boiler, its dimensions being enlarged at the rate of one cubic foot for every 2000 cubic feet of space, to be heated to the temperature of 70° or 80°. A boiler adapted to an engine of one-horse power is sufficient for heating 50,000 cubic feet of space. Hence an apparatus specially erected for the purpose need not be of very large size, nor is the quantity of fuel consumed great. If the fire under a small boiler be carefully managed, 14 lbs. of coal will convert one cubic foot of water, at 50°, into 1800 cubic feet of steam, at 216°; and only 12 lbs. of coal are required to convert the same quantity of water into steam, at 212°. The shape of the boiler, and the method of setting it, must also be considered, and the furnace must be arranged so as to admit no more air than is required to support the combustion. The hot air must also be kept in contact with the sides of the boiler, until as much of the heat as possible be abstracted from it. In such an arrangement, according to Dr. Arnott, nearly half of all the heat produced in the combustion is applied to use.

In estimating the extent of surface of steam-pipe required to raise the rooms to the proper temperature, it is necessary to consider how the heat is expended. This is done in three ways:—1, Through the thin glass of the windows. 2, More slowly through the walls, floors, and ceiling; and 3, In combination with the air which escapes at the joinings of the windows and doors, or through openings expressly made for the purpose of ventilation. The amount of heat lost in this way has been variously estimated by different writers; but Dr. Arnott states it thus:—That in a winter day, with the external temperature at 10° below freezing, to maintain in an ordinary apartment the agreeable and healthful temperature of 60°, there must be of surface of steam-pipe, or other steam vessel heated to 200°, (which is the average surface-temperature of vessels filled with steam of 212°,) about one foot square for every six feet of single glass window of usual thickness; as much for every 120 feet of wall, roof, and ceiling of ordinary material and thickness; and as much for every six cubic feet of hot air escaping per minute as ventilation, and replaced by cold air. A window, with the usual accuracy of fitting, allows about eight feet of air to pass by it in a minute, and there should be for ventilation at least three feet of air per minute for each person in the room. According to this view, the quantity of steam-pipe or vessel needed, under the temperature supposed, for a room 16 feet square by 12 feet high, with two windows, each 7 feet by three, and with ventilation, by them or otherwise, at the rate of 16 cubic feet per minute, would be—

For 42 square feet of glass (requiring 1 foot for 6)	7 feet.
" 1238 feet of wall floor and ceiling (requiring 1 foot for 120)	$10\frac{1}{3}$ "
" 16 feet per minute for ventilation (requiring 1 foot for 6)	$2\frac{2}{3}$ "
Total of heating surface required	20 feet.

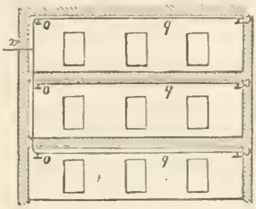
Which is 20 feet of pipe, 4 inches in diameter, or any other vessel having the same extent of surface,—as a box two feet high, with square top and bottom of about 18 inches. It may be noticed, that nearly the same quantity of heated surface would suffice for a larger room, provided the quantity of window-glass and of the ventilation were not greater; for the extent of wall, owing to its slow conducting quality, produces comparatively little effect.

The same authority also supplies the following illustrations:—A heated surface, as of iron, glass, &c., at temperatures likely to be met with in rooms, if exposed to colder air, gives out heat with rapidity, nearly proportioned to the excess of its temperature above that of the air around it, less than half the heat being given out by radiation, and more than half by contact of the air. Thus, if the external surface of an iron pipe, heated by steam, be 200°, while the air of the room to be warmed by it is at 60°, showing an excess of temperature in the pipe of 140°, such pipe will give out nearly seven times as much heat in a minute as when its temperature falls to 80°, because the excess is reduced to 20°, or $\frac{1}{7}$ of what it was. Supposing window-glass to cool at the same rate as iron-plate, one foot of the steam-pipe would give out as much heat as would be dissipated from the room into the external air by about five feet of window, the outer surface of which were 30° warmer than that air. But as glass both conducts and radiates heat about $\frac{1}{7}$ slower than iron, the external surface of the glass of a window of a room, heated to 60°, would, in an atmosphere of 22°, be under 50°, leaving an excess of less than 30°; and about six feet of glass would be required to dissipate the heat given off by one foot of the steam-pipe. In double windows, whether of two sashes or of double panes, only half an inch apart in the same sash, the loss of heat is only about one-fourth of what it is through a single window. It is also known that one foot of black or brown iron surface, the iron being of moderate thickness, with 140° excess of temperature, cools in one second of time 156 cubic inches of water one degree. From this standard fact, and the law above given, a rough calculation may be made for any other combination of time, surface, excess, and quantity. And it is to be recollected, that the quantity of heat which changes, in any degree, the temperature of a cubic foot of water, produces the same change on 2850 cubic feet of atmospheric air.

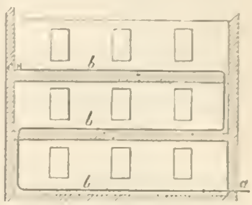
The arrangement of the steam-pipes has next to be considered. A common method is shown in Fig. 3704, in which *a* is the pipe from the boiler, rising at once to the upper story. From this pipe proceed horizontal branches *b b* to each floor. Each branch is furnished with a stop-cock at *o*, by which means the steam can be turned on or off at pleasure, in any one of the three stories. The water arising from the condensation of the steam in each pipe flows back into the boiler along the ascending pipe But if it be not convenient to place the boiler below the level of the lowest floor, the condensed steam is received into a reservoir, from which it is pumped into the feeding-cistern. At the extremity of each horizontal branch C is a stop-cock, which is opened when the steam is filling, to allow the air to blow off.

Another arrangement of the heating pipes is shown in Fig. 3705. Steam from the boiler enters by the connecting-pipe *a* into the heating-pipe *b*, placed near the floor; and this is carried, with a gentle slope, to the opposite side of the room, whence it rises into the next story, and returns along its floor to the opposite side, where it rises to the third floor, and proceeds as before. Here, also, the condensed water flows back in a direction contrary to the current of the steam, and is removed by a siphon at *a*. The air-vent is fixed at the highest point of the arrangement *c*.

3704.

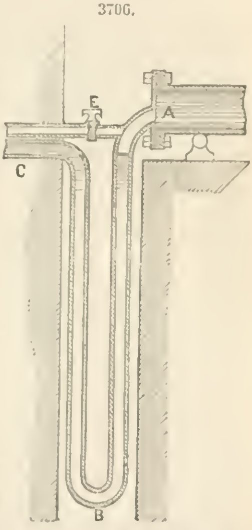


3705.



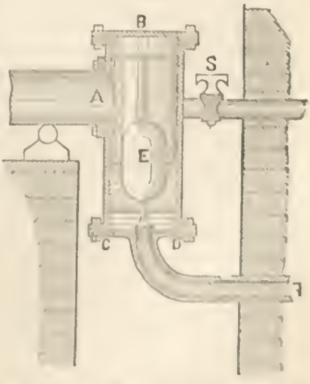
It is necessary to prevent the condensed water from accumulating in the pipes, otherwise it would be impossible to maintain them at a uniform temperature. Moreover, this water condenses the steam so rapidly, that a vacuum is formed within the boiler and pipes; and should they not be firm enough to resist the external pressure of the atmosphere, the boiler may be crushed in, and the whole system deranged. By a special arrangement, the condensed water is collected at certain parts of the system, where it continues to give out heat after the steam has ceased to flow into the pipes. In such cases, stop-cocks may be employed, so arranged as to allow the water to be afterwards withdrawn from the pipes; the same cocks also serve for letting the air out of the pipes when the steam is first admitted. But when the water is returned into the boiler, the advantage of this supply of heat cannot be reserved; and in these cases, a self-acting apparatus is used for taking off the water of condensation. Such a siphon is represented in Fig. 3706. The pipes are so fixed, that A is the lowest point of a branch pipe, so that any quantity of water that may be formed in it will flow into the siphon, A B C, at A, and escape at C, where it may be received into any vessel; for as the water is pure distilled water, it may be useful for a variety of purposes. The water in the legs of the siphon acts as a trap to the steam in the pipe A; hence, the length of the leg A B should not be less than is equivalent to the force of the steam in the pipes. When, for example, the steam is worked at the rate of ten pounds per square inch, the column of water should not be less than ten feet; and even with this pressure, there will be considerable oscillations, unless a valve be placed at some intermediate point between A and B. When the legs are both filled with water, and at rest, this valve should be open, so as to close whenever the water has a tendency to return into the pipe. The siphon should be large enough to carry off all the water of condensation, but not too large, or there would be a loss of heat in the leg A B, from its being filled with steam; and, in all cases, the siphon should be protected from frost. In connection with the siphon, it is usual to place a cock for letting the air out of the pipe, instead of the stop-cock above referred to. Such a cock is shown at E, and it is made to range with the lower part of the pipe, because the air being heavier than steam, will occupy only the lower portion of it.

3706.



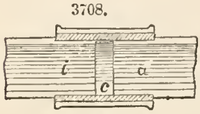
In cases where sufficient depth cannot be afforded for a siphon, a steam-trap or valve, made to open by a float-ball, is employed. Tredgold's arrangement is as follows:—B C, Fig. 3707, is a square box attached to the end A of the steam-pipe; D is a hollow copper cylinder, fixed to a conical valve E. When steam is condensed, the square box will fill with water, which will float the hollow cylinder, and the water will escape, and run by the pipe F into the drain. Whenever the quantity of water in the box is greater than is required just to float the cylinder, and when there is less than will float it, the valve will be closed. In this case, also, a stop-cock S will be necessary to let out the air while the pipes are being filled with steam.

3707.

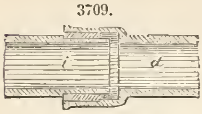


The various methods of connecting the cast iron pipes are by the flange joint, and the spigot and faucet, or socket joint. Mr. Buchanan gives minute directions for these, but he seems inclined to recommend the thimble joint. Care must of course be taken, in joining the pipes, to allow room for expansion. This is sometimes done in the thimble joint, Fig. 3708, in which the adjoining ends of the pipes *a i* are turned true on the outside, and have a thimble, or short cylinder of wrought-iron, to inclose them, leaving only a small space for the current. A piece of tin *c*, or inner thimble, is interposed, and made to fit well to the turned parts of the pipes, which, under the influence of heat or cold, work forwards or backwards, like a piston in a cylinder. In a range of pipes 120 feet in length, there was a motion from expansion of three quarters of an inch; but the usual allowance for the expansion of cast-iron pipes is one-eighth of an inch in 10 feet, or $\frac{1}{960}$ of their length. Cast-iron, heated from 32° to 212°, expands $\frac{1}{900}$ of its length, which is nearly $1\frac{3}{8}$ of an inch in 100 feet. A similar expansion-joint applied to the spigot and faucet connection, Fig. 3709, answered very well. Lead cannot be substituted for tin or iron cement in joints, for, by frequent heating, it becomes permanently expanded; while the iron pipes always contracting in cooling, and the lead not participating in the contraction, the joints soon get loose. Count Rumford introduced an expansion-drum *x*, Fig. 3710, of thin copper, between the extremities of two pipes *a i*, which, in elongating, pressed the sides of the drum inwards, and in cooling drew them outwards. The pipes should not be connected with any part of the building, but be quite independent thereof. All the horizontal branches should be supported on rollers, and nothing done to interfere with the expansion of the different parts

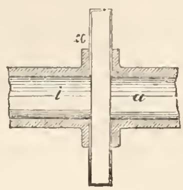
3708.



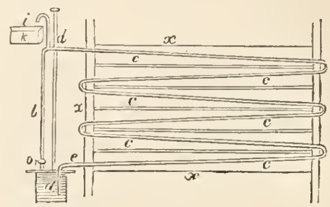
3709.



3710.



3711.



In private dwellings, where the appearance of the pipes is objectionable, they may be concealed behind perforated mouldings, or skirtings, or cornices; or the steam may be brought into ornamental vases dispersed about the room, each furnished with a small stop-cock, to allow the air to escape while the steam is entering.

The method of heating buildings by steam has been superseded by hot-water apparatus of various kinds, which, however, may be resolved into two distinct forms or modifications, dependent on the temperature of the water. In the *first* form of apparatus, the water is at or below the ordinary temperature of boiling. In this arrangement, the pipes do not rise to any considerable height above the level of the boiler, so that the apparatus need not be of extraordinary strength. One pipe rises from the top of the boiler, and traverses the places to be warmed, and returns to terminate near the bottom of the boiler. Along this tube the heated water circulates, giving out its heat as it proceeds. The boiler may be open or closed. If open, the tube, when once filled with water, acts as a siphon, having an ascending current of hot water in the shorter leg, and a descending current of cooled water in the longer leg. If the boiler be closed, the siphon action disappears, and the boiler, with its tubes, becomes as one vessel. In the *second* form of apparatus, the water is heated to 350° and upwards, and is, therefore, constantly seeking to burst out as steam, with a force of 70 lbs. and upwards on the square inch, and can only be confined by very strong or high-pressure apparatus. The pipe is of iron, about an inch in diameter, made very thick. The length extends to 1000 feet and upwards; and where much surface is required for giving out heat, the pipe is coiled up like a screw. A similar coil is also surrounded by the burning fuel, and serves the place of a boiler.

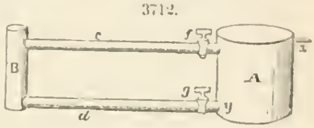
The heating of rooms by the circulation of hot water in pipes seems to have occupied the attention of a few speculative individuals, long before the attempt was actually made. The first successful attempt, on a large scale, was made in France, in 1777, by M. Bonnemain, in an apparatus for hatching chickens, for the purpose of supplying the market of Paris. A section of this heating apparatus is shown in Fig. 3711, in which *a* is the boiler, *d* a feed-pipe, *o* a stop-cock, for regulating the quantity of ascending hot water, *b* the pipe by which the hot water ascends from the boiler into the heating pipes *c c* which traverse the hatching-chamber. These heating pipes have a gradual slope towards the boiler, to which the water returns by the pipe *e*, carried nearly to the bottom. In this way the water cooled by being circulated through a long series of pipes, is being constantly returned to the lowest part of the boiler, where it receives a fresh amount of heat; and being thus rendered lighter, rises up the pipe *b*, and descends the inclined planes of the pipes, losing a portion of its heat on the way, and at the same time increasing in density; the velocity of the current depending on the difference between the temperature of the water in the boiler and that in the descending pipe. At the highest point of the apparatus is a pipe *i*, furnished with a stop-cock for the escape of the air which the cold water holds in solution on entering the boiler. The water that rises along with it is received into the vessel *k*.

Whatever be the arrangement adopted for warming buildings by this method, two considerations must be specially attended to, viz., sufficient strength to bear the hydrostatic pressure, and freedom of motion for currents of water, of varying temperatures, and consequently of varying densities. As fluids transmit their pressure equally in every direction, a column of water rising from a strong vessel to a certain height, may be made to burst the vessel with enormous force. Thus a tube whose sectional area is one inch, rising to the height of $34\frac{1}{2}$ feet from the bottom of a vessel of water, will, if the tube be also full of water, exert a bursting pressure on every square inch of the inner surface of such vessel of one atmosphere, or 15 lbs. If the sectional area of the tube be increased, the pressure remains the same, because it is distributed over a larger surface of the vessel. If a boiler be 3 feet long, 2 feet wide, and 2 feet deep, with a pipe 28 feet high from the top of the boiler, when the apparatus is filled with water, there will be a pressure on the boiler of 66,816 lbs., or very nearly 30 tons. This will show the necessity for great strength in the boiler, especially when it is considered that the effect of heat upon it is to diminish the cohesive force of its particles. But even supposing the apparatus were to burst, no danger would arise, because water, unlike steam, has but a very limited range of elasticity. The boiler just described would contain about 75 gallons of water, which, under a pressure of one atmosphere on the square inch, would be compressed about one cubic inch; and if the apparatus were to burst, the expansion would only be one cubic inch, and the only effect of bursting would be a cracking in some part of the boiler, occasioning a leakage of the water.

The circulation of the water is brought about by the principle of convection. When heat is applied to a vessel containing water, the principle of conduction altogether fails, for water is so imperfect a conductor of heat, that if the fire be applied at the top, the water may be made to boil there without greatly affecting the temperature below. But when the fire is applied below, the particles in contact with the bottom of the boiler, being first affected by the heat, expand, and thus becoming specifically lighter than the surrounding particles, ascend, and other particles take their place, which in like manner becoming heated, ascend also; and the process goes on in this way until the whole contents of the boiler have received an accession of temperature. If the process be continued long enough, the water will boil and pass off in steam. If the boiler be closed in on all sides, so as to prevent the escape of steam, it will burst with a fearful explosion. If a tube full of water rise from the top of the boiler in a vertical line to any required height, and then by a series of gentle curves descend, and enter near the bottom of the boiler, the process of heating is still the same. The particles of water first heated will rise, and, in doing so, distribute their heat to other particles, which will also rise. These in their turn will lose a portion of their heat to other particles, which rise in their turn; until at length an equilibrium is established. But as the source of heat is permanent, other particles are rapidly brought under its action, and, being heated, ascend. By continuing the process a short time, the particles in the vertical tube become heated, and, by their expansion, exert a pressure on the water contained in the lateral branches. This, together with the increasing levity of the water in the boiler, establishes a current, and the water from the branches begins to set in in the direction of the boiler; the water in the lowest branch, where it enters the boiler, supplying colder and heavier particles every moment to take the place of the warmer and lighter particles which are being urged upwards along the vertical pipe.

Now to ascertain the force with which the water returns to the boiler, we must know the specific gravities of the two columns of water, the ascending and the descending, and the difference between them will be the effective pressure or motive power. This can be done by ascertaining the temperature of the water in the boiler and in the descending pipe. When the difference amounts to only a few degrees, the difference in weight is very small, but quite sufficient, in a well-arranged apparatus, to maintain a constant circulation. For example, suppose an apparatus to be at work, in which the temperature in the descending pipe is 170 deg., and the temperature of the water in the boiler, the height of which is 12 inches, is 178 deg. The difference in weight is 8·16 grains on each square inch of the section of the return pipe. If the boiler A, Fig. 3712, be two feet high, and the distance from the top of the upper pipe *c* to the centre of the lower pipe *d* be 18 inches, and the pipe four inches in diameter, the difference of pressure on the return pipe will be 153 grains, or about one-third of an ounce weight; and this will be the amount of motive power of the apparatus, whatever be the length of pipe attached to it. If such an apparatus have 100 yards of pipe, four inches in diameter, and the boiler contain 30 gallons, there will be 190 gallons or 1900 lbs. weight of water kept in continual motion by a force equal to only one-third of an ounce.

3712.



Another method of estimating the velocity of motion of the water of a hot-water apparatus, is to regard the two portions of the system as the lighter and heavier fluids in the two limbs of a barometrical aeriometer. This instrument is an inverted siphon, Fig. 3713, and its use is to ascertain, in a rough way, the specific gravities of immiscible fluids. If mercury be poured into one limb A and water into the other B, and the stop-cock between them be turned so as to establish a communication, it will be found that an inch of mercury F D in one limb will balance 13½ inches of water I E in the other limb, thus showing that the densities or specific gravities of the two fluids are as 13½ to 1. If oil be used instead of mercury, it will require 10 inches of oil to balance 9 inches of water. Or if equal bulks of oil and water be poured into the limbs of the siphon and the stop-cock be then turned, the oil will be forced upwards with a velocity equal to that which a solid body would acquire in falling by its own gravity, through a space equal to the additional height which the lighter body would occupy in the siphon. Now as the relative weights of water and oil are as 9 to 10, the oil in one limb will be forced upwards by the water with a velocity equal to that which a falling body (in this case the water) would acquire in falling through one inch of space, and this velocity is equal to 138 feet per minute.

3713.

In estimating the velocity of motion of the water in a hot-water apparatus, the same rule will apply. "If the average temperature be 170 deg., the difference between the temperature of the ascending and descending columns 8 deg., and the height 10 feet; when similar weights of water are placed in each column, the hottest will stand ·331 of an inch higher than the other, and this will give a velocity equal to 79·2 feet per minute. If the height be five feet, the difference of temperature remaining as before, the velocity will be only 55·2 feet per minute; but if the difference of temperature in this last example had been double the amount stated—that is, had the difference of temperature been 16 deg., and the vertical height of the pipe five feet—then the velocity of motion would have been 79·2 feet per minute, the same as in the first example, where the vertical height was 10 feet, and the difference of temperature 8 deg."

But in all these calculations a considerable deduction must be made for the effects of friction. In the centre of the ascending pipe, the heated particles meet with the smallest amount of obstruction, and there the motion is quickest; but at and near the circumference of the pipe, the retarding effects of friction are most apparent. In the descending pipe the friction is less, for the water descends more as a whole, and is, moreover, assisted by the gravity of the mass. In an apparatus where the length of pipe is not great, where the pipes are of large diameter, and the bends and angles few, a large dedution from the theoretical amount must still be made, to represent with any thing like accuracy the true velocity; and Mr. Hood states that in more complex apparatus the velocity of circulation is so much reduced by friction that it will sometimes require from 50 to 90 per cent. and upwards to be deducted from the calculated velocity, in order to obtain the true rate of circulation.

The amount of friction not only varies according to the arrangement of the apparatus, but also according to the size of the pipes. It is much greater in small pipes than in large ones, on account of the relatively larger amount of surface in the former; besides this, small pipes cool quicker than large ones, and this increases the velocity of the circulation, and with it the friction is also increased. When the velocity with which the water flows is the same in pipes of different sizes, the relative amount of friction is as follows:

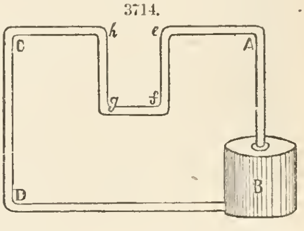
Diameter of the pipes,	½ in.,	1 in.,	2 in.,	3 in.,	4 in.
The amount of friction,	8,	4,	3,	1·3,	1.

So that, if the friction in a pipe of 4 inches diameter be represented by 1, the friction of a pipe 2 inches in diameter is twice as much, and a 1-inch pipe four times as much. By increasing the velocity, the friction increases nearly as the square of the velocity; but as the water in a hot-water apparatus circulates with various degrees of speed in its different parts, it is not easy to calculate the amount of friction from this cause.

It will be seen, then, that when all the deductions are made, the circulation of the water is produced by a very feeble power, so that, as may be supposed, a very slight cause is sufficient to neutralize it. Mr. Hood has known so trifling a circumstance as a thin shaving accidentally getting into a pipe, effectually to prevent the circulation in an apparatus otherwise perfect in all its parts.

But the great point to be attended to, is so to dispose the pipes, that the water, in its descent, may not be obstructed by differences of level, or angles in the pipes, where air may accumulate; for this, by dividing the stream, effectually prevents the circulation. For example, in an apparatus constructed in the form represented in Fig. 3714, the motion through the boiler and pipe A B takes place by convection, and through the descending pipe C D by the force of gravity, as already described. But it will be seen that, when the motion commences in the return pipe D B, in consequence of the greater pressure of C D than of A B, the water in A will be forced towards *e*, while the water in *e f g h* flows towards C. But when a very small quantity of hot water has passed from the pipe and boiler A B into the pipe *e f*, the column of water *g h* will be heavier than the column *e f*, and the current will, therefore, tend to move along the upper pipe towards the boiler, instead of from it. This force, whatever its amount, must oppose that in the lower or return pipe, in consequence of the pressure of C D being greater than A B; and unless the force of motion in the descending pipe C D be sufficient to overcome this tendency to a retrograde motion, and leave a residual force sufficient to produce direct motion, no circulation of the water can take place.

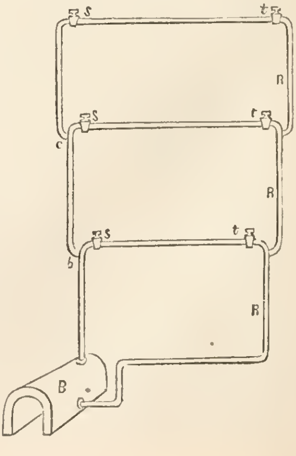
3714.



With respect to the accumulation of air in the pipes, every part of the apparatus, where an alteration of level occurs, must be furnished with a vent for the air. Thus, in Fig. 3714, if the air accumulate in the pipe between A and *e*, it is evident that a vent at C, although it would take off the air from *g h*, and from C D, could not receive any portion of that which is confined between A *e*, or between *e f*, because, in that case, it must descend through the pipe *e f* before it could escape, and as air is so very much lighter than water, it cannot possibly descend so as to pass an obstruction lower than the place where it is confined. The same remark applies to all cases, however large or small the descent may be, and the accidental misplacing of a pipe in the fixing, by which one end may be made a little higher than the other, will as effectually prevent the escape of air through a vent placed at the lower end, as though the deviation from the level were as many feet as it may, perhaps, be inches.

When it is required to heat a number of separate stories by the same boiler, one of two methods may be adopted. The vertical pipe from the boiler may be carried up to the highest story, and the return pipe meander through each story, until it finally terminates in the boiler. But it is obvious, that in such case, the top story will get the larger share of the heat, and the lower stories will be gradually less heated, on account of the cooling of the water in its passage to the boiler. The second method is to supply each story with a separate range of pipes branching out from the main pipe, and returning either together or separately into the boiler. The application of this principle, however, requires caution, for if the branch pipes are simply inserted into the side of a vertical ascending pipe, the hot current may pass by, instead of flowing into, them. Some contrivance is, therefore, necessary to delay the motion of the upward current, and to cause it to turn aside at the points required. This may be done by the arrangement shown in Fig. 3715, which is also copied from Mr. Hood's work. Here it will be perceived, that as the water ascends from the boiler B it receives a check at *b*, whereby it tends to flow through the horizontal pipe, at that level. The same also occurs at *c*, and, by this means, a nearly equal flow of hot water may be obtained. If it be required to cut off the supply of heat from one story, while the others are being heated, this may be done by turning a stop-cock at *s*, by

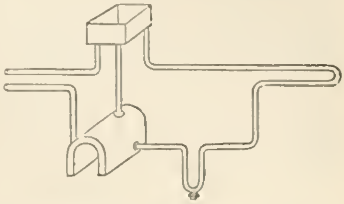
3715.



which the heated current is prevented from flowing along the particular branch so closed. But whenever a branch is closed as at *s*, it is necessary also to close the other end *t* of the same branch, otherwise the water in the descending return pipe R, being warmer and lighter than that in the branch closed at *s*, will circulate therein, and thus raise the temperature of the room intended to be kept cool.

In some arrangements, the hot ascending current of the vertical main is made to discharge into an open cistern at the top, as in Fig. 3716, and from the bottom of this cistern the various flow-pipes are made to branch off. By this means, the expense of cocks or valves is avoided; for by driving a wooden plug into one or more of the pipes which open into the cistern, the circulation will be stopped until the apparatus is heated; but, in that case, water will flow back through the return pipe. This, however, may be prevented, by bending a lower portion of the return pipe into the form of an inverted siphon, as shown in the figure. This will not prevent the circulation when the flow-pipe is open; but if that be closed by a plug in the cistern, the hot water will not return back through the lower pipe. Any sediment that may accumulate in the siphon may be removed, from time to time, by taking off the cap at the lower part of the bend.

3716.



In such an arrangement as that shown in the last two figures, the vertical main pipe need not be of larger diameter than the branches, unless these extend to a very considerable distance, and then the diameter of the main pipe may be somewhat enlarged. It is not, however, desirable to increase the diameter of the main, because it is an object to economize the heat in this pipe, and there are circumstances in which a small main loses less heat than a large one, as, for example, in the arrangement shown in Fig. 3716. If one main pipe, eight inches in diameter, supply four branches in a given time, it is evident, that by reducing the main to four inches in diameter, the water must travel four times faster through the smaller pipe to perform the same amount of work; and, under such circumstances, the water will lose only half as much heat in passing through the small main as it would do in ascending the larger one, for the loss of heat sustained by the water is directly as the time and the surface conjointly.

Hence, in warming by the same boiler two rooms separated from each other by a considerable distance, the pipe connecting the two rooms may be of smaller diameter than the pipes used for diffusing the heat. Thus a pipe of one inch diameter may be used to connect pipes four inches in diameter.

The great specific heat of water, whereby it is enabled to retain its heat for a very long time, has been already shown (page 743) to be a great advantage of this method of warming buildings. The rate at which this apparatus cools depends chiefly on the quantity of water contained in it with respect to the amount of surface exposed, and the excess of temperature of the apparatus above that of the surrounding air; but for temperatures below the boiling point, this last circumstance need only be taken into account in estimating the velocity with which this apparatus cools. Now the variation in the rate of cooling for bodies of all shapes, is inversely as the mass divided by the superficies. In cylindrical pipes, the inverse number of the mass divided by the superficies is exactly equal to the inverse of the diameters; so that, supposing the temperature to be the same in all,

In pipes of............................	1	2	3	4	inches diameter,
The ratio of cooling will be	4	2	1·3	1	"

That is, a pipe of one inch in diameter will cool four times as quickly as a pipe of four inches in diameter, and so on. These ratios, multiplied by the excess of heat in the pipes above that of the surrounding air, will give the relative rates of cooling for different temperatures below 212 deg.; but if the temperatures be the same in all, the simple ratios given above will show their relative rate of cooling without multiplying by the temperatures.

These calculations supply practical rules for estimating the size of the pipes under different circumstances. If the heat be required to be kept up long after the fire is extinguished, large pipes should be used; if, on the contrary, the heat is not wanted after the fire is put out, then small ones will answer the purpose. Pipes of larger diameter than four inches should never be used, because they require a very long time in being heated to the proper temperature. Pipes of four inches in diameter are well adapted for hot houses, green houses, and conservatories. Pipes of two or three inches may be used for warming churches, factories, and dwelling houses; such pipes retain their heat for a sufficient length of time, and they can be more quickly and more intensely heated than larger pipes, so that, on this account, a smaller quantity of pipe will often suffice.

With respect to the quantity of pipe required for warming a building of ascertained size, it is necessary to bear in mind the rate at which a given quantity of hot water, in an iron pipe, will impart its heat to the surrounding air. Now, it has been shown by Mr Hood, that the water contained in an iron pipe four inches in diameter internally, and four and a half inches externally, loses ·851 of a degree of heat per minute when the excess of its temperature is 125 deg. above that of the surrounding air; and, as one cubic foot of water in losing 1 deg. of its heat will raise the temperature of 2990 cubic feet of air the like extent of 1 deg., so one foot length of four inch pipe will heat 222 cubic feet of air 1 deg. per minute, when the difference between the temperature of the pipe and the air is 125 degrees.

We must now take into account the loss of heat per minute arising from the cooling power of glass, ventilation, radiation, cracks in doors and windows, and other causes. An allowance of from three and a half to five cubic feet of air ought to be made per minute for each person in the room, so that, for the purposes of respiration, this quantity will have to be discharged, and an equal supply of air brought in to be warmed.

One square foot of glass will cool 1·279 cubic feet of air as many degrees per minute as the internal temperature of the room exceeds the temperature of the external air. If the difference between them be 30 deg., the 1·279 cubic feet of air will be cooled 30 deg. by each square foot of glass, that is, as much heat as is equal to this will be given off by each square foot of glass.

The quantity of air to be warmed per minute in habitable rooms and public buildings must be three and a half cubic feet for each person the room contains, and one and a quarter cubic feet for each square foot of glass. For conservatories, forcing-houses, and other buildings of this description, the quantity of air to be warmed per minute must be one and a quarter cubic feet for each square foot of glass which the building contains. When the quantity of air required to be heated has been thus ascertained, the length of pipe which will be necessary to heat the building may be found by the following rule:—multiply 125 (the excess of temperature of the pipe above that of the surrounding air) by the difference between the temperature at which the room is purposed to be kept when at its maximum, and the temperature of the external air; and divide this product by the difference between the temperature of the pipes and the proposed temperature of the room; then, the quotient thus obtained, when multiplied by the number of cubic feet of air to be warmed per minute, and this product divided by 222 (the number of cubic feet of air raised 1 deg. per minute by one foot of 4-inch pipe) will give the number of feet in length of pipe four inches diameter, which will produce the desired effect.

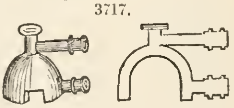
When 3-inch pipes are used, the quantity of pipe required to produce the same effect will, of course, be different. To obtain it, the number of feet of 4-inch pipe obtained by the above rule must be multiplied by 1·33. If 2-inch pipe be used, the quantity of 4-inch pipe must be multiplied by two.

If we wish to determine the quantity of pipe required to maintain a constant temperature of 75 deg. in a hot-house, we must suppose the external air occasionally to fall as low as 10 deg., and calculate from this temperature. The amount of heat to be supplied by the pipes is obviously that which is expended by the glass, the cooling power of which is exactly proportioned to the difference between the internal and the external temperature, the actual cubical contents of the house making no difference in the result. If such a house have 800 square feet of glass, it can easily be calculated, from the preceding data, that this quantity will cool down 1000 cubic feet of air per minute from 75 deg. to 10 deg., which will require 292 feet of 4-inch pipe. If the maximum temperature of the pipe be 200 deg., and the water be at 40 deg. before lighting the fire, the maximum temperature will be attained in about four hours and a half; with 3-inch pipe, in about three hours and a quarter; and with 2-inch pipe, in about two hours and a quarter; depending, however, upon the structure of the furnace, and the quantity of coal consumed. If the external temperature be higher than 10 deg., the effect will be produced in a proportionally shorter time.

In churches and large public rooms, with an average number of doors and windows, and moderate ventilation, a more simple rule will apply for ascertaining the quantity of pipe required. Where a number of persons are assembled, a large amount of heat is generated by respiration, so that a very moderate artificial temperature is sufficient to prevent the sensation of cold. In such a case, the air does not require to be heated above 55 deg. or 58 deg., and the rule is to take the cubical measurement of the space to be heated, and dividing this by 200, the quotient will be the number of feet of 4-inch pipe required.

The efficiency of any form of hot-water apparatus will, of course, greatly depend on the boiler, which ought to be so constructed as to expose the largest amount of surface to the fire in the smallest space; to absorb the heat from the fuel, so that as little as possible may escape up the chimney; to allow free circulation of the water throughout its entire extent, and not be liable to get out of order by constant use. A variety of boilers are figured in Mr. Hood's work, and their respective merits considered on scientific grounds. One of these boilers is shown in Fig. 3717. It is of cast-iron, and the part exposed to the fire is covered with a series of ribs two inches deep, and about one-fourth or three-eighths of an inch thick, radiating from the crown of the arch at an average distance of two inches from each other. These ribs greatly increase the surface exposed to the fire, exactly where the effect is greatest; for being immediately over the burning fuel, it receives the whole of the heat radiated by the fire. The form of this boiler being hemispherical, will also expose the largest amount of surface within a given area. The boiler shown in Fig. 3715 being of wrought-iron, and, therefore, thinner than cast-iron, absorbs the greatest amount of heat from the fuel.

3717.



With respect to the size of the boiler, it has been shown by experiment that four square feet of surface in an iron boiler will evaporate one cubic foot of water per hour when exposed to the direct action of a tolerably strong fire. The same extent of heating surface which will evaporate one cubic foot of water per hour from the temperature of 52 deg., will be sufficient to supply the requisite amount of heat to 232 feet of 4-inch pipe, the temperature of which is required to be kept 140 deg. above the surrounding air; or one square foot of boiler surface exposed to the direct action of the fire, or three square feet of flue surface, will supply the necessary heat to about 58 superficial feet of pipe; or, in round numbers, one foot of boiler to 50 feet of pipe. But as this is the maximum effect, a somewhat larger allowance ought in general to be made. If the difference of temperature be 120 deg. instead of 140 deg., the same surface of boiler will supply the requisite amount of heat to one-sixth more pipe, and if the difference be only 100 deg., the same boiler will supply above one-third more pipe than the quantity stated.

With respect to the furnace, the rate of combustion of the fuel will depend chiefly on the size of the furnace-bars, provided the furnace-door be double and fit tightly. The ash-pit should also be provided with a door to exclude the excess of air when the fire is required to burn slowly. A dumb-plate should also be provided, to cause the combustion to be most active at the hinder part of the furnace instead of directly under the boiler. The fuel will thus be gradually coked, the smoke consumed, and the fuel economized.

In an apparatus containing 600 feet of 4-inch pipe, the area of the furnace-bars should be 300 square inches, so that 14 inches in width and 22 inches in length will give the amount of surface required. To obtain the greatest heat in the shortest time, the area of the bars should be proportionally increased, so that a larger fire may be obtained. The fire ought at all times to be kept thin and bright; and to obtain a good effect from the fuel, one pound weight of coal ought to raise 39 lbs. of water from 32 degrees to 212 degrees.

The best kind of pipes for hot-water apparatus are those with socket-joints, flange-joints having long been out of use for this purpose. Where the socket-joints are well made, there is no fear of leakage, for the pipes themselves will yield before the joints will give way, or before the faucet end of one pipe can be drawn out of the socket of the other. The joints must be well caulked with spun yarn, and filled up with iron cement, or with a cement made of quicklime and linseed oil.

Soft or rain water ought always to be used in the hot-water apparatus, because, if hard water be used, its salts will form a sediment or crust in the boiler, and interfere with its action. But as there is very little evaporation from this kind of apparatus, the boiler will not require cleaning out for years, if a moderate degree of attention be bestowed on the water employed.

When the apparatus is not in use, care must be taken to prevent the water from freezing in the pipes, or the sudden expansive force of the water in freezing may crack them. If the apparatus is not likely to be used for some time during winter, it is better to empty the pipes than incur the risk of freezing. It has been proposed to fill the pipes with oil instead of water, and as the boiling point of oil is nearly three times higher than that of water, it was thought that a temperature of 400 deg. might be safely given to the pipes. It was found, however, that the oil at high temperatures became thick and viscid, and at length changed into a gelatinous mass, completely stopping all circulation in the pipes.

In the forms of apparatus to which the preceding details refer, the temperature of the water never rises to the ordinary boiling point, (212 deg.;) but we have now to notice a method in which the temperature of the water is often beyond 300 deg.; this is the high-pressure method contrived by Mr. Perkins. In its simplest form, the apparatus consists of a continuous or endless pipe, closed in all parts, and filled with water. There is no boiler to this apparatus, its place being supplied by coiling up a portion of the pipe (generally one-sixth of the whole length) and arranging this in the furnace. The remaining five-sixths of the pipe are heated by the circulation of the hot water, which flows from the top of the coil, and cooling in its progress through the building, returns to the bottom of the coil to be reheated. The diameter of the pipe is one inch externally, and half an inch internally, and is formed of wrought-iron. The coil in the furnace being entirely surrounded by the fire, the water is quickly heated, and becoming also filled with innumerable bubbles of steam, these impart a great specific levity to the ascending current. At the upper part of the pipe, the steam bubbles condense into water, and uniting with the column in the return pipe, which is comparatively cool, the descent is rapid in proportion to the expansion of the water in the ascending column, or, in other words, according to the relative specific gravities of the two columns of water.

As the expansive force of water is almost irresistible, in consequence of its extremely limited elasticity, it is necessary in the high-pressure apparatus to make some provision for the expansion of the water when heated. The necessity for this will appear from the fact, that water heated from 39·45 deg. (the point of greatest condensation) to 212 deg., expands about 1-23d part of its bulk; and the force exerted on the pipes by this expansion would be equal to 14,121 lbs. on the square inch. The method adopted is to connect a large pipe, called the expansion-pipe, 2½ inches diameter, with some part of the apparatus, either horizontally or vertically. It should be placed at the highest point of the apparatus, and at the bottom of the expansion-pipe is inserted the filling-pipe through which the apparatus is filled. While the apparatus is being filled with water, the expansion-tube is left open at the top; water is then poured in through the filling tube, and as it rises in the pipes, drives out the air before it. When the pipes are full, the filling-pipe and the expansion-tube are carefully closed with screw-plugs. It is important to expel all the air from the pipes, and this is done, in the first instance, by pumping the water repeatedly through them. The expansion-pipe is, of course, left empty, as its use is to allow the water in the pipes to expand on being heated, and thus prevent the danger of bursting. From 15 to 20 per cent. of expansion space is generally allowed in practice.

The furnace is generally so arranged in the building required to be heated, as to allow the tube proceeding from the top of the coil to be carried straight up at once to the highest level at which the water has to circulate; here the expansion-tube is situated, and from this point two or more descending columns can be formed, which, after circulating through different and distant parts of the building, unite at length in one pipe, just before entering the bottom of the coil in the furnace.

The whole arrangement will be better understood by referring to Fig. 3718, in which *a* is the ascending column; *b*, the expansion tube; *c*, the descending columns; *d*, the coil in the furnace; and *s s s s*, stop-cocks for turning off the circulation from the coils when desired.

The heat is communicated to the air of the rooms from the external surface of the pipes, which are coiled up as at *e e*, and placed within pedestals, ranged about the room with open trellis-work in front, or they may be sunk in stone floors, placed behind skirtings, or in the fireplaces of each floor, the flues being stopped, or arranged in any other convenient manner.

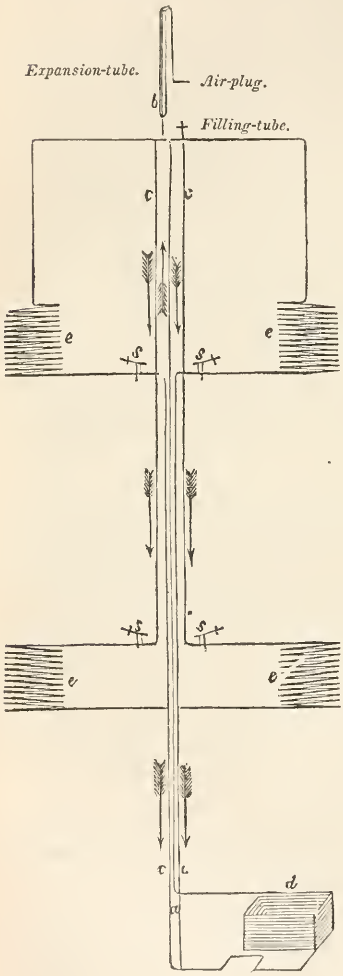
In consequence of the great internal pressure which these tubes have to sustain, considerable care is required in their manufacture. They are made of the best wrought iron, rolled into sheets a quarter of an inch thick, and of the proper width. The edges are then brought nearly together the whole length of the iron, which is generally about 12 feet. In this state it is placed in a furnace, and heated to a welding heat. One end is then grasped by an instrument firmly attached to an endless chain, revolving by steam power, and a man applies a pair of circular nippers, which, when closed, press the tube into the required size, and which he holds firmly while the tube is drawn through them by the engine. The edges are thus brought into perfect contact, and are so completely welded after passing two or three times through the nippers, that a conical piece of iron driven into the end of the tube will not open it at the joint sooner than at any other part.

When the tubes are screwed together at each end, they are proved by hydrostatic pressure, with a force equal to 3000 lbs. on the square inch of internal surface.

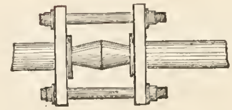
When the tubes are properly arranged and fixed in the building, the whole apparatus is filled with water by a force-pump, and subjected to considerable pressure, before lighting the fire. In this way faulty pipes or leaky joints are detected.

The tubes are joined by placing the ends within a socket, forming a right and left hand screw, the edge of one tube having been flattened, and the other sharpened; they are then screwed so tightly together, that the sharpened edge of one pipe is indented in the flattened surface of the other. Another method of connecting the pipes is by a cone-joint. A double cone of iron is inserted into the ends of the pipes to be joined, and is made tight by two screw-bolts, as shown in Fig. 3719. This joint is quickly made, and is very strong.

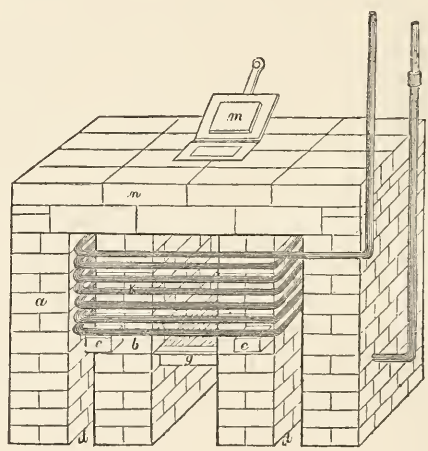
3718.



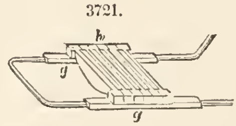
3719.



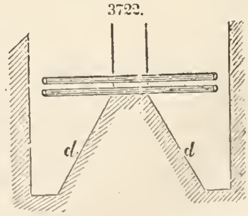
3720.



3721.



3722.



The furnace varies in form and dimensions according to circumstances; but a very common arrangement is shown in Fig. 3720. The size is about three and a half feet square, increasing to six feet, according to the extent of pipe connected with it. The fire occupies a small space in the centre, raised about one foot from the ground, and the fuel is supplied through the hopper-door *m* at the top. The outer casing *a* is of common brick-work; *c c* are fire-bricks, supporting the coil *k*; *d d* reservoirs for the dust and soot, which would otherwise clog the coil; *g* bearing-bars for the grate; *h* the grate: the fire-door is double, and there are also doors to the ash-pit and dust reservoirs. Fig. 3721 shows the descending tube entering the fire-chamber, and passing through the bearing-bars *g g* of the grate *h*. Fig. 3722 is a section of the back well or reservoir *d d*, formed so as to support the coil, and to cause the soot and dust to fall to the bottom.

In this arrangement of the furnace, the ignited coal is surrounded on three sides by a thickness of nine-inch fire-brick; the hopper-door is also placed in one of these lumps; the coil is contained in a chamber round the fire-brick, four and a half inches wide; the pipe enters this chamber, passing through the bearing-bars of the grate, which tends to preserve the grate from burning; the pipe passes out from the top of the coil, at the upper part of the chamber. The smoke passes through the chamber containing the pipes, and escapes through an opening at the back. The coil is in actual contact with the fire only in front. The best fuel for this furnace is coke or Welsh hard coal, such as is not liable to clog. The furnace may be placed in a cellar, or be completely removed from the building to be warmed. The heat of the furnace can be moderated by closing the ash-pit door, and opening the furnace door, or the reservoir doors, so as to lesson the draught and admit cold air to the coil.

In the apparatus erected at the British Museum for warming the print-room and the bird-room, the furnace is in a vault in the basement story, and the pipes, entering a flue, are carried up about forty feet to two pedestals, one in each room; one containing 360 feet of pipe, and the other 400 feet. About 110 feet of pipe are employed in the flow and return pipes in the flue, and 150 feet are coiled up in the furnace. In this way, 1050 feet of pipe are employed: the apparatus is very powerful, and supplies the requisite amount of heat. The print-room is about 40 feet long, by 30 feet wide, and the ceiling contains large sky-lights. The temperature of 65 deg. can easily be maintained in this room during winter. The fire is lighted at 6 A. M., and is allowed to burn briskly till sufficient heat is produced in the rooms, when the damper in the flue is partially closed. A slow fire is thus maintained: at 11 A. M., a fresh supply of fuel is added, and this supports the fire till 4 P. M., when all the fires at the Museum are extinguished.

The above details will suffice to show the nature and application of this apparatus.

It is, however, of great importance to ascertain whether this apparatus is perfectly safe, for even a doubt on the subject must be fatal to its general introduction. The average temperature of the pipes is stated to be generally about 350 deg.; but a very material difference in temperature, amounting sometimes to 200 deg. or 300 deg., is said to occur in different parts of the apparatus, in consequence of the great resistance which the water meets with in the numerous bends and angles of this small pipe. The temperature of the coil will, of course, give the working effect of the apparatus, but the temperature of any part of the pipe will furnish data for estimating its safety; for whatever is the temperature, and, consequently, the pressure in the coil, must be the pressure on any other part of the apparatus; for by the law of equal pressures of fluids, an increased pressure at one part will generate an equally increased pressure at every other part of the system.

A very elegant method of ascertaining the temperature of a heated surface of iron or steel, consists in filing it bright, and then noting the color of the thin film of oxide which forms thereon, as follows:

Steel becomes a very faint yellow	at 430	deg. Fahr.
" pale straw-color	" 450	"
" full yellow	" 470	"
" brown	" 490	"
" brown, with purple spots	" 510	"
" purple	" 530	"
" blue	" 550	"
" full blue	" 560	"
" dark blue, verging on black	" 600	"

Mr. Hood states, that in some apparatus, if that part of the pipe which is immediately above the furnace be filed bright, the iron will become of a straw color, showing a temperature of about 450 deg. In other instances, it will become purple = about 530 deg., and, in some cases, of a full blue color = 560 deg. Now, as there is always steam in some part of the apparatus, the pressure can be calculated from the temperature, and a temperature of 450° = a pressure of 420 lbs. on the square inch; 530° = 900 lbs.; and 560° = 1150 lbs. per square inch.

Although these pipes are proved, at a pressure of nearly 3000 lbs. per square inch, and the force required to break a wrought-iron pipe of one inch external, and half an inch internal diameter, requires 8822 lbs. per square inch on the internal diameter, yet these calculations are taken for the cold metal. By exposing iron to long-continued heat, it loses its fibrous texture, and acquires a crystalline character, whereby its tenacity and cohesive strength are greatly weakened.

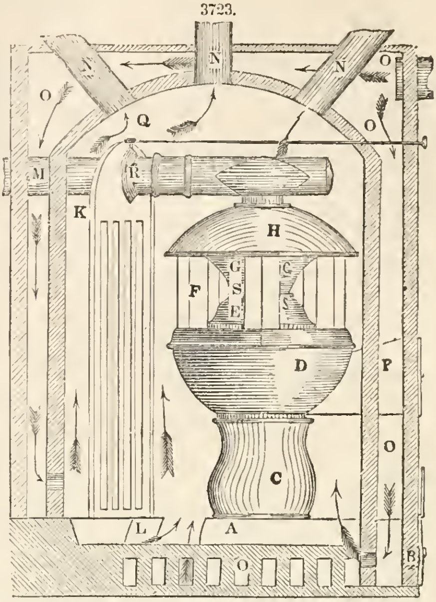
In order to make this apparatus safe, Mr. Hood suggests that, instead of hermetically sealing the expansion-pipe, it should be furnished with a valve so contrived as to press with a weight of 135 lbs. on the square inch. This would prevent the temperature from rising above 350 deg. in any part: the pressure would then be nine atmospheres, which is a limit more than sufficient for any working apparatus where safety is of importance.

But, supposing the apparatus were to burst in any part, the effects would, by no means, resemble those which accompany the explosion of a steam boiler. One of the pipes would probably crack, and the water, under high-pressure, escaping in a jet, a portion of it would instantly be converted into steam, while that which remained as water would sink to 212 deg. This would have the effect of scalding water under ordinary circumstances, but the high pressure steam would not scald, because its capacity for latent heat is greatly increased by its rapid expansion, on being suddenly liberated, so that instead of imparting heat, it abstracts heat from surrounding objects. The only real danger that would be likely to ensue, would be from the jet of hot water, and this must, in any case, be of trifling amount.

The methods of warming most generally practised in this country are the hot-air furnaces, so called, in which anthracite coal is consumed in an inclosed iron furnace, lined usually with fire brick, and placed within a brick chamber, either double or single; and the heated air, after being moistened by the evaporation of water, is conveyed through the building by tin conductors. The external air is introduced in large quantities, supplying the means of a continuous current of fresh warm air. We give several methods now in use

Culver's hot-air and portable furnaces.—These furnaces are represented in the accompanying drawings, Figs. 3723, 3724, and 3725.

3723.



A, Fig. 3723, iron or brick ash-pit.
B, ash-pit door.
C, pot, or coal-burner, with or without soapstone lining.
D, fire-chamber.
E, lower half of tubular drum.
F, elliptical tubes.
G, upper half of tubular drum.
H, top of tubular drum.
I, cap and smoke-pipe.
K, flat radiator.
L, water-basin, or evaporator.
M, smoke-pipe to chimney.
N, conductors of hot air.
O, cold-air conductor and chamber.
P, feed-door.
Q, hot-air chamber.
R, damper in globe with rod attached.
S, pendulum valve for cleaning.

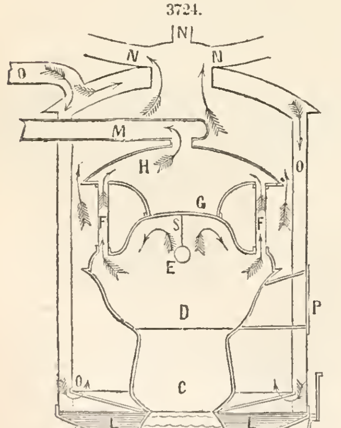
The arrows show the direction of the currents of hot or cold air.

Fig. 3724 represents a large size portable furnace in outline or skeleton form, in double coverings of sheet-iron, tin, or zinc, with same letter references as in Fig. 3723.

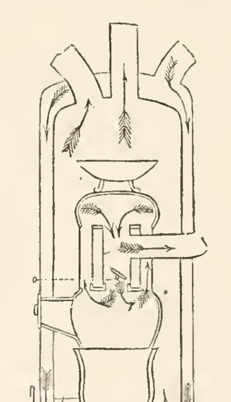
These portables may be used to warm stores or buildings where it is not convenient or desirable to erect brick walls, and may be placed in basements or cellars, warming the rooms in which they stand, if need be, as well as those above. They have sufficient power to warm a moderate sized building, and can be removed as easily as a common stove.

Fig. 3275´ represents a portable furnace with two metal coverings, with the inlets and outlets of cold and hot air, smoke-pipe, &c., with evaporating pan standing upon the top of the drum.

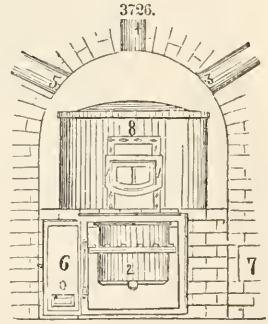
3724.



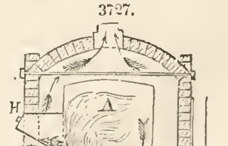
3725.



3726.



3727.



McGregor's hot-air furnace.—Fig. 3726 is a front view of largest furnace set in mason-work. 1, feed door; 2, fire-chamber; 3, 4, and 5, hot-air pipes; 6, ash-pit door; 7, cold-air box; 8, cylinder chamber for generating hot air.

Fig. 3727 exhibits an internal view of the structure of the furnace. A C D, the course of the heat ascending into the drum, descending and passing off into the smoke-pipe. H, the feed-door for fuel, D, the back damper by which the fire is checked by admitting cold air into the smoke-pipe.

The aim of this furnace is to exclude entirely the red and unwholesome heat made by the hot or fire chamber, in which the coal is burnt, from coming into the hot-air chamber, and instead, all the heat is thrown into the large cylinder drum in the air-chamber, which is never allowed to become so heated as to burn the air; and into this chamber is continually allowed to pass a large volume of fresh air, and from thence into the apartments. The serious objection to furnaces has been, not that they would not produce sufficient heat, but that the air was burnt and poisoned by coming in contact with the red-hot cylinder as it passed through the hot-air chamber, which in this furnace is obviated by shutting off in a separate brick chamber all the heat thrown out from the cylinder.

Walker's hot-air furnace for heating and ventilating dwellings, churches, school-houses, &c.—Walker's hot-air furnace is now very much in vogue, and we extract from his treatise on warming as follows:

The principle of heating by hot-air furnaces is to take fresh air from outside the building, warm it, and then let it flow into the rooms as temperature and ventilation require. Thus, a pipe conducts the air from outside of the building to the air-chamber of the furnace, *i. e.*, the space inclosed about the furnace; here it is warmed, and is then conducted by pipes into the apartments, while the smoke and gas generated by the combustion of the fuel pass off by another pipe to the chimney.

But if the air-chamber and the pipes leading from it are small, or if the furnace itself is so small that in order to get the heat required its surface must be kept at a high red-heat, a furnace will be found to be one of the most expensive and disagreeable modes of heating. To construct a good furnace, therefore, several things must be considered.

1. *Ventilation.*—The problem is how to secure a pleasant, genial heat, with thorough ventilation. Either of these alone may be very easily and economically obtained. Stoves of various kinds will produce heat at little cost, but they afford no ventilation. Open doors and windows will produce ventilation, but at the expense of that warmth which health and comfort require.

To make a furnace the means of ventilating an apartment does not appear to have been thought of. The uniform plan was to admit into the apartments to be warmed by the furnace but a small quantity of air, which, to produce sufficient heat, was necessarily raised to a very high temperature—intensity of heat being substituted for quantity. This was in various ways productive of bad results. The small volume of air introduced into a room from the air-chamber of the furnace was worth very little for ventilation.

But the question arises, how is the requisite amount of ventilation to be secured? What limit shall be assigned to the introduction of fresh air into an apartment which is to be heated to a given temperature? The answer to this question must vary with the relative importance of economy in fuel, and of the health and comfort of the occupants of the room. The limit of the amount of ventilation must sometimes be that which can be afforded. The heating of air for this process is just so much fuel thrown away.

The most economical stove is that which is placed in the room to be warmed, and the smoke of which is reduced to the temperature of the room; if no change of air then take place, by crevices or otherwise, we have arrived at perfection in the economy of fuel. Whether it is advisable to practise such economy, or rather parsimony, for this is its nature, is quite another question. It is upon this principle of the non-renewal of the air and low temperature of the smoke, that *air-tight stoves* consume but little wood; that the odor of the rooms warmed by them, in which several people are assembled, is offensive, and their influence upon the health injurious. In New England the winter temperature is such that the expense of heating up the air to a comfortable point is a serious item, and the temptation to economize in this respect is with some not easily resisted.

If pure and healthy air be *worth what it will cost*, then should hot-air furnaces be so constructed as to admit freely large quantities of fresh air into the apartments. But while this object is secured, furnaces should be so constructed also that the ample volume of air thus freely introduced shall be raised to the required temperature with the least possible expense of fuel.

2. *Evaporation.*—There appears to be a great want of information on this branch of the subject, even among those who ought to be sufficient masters of their business to know its use. Thus one man will advertise as a recommendation of his furnace, that "a large quantity of water is evaporated, to restore to the air the oxygen taken from it by the heat of the furnace." Another has a furnace "so constructed that evaporation is not necessary, as it never becomes sufficiently hot to destroy the vitality of the air," it being lined with soap-stone, or something similar.

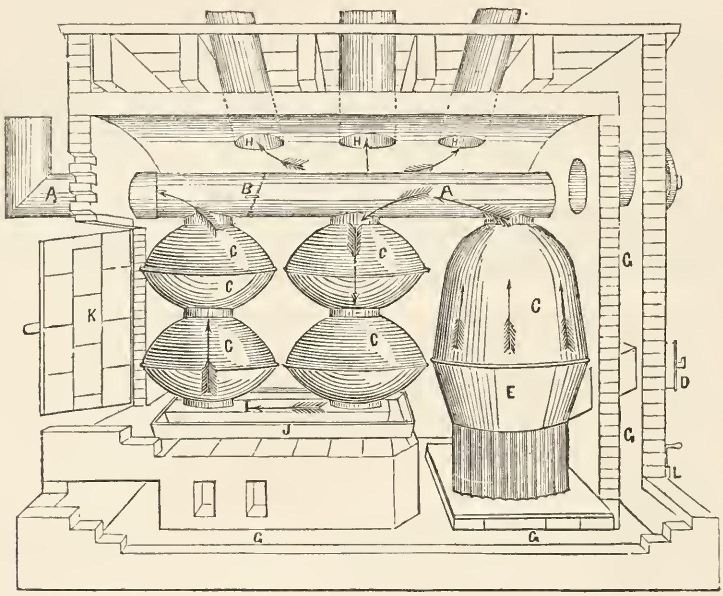
But all such statements are based upon an incorrect idea of the use of evaporation. They imply that heat destroys the vitality of the air, and that the evaporation of water will restore it, neither of which is correct. Heat without combustion does not destroy the vitality of the air; and if it did, evaporation would not be a remedy. The necessity for evaporation arises wholly from the fact, that as the temperature of the air is increased, its capacity to hold and its tendency to absorb moisture are increased also. Thus a given volume of air at the temperature of 40 deg. is capable, like a sponge, of holding in suspension a certain quantity of water. If now, without adding to the quantity, the temperature be raised to 65 deg., the capacity for moisture is nearly doubled; if raised to 90 deg. it is nearly quadrupled; and if additional moisture is not supplied by the evaporation of water, what may be termed, for convenience, the *drying powers* of the air will be manifested in its effects upon the wood work of the apartments, upon the furniture, and also upon the skin and lungs of the occupants. It is impossible, therefore, to contrive a heating apparatus which shall dispense with the necessity for evaporation. The laws of nature require this expedient, to supply air at an increased temperature with the moisture which it demands.

But evaporation, important as it is, must be judiciously conducted. The evaporating pan should have a large surface, and should be so arranged that the water shall never be heated to the boiling point. When water boils, steam will rise whether the air requires it or not; but when the water is below the boiling point, evaporation proceeds in some measure according to the wants of the air. When the air is very dry the evaporation is rapid, and when moist it proceeds slowly. In a dry day a number of gallons will be evaporated, while in a very moist state of the atmosphere, when the same amount of heat is required, the evaporation is scarcely perceptible. If nature is consulted in arranging this department of the furnace, the supply of moisture will always be regulated by the demand.

3. *Temperature.*—To keep the apartments at a comfortable temperature, well ventilated, without dust or gas, and without injury to furniture or to health by the extreme dryness of the atmosphere, in a word, to keep up a continual supply of pure, fresh, invigorating air at summer heat, is the *desideratum* in a hot-air furnace. To effect this the heat must be imparted by a surface so large that no part of it will be highly heated in obtaining the requisite temperature. The chief objections against furnaces have arisen from the fact that very small surfaces have been used, and were heated to such a degree that the innumerable particles of animal and vegetable matter that are always floating in the air were burned, rendering the air offensive and unhealthy. The air also was very highly heated, which not only made it very unpleasant, especially when it came in contact with the person before its temperature was reduced, causing headache, lassitude, and other disagreeable sensations, but also very injurious to the pannels and other wood-work of the room, furniture, &c., by reason of its extreme dryness.

When the temperature of the air cannot be diminished without depositing water upon the walls of the containing vessel, or appearing as a mist, it is said to be saturated. If the temperature of saturated air be raised, it will, to the feelings, become drier, and will immediately begin to take up water which is exposed to it; air is dry or moist, not in proportion to the water it contains, but in proportion as it is more or less removed from the point of saturation.

3728.

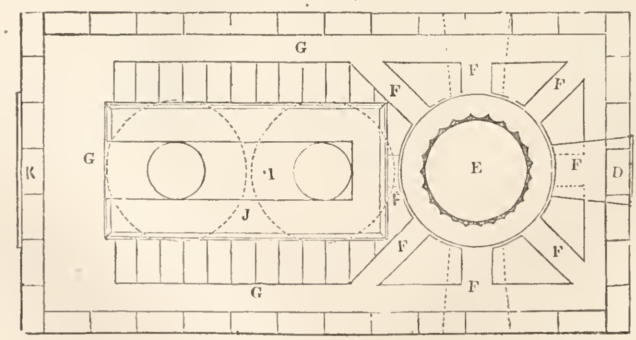


Walker's patent improved hot-air furnace, manufactured at No. 89½ Leonard-street, New York, is represented in Figs. 3728 and 3729.

The objects aimed at by the patentee in the construction of his hot-air furnace are—

1st. By means of one fire to produce a mild, uniform, and agreeable temperature throughout several apartments, and to warm a whole house sufficient for sleeping-rooms, or to keep plants of all kinds in the coldest weather.

3729.



2d. To avoid all dust and gas, and to keep the apartments well ventilated by means of a constant supply of fresh air from without.

3d. To be simple, so that any one capable of managing a stove can take care of it.
4th. To be economical in point of fuel.
5th. To be durable, so as not to require frequent or expensive repairs.
The furnace is constructed of cast-iron, is placed in the cellar and inclosed in brick walls, in such a manner that there is very little heat wasted by escaping into the cellar or chimney-flue. Consequently all the fuel consumed is made available to heating the apartment; and in no case where they have been erected, have they failed to give entire satisfaction.

Literal References.

A, upper smoke-pipe.
B, damper.
C, drums, or radiators.
D, feed-door.
E, fire-pot, fluted.
F, cold-air flues.
G, space between walls for cold air.
H, hot-air flues.
I, lower smoke-pipe.
J, evaporating pan—12 gallons.
K, door to put in or take out the heater.
L, door to remove ashes.

We extract from the Journal of the Franklin Institute a report on warming and ventilating the west half of the Lunatic Asylum of Blockley Alms-house, Philadelphia, by steam:

Much difficulty was experienced in the adaptation of an old edifice, not originally designed for such a system as has been adopted, and which added greatly to our labor and made it more difficult to effect our purpose.

In constructing the heating chambers and necessary flues, we were obliged to cut through a system of arches, which, on account of the substantial manner in which the building was constructed, added greatly to the expense and time attending the prosecution of the work. The want of proper flues and conduits for the warmed and extracted or foul air, all of which we were obliged to construct, or alter to answer the purpose of the present arrangement; the insufficient height of the cellar ceiling for our purposes, and the impossibility of going any deeper on account of water, presented another serious difficulty in the great distance the steam had to be conveyed and the condensed water returned again to the boilers, being 500 feet; a greater depth would have facilitated the return of the condensed water.

Running underneath the building are a number of sewers, into which the sinks are drained, consequently making them very foul. These made a system of ventilation very desirable, but at the same time greatly interfered with our efforts to produce a pure atmosphere throughout the building. The building itself is one very difficult to warm, on account of the great height of the ceilings, the first story being 14 feet 11 inches, the second 16 feet 4 inches, and the third 14 feet 8 inches in height. The number and large size of the windows making the glass surface equal to 3447 square feet, and the imperfect fitting of the windows, together with the large size of the doors, and the very exposed situation of the building, render it, perhaps, more difficult to warm than any of the buildings connected with the Institution.

Explanation of the figures.—Fig. 3730, plan of building, and warming and ventilating.
Fig. 3731, elevation of heating chambers.
Fig. 3732, longitudinal vertical section of the arrangement for warming and ventilating.
Fig. 3733, plan of a part of the heating and ventilating chamber.
Fig. 3734, elevation of Fig. 3733.

Fig. 3731 is a plan of the west half of the Lunatic Asylum: the main building, running east and west, is 168 feet long by 59 feet wide, inside measurement, three stories high, with an attic. On each floor of the main building there is a large hall running the length of it, a stairway, kitchen, dining-room, and three large associate rooms, in each of which there is a nurse's room, wash-room, and water-closet.

The wing at right angles to the main building is 119 feet long by 46 feet wide, inside measurement, three stories high, with an attic. On each floor of the wing there is a hall running the length of it, and connected with the main building by another hall, two stairways, a nurse's room, a bath-room, two associate rooms, and twenty cells.

Great pains have been taken to procure air for the supply of the house from pure sources, and to keep it from being contaminated while in the equalizing and heating chambers under the building. The arrangements are such that the patients cannot interfere with them in any way; there are no valves in any of the flues except those in the hall, nor have they been found desirable, as there is but a trifling difference in the temperature of the different parts of the house, thus avoiding the consequent annoyance from interference with them.

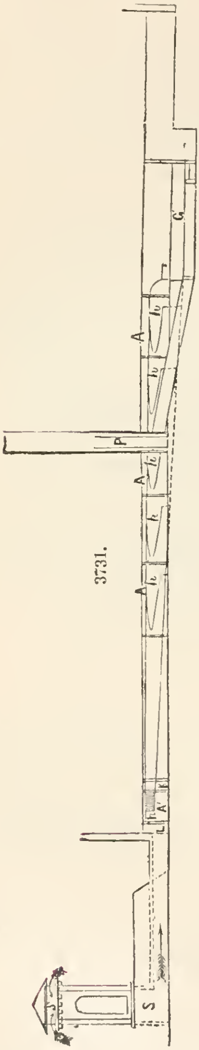
The heating chamber A A, for warming the main building, runs along the centre of the cellar until within 23 feet of the wing, where it was found necessary to stop, on account of a sewer crossing it at right angles. For warming the halls in the main building, another chamber B is constructed. For warming the cells and halls in the wing, the heating chamber A′ runs the length of the wing at right angles to the main chamber. For warming the associate and nurse's rooms, the chambers A″ A″ A″ are constructed.

The air for supplying the main building is drawn from the garden on the south side into equalizing chambers L L L, and from thence through the small apertures O O O, &c., in the bottom of the chamber wall, as indicated by the arrows, Fig. 3733, into the heating chamber A where it is heated, and then distributed through the flues F F F, Figs. 3732, 3733, and 3734, into the different parts of the house to be warmed.

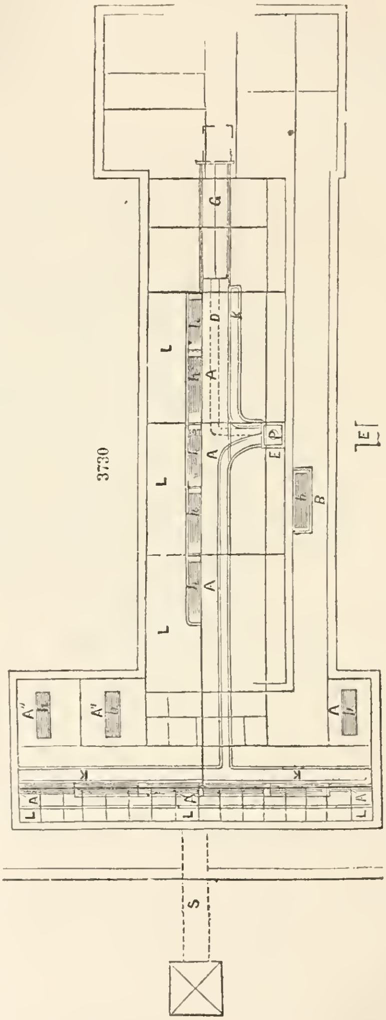
The air for supplying the cells and halls in the wing is drawn from the inclosure on the west side of the building. It is received into a shaft S sufficiently high to be beyond the reach of the patients who may be exercising in the yard, conveyed down this and through a tunnel 50 feet in length into the heating chamber A′, where it is heated, and from thence distributed into the cells and halls.

The associate rooms in the wing receive their supply of air from the garden, and the nurse's rooms from the yard. Their arrangements for the equalizing and heating chambers, flues, &c., are the same as the others.

The arrangements by which the heated air is introduced and the foul air extracted from the rooms, will be understood by referring to Figs. 3732, 3733, and 3734, which represent the arrangement for warming and ventilating three of the large associate rooms in the main building, which are each 47 by 44 feet. The flues F F F lead from the heating chamber A to near the ceiling in the centre of the rooms; these supply the heated air for warming the rooms, throwing it out in the directions as indicated by the arrows.



3731.



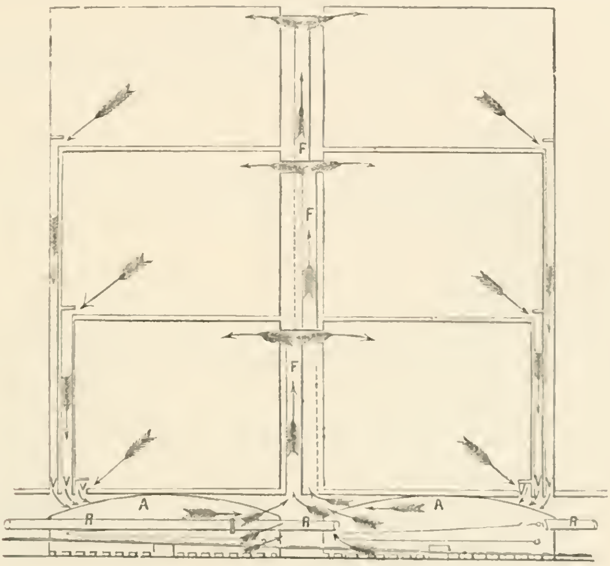
3730

The foul air is drawn off by means of the foul-air flues V V placed in the sides of the rooms, opposite to the entrance for warm air; they open close to the floor, thus producing a downward ventilation. Through these it is conducted to the main foul-air flue K K, Figs. 3733 and 3734; from thence conducted to the extracting shaft E, which is 90 feet high, fitted with a cast-iron chimney 30 inches diameter and 25 feet high, through which the smoke and gases from the fire are discharged. The extracting shaft is also fitted with a steam-jet, by means of which additional force can be given to the ventilation if it should be desirable. There is also a small furnace in the base of the shaft, so arranged as to produce ventilation when the heating apparatus is not in use.

The main sewer which runs under the building is so connected with the fire under the boiler that the necessary air for supplying the furnace may be drawn from it, thus creating a current of air into the sewer, and in a measure preventing the escape of fetid gases.

G G, Figs. 3730 and 3731, are two cylindrical boilers, 36 inches in diameter and 40 feet long, having a capacity, together, equal to 565 cubic feet. We would here assure you of the perfect safety of these boilers. They are constructed of the best Pennsylvania iron, by experienced workmen, and are of unusual thickness; the heads, although of cast-iron, are concave; the boilers weigh together 12,186 lbs., the great amount of water they contain, and consequently the amount of time necessary to evaporate it, makes them safe as regards explosion from the most frequent cause, the want of water; and their proportion in relation to the fire and radiating surfaces is such that, were the safety-valves chained down, it would be impossible to generate a pressure of 100 lbs. to the square inch. With the present weight at the extreme end of the safety-valve levers, 72 lbs. pressure would raise them. The boilers will sustain a pressure of 300 lbs. to the square inch without any danger; 30 lbs. is the greatest pressure under which the apparatus is generally worked. Plain cylinder boilers are always preferable to tubular boilers where there is room enough to make them sufficiently large—they can be made stronger on account of their form; they have, also, more steam and water room. The boiler of a first-class locomotive of ordinary construction will generate enough steam, when the fire is in full operation, to fill the steam space in four seconds, and enough, could there none escape, to burst the boiler in about ten minutes; they will evaporate the water so as to become dangerous in from 30 to 60 minutes when the supply of water is stopped.

3732.

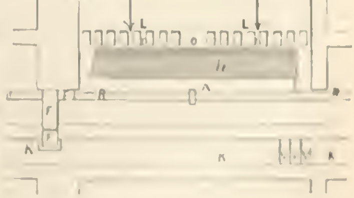


The smoke and gases from the furnace are conveyed through the smoke flue D, Figs. 3730 and 3731, within the heating chamber A, until it is opposite the extracting shaft E; from here it is conducted across and into the cast iron chimney P, within the extracting shaft E. The smoke-flue within the heating chamber A is covered with cast-iron plates, and these with clean sand. The arrangements are such that the temperature of the smoke and gases is reduced below 200 deg. Fahr. before they are permitted to escape, thus preventing any unnecessary waste of heat, and consequently of fuel.

To the boilers are connected, by means of a 6 inch cast-iron main R, systems of radiating pipes *h h h* of wrought-iron, ¾ inch inside diameter; they are distributed through the different heating chambers A A′ A″, &c. These systems are so arranged that the condensed water is returned to the boilers to be again converted into steam, thus producing a circulation. There are between 8000 and 9000 feet of radiating pipe distributed through all the heating chambers.

3734.

3733.



If a rapid circulation through the radiating pipes is desired, for the purpose of raising the temperature of the building in a comparatively short time, it is effected by opening a blow off cock which discharges into a sewer; or by means of a steam pump, so arranged as to take the water from the condensed water pipes and force it into the boilers. This pump is also used for supplying the boilers with water when the pressure of steam is too great to do so from the reservoir.

In the third story of the wing is an iron tank, of a capacity of 1200 gallons, in which the water for washing and bathing purposes is heated by means of a coil which is supplied with steam from the boilers G G, a distance of 200 feet.

The boilers also supply the steam for cooking the food for the inmates. In the kitchen are two boilers of 95 gallons each, and one of about 50 gallons; in these the food is cooked. The kitchen in the eastern or male part of the house is arranged in the same way. They are all supplied with steam from the same source.

There is no fire in the west half of the Asylum excepting under the boilers G G, and a small cooking stove for preparing food for the sick.

The cubical contents of the building warmed, without deducting partition walls, stairways, &c., is 780,000 cubic feet; the amount actually warmed by the apparatus, deducting partition walls, stairways, &c., is 730,000 cubic feet, or 90 rooms and 6 halls.

The consumption of fuel in cold weather is 1½ tons of coal per day, (24 hours;) allowing 75 days cold and 100 days moderate weather through the winter, the consumption would be 213—say 225 tons; 30 tons of this should be deducted, which is the amount used in cooking, and 15 tons of this should be charged to the eastern or male part of the house. The consumption of fuel, as near as we can ascertain, for heating this part last year by close stoves, &c., and there was no ventilation, was from 275 to 300 tons of coal, say 275 tons, when but a portion of the rooms were warmed, and that imperfectly; while by the arrangement introduced by us, the whole of the building is warmed at a saving of at least 75 tons of coal, which, at $4 per ton, would be $300.

The advantages of the present arrangement are—

1st. Producing a pure atmosphere throughout the building, the air being supplied in great abundance from pure sources, and so arranged as to keep it from contamination.

2d. A system of downward ventilation, which diffuses the warmth uniformly throughout the various apartments; the air being admitted near the ceiling and drawn off at the floor is constantly sinking, and in this way the colder and impure air passes off by the foul-air flues, and is ejected from the extracting shaft above the building.

3d. The safety from fire, both in the building and as regards the patients, which, in a lunatic asylum, is a very important consideration.

4th. The freedom from noise, dust, and dirt usually attendant upon fires in grates and stoves.

5th. The whole heating arrangement being under the care of a single individual, is more easily managed than by a number of attendants, who are now dispensed with.

6th. The economy of the arrangement, saving about 25 per cent. in fuel; the repairs will not exceed those of stoves and grates.

Ventilation.—The following hints on ventilation will be found of value in this place; they are by W. Walker, Engr., of Manchester.

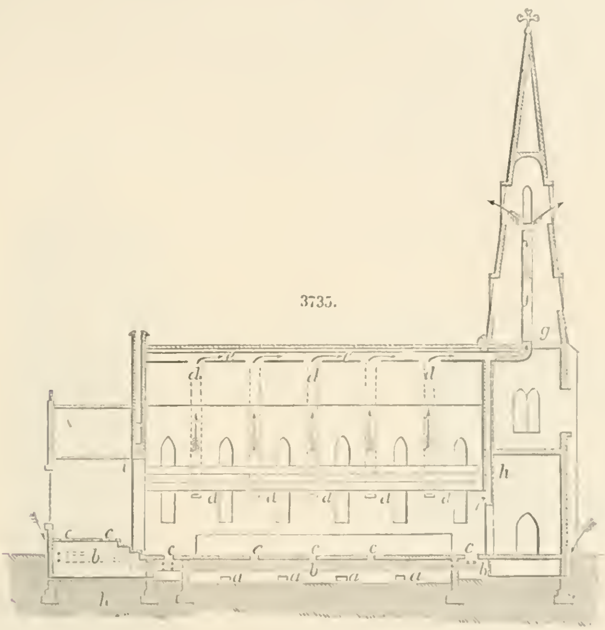
However useful steam agency, as applied to ventilating purposes, may be in factories or buildings connected with them, and in theatres or other places liable to great and sudden influx or efflux of persons—and well as it has been found to answer in its appplication to other buildings, such as club-houses, banks, collegiate institutions, and hospitals, in which manifest advantages have been derived from its employment—there will still be great numbers and many classes of edifices in which it would be from various causes inadmissible. Churches, chapels, and houses for worship, may be enumerated under this head—the numbers contained within their walls being, on the whole, tolerably constant, and not liable to very sudden fluctuations; but especially from the circumstance that they are seldom used more than two days in the week, with intervals of two or three days between; and when used it is only for two hours consecutively, with intervals of two or three hours between. With such proper quantity and sizes of ingress and egress flues as can readily be obtained in the thick walls and piers of such edifices, (if planned prior to their construction,) this short period of occupation will not permit their atmosphere to become very highly charged with impurities, while the intervals between the services will be found sufficient for an entire change of the whole atmosphere left in them at the close of each service, without resorting to mechanical means. In churches with lofty open roofs, of the mediæval or early English construction, without galleries, the total cubic space bears so large a proportion to that portion of it occupied at the floor level by the congregation, that scarcely any injurious vitiation of the entire atmospheric contents can take place during the short period of occupation, provided moderate preparations have been made for ingress and egress. Hence, very sudden and powerful ventilation is scarcely required in such churches, and the purification of their atmosphere may safely be left to the spontaneous action of those preparations; but on special occasions, and in hot weather, the action of the fresh-air flues may be accelerated by the exhausting power of a shaft or trunk of adequate size running up within the tower or steeple, its upper end discharging into the external air, while its lower end communicates with the interior by openings in or near the roof; and this shaft may be made, in very hot weather, to perform two or three times its usual duty, by rarefaction produced at its lower end *g*, Fig. 3735, by a large number of gas-burners fixed there in tolerably close proximity with each other, and supplied with gas from the mains which furnish light to the whole building. These ideas have been successfully carried out in numerous instances, and in large buildings. The whole process recommended for such a building will be better understood by a reference to the upper portion of Fig. 3735, which represents a section of a church ventilated in this manner; *a a* are openings all round the church for admission of fresh air; *b b*, hot-water pipes, over which it is made to pass on its way to the gratings *c c*; *d d* are openings, by which the vitiated air enters a horizontal trunk *e*, from the end of which rises the shaft *f*, with a collection *g* of gas-jets in the bottom of it; *h i* is the gallery line, and *k* an excavated room for the boiler, the floor of which should be five feet below the floor line of the church.

By simply turning the cock in the gas-pipe which supplies the jets, the rarefaction in the shaft, and, consequently, the velocity and quantity of the air passed through the church, may be controlled with tolerable accuracy, and instantly proportioned to any greater or smaller number of persons assembled. The cost of piping and cock for bringing the gas to the jets has been found to be but trifling; and as they need only be lighted during the time the church is occupied for worship, which is seldom of longer duration than two hours and a half, the consumption of gas is not very great, and amply compensated by the beneficial result obtained.

The means most proper to be adopted for the plentiful supply of fresh air in the low-roofed, galleried and crowded meeting-house, will be found to consist in abundance of fresh-air openings all round under the windows, communicating by brick flues with the lower part of the spaces under the aisles and seats in which the hot-water pipes that are to warm the air should be fixed. Fresh-air flues should be constructed in all the piers between the windows, running as high as the gallery, to supply it with fresh warmed air. A vitiated air-flue should also commence in each pier under the gallery (in order to give free egress to that which would otherwise be intercepted and detained under the gallery) and pass up into a horizontal trunk, running over the roof, along each side, into the foot of the upright shaft below the gas-jets, as before explained. Openings should also be left in the roof, communicating with these horizontal trunks, to carry off the bad and heated air over the galleries. Hot-water pipes should be conveyed along the side-walls, under the floor, so as to warm the air that passes up within the piers into the gallery.

The leading points to be observed in such a case are delineated in the lower part of Fig. 3735, below the line *h i*.

3735.



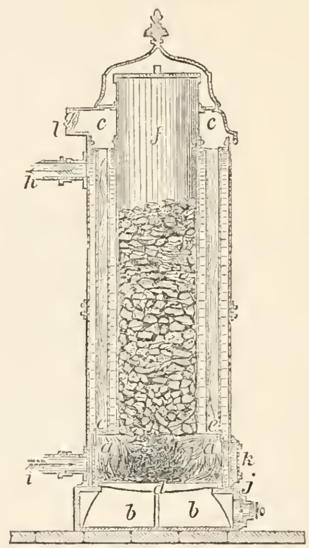
A much larger provision should be made for supplying fresh air to such a house for worship, or other galleried building, than in one which has no gallery, and which possesses the advantage of an open roof; and those who would object to the copious measures here recommended as unnecessary, should well consider the following facts and calculations. A chapel or meeting-house with large galleries nearly all round, capable of accommodating on special occasions 2000 persons, is frequently made about 75 feet square and 25 feet average height, giving a total cubic content of rather more than 140,000 feet. Now the authorities from Tredgold to Reid who have written on the subject of the quantity of fresh air required per minute by each individual, to replace that which such individual has rendered unfit for respiration, vary in their conclusions from 3½ to 10 cubic feet; and if 7 cubic feet be assumed to be the proper quantity, an allowance near the average of their scientific opinions will be given. The total quantity required, therefore, on this low standard in such a building, to maintain its atmosphere in a state of purity when filled, will be (2000 × 7 = 14,000 cubic feet every minute, and a like quantity of vitiated air must be carried off in the same time. The atmosphere of the building will therefore require to be completely changed or renewed (140,000 ÷ 14,000 = 10) *once in every ten minutes.* Let it now be supposed that the unusual provision of 16 openings has been made all round the building for fresh air, each opening measuring 18 inches by 6 inches. Deducting one-third of the area for impediment caused by gratings, will allow to each opening a clear area of half a superficial foot, and the aggregate area of all the openings will be eight feet. Now, to supply the required quantity of air (14,000 cubic feet) in the given time (one minute) through these openings, the air must pass through them all at the velocity of (14,000 ÷ 8 = 1750 feet per minute, or more than 20 miles per hour: which it will not do, especially on a calm day in hot weather, *when ventilation is most needed,* without the aid of some powerful stimulus; and if such artificial impulse be wanting, these openings will, under the circumstances, be quite insufficient to prevent the rapid deterioration of the atmosphere within, and ought, therefore, to be considerably enlarged. The bad effects of the usual way of obtaining a partial supply of air in such a case by opening the windows, have been already commented on.

Take another example from a large Gothic church, with galleries and lofty side-aisles and nave, in the neighborhood where this is written; measuring 80 feet by 65 feet, with a roof approaching to that ness, about 30 feet in average height. This church has often contained 1800 persons; its cubic contents being 156,000 feet, and the requirement of air, allowing, as before, seven feet per minute to each person, (1800 × 7 =) 12,600 feet. The time in which the whole atmosphere of this church would, when containing its full complement of persons, require to be changed, is (156,000 ÷ 12,600 =) 12½ minutes; and large openings will obviously be required to pass the quantity in the time.

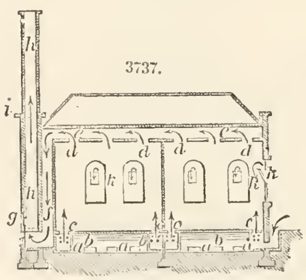
These figures will suffice to show the necessity for a very much larger provision for ventilation than has been customary in buildings containing galleries, in which the cubic contents bear a small proportion to the numbers assembled.

The management of the warming of a church being a matter frequently intrusted to a sexton or verger charged with other duties, which necessitate his making a clean appearance, and demand his exclusive attention during the service, it is a matter of some importance, where hot-water apparatus are used, to adopt such form of boiler as will require the smallest possible attention. The kind shown in Fig. 3736, in section, will be found to fulfil this requirement. In this, *a* is the fire-box; *b*, ash-box; *c*, smoke-box; *d*, fire-bars; *e*, smoke-tubes; *f*, fuel-box; *g*, damper; *h*, flow or steam pipe; *i*, return or condensation pipe; *j*, ash-box door; *k*, fire-door; *l*, smoke-pipe. Many large churches have been kept by it at a uniform temperature with only three attendances in twenty-four hours. This sort of boiler will be found very desirable in many other buildings besides churches. They are to be filled to the top with coke broken into small pieces, which falls on the fire as required. A very useful kind of Arnott stove has been largely adopted on the same principle.

3736.



3737.



The stove here described appears to us a very simple arrangement for effecting the purposes desired, and to be well worthy of adoption.

In the whole range of ventilation there is, perhaps, nothing so much neglected as the ventilation of schools; and as it is most desirable public attention should be turned to the subject, we give room to Mr. Walker's statement of his views on the subject:

Schools are frequently very crowded, and their atmosphere in a most unwholesome condition. The great increase in their number in the populous manufacturing districts, is a gratifying sign of the times, and affords good reason to hope that the succeeding generation will grow up with improved ideas and habits, and, as is most needful in those districts, stand some degrees higher than their predecessors in the scale of civilization.

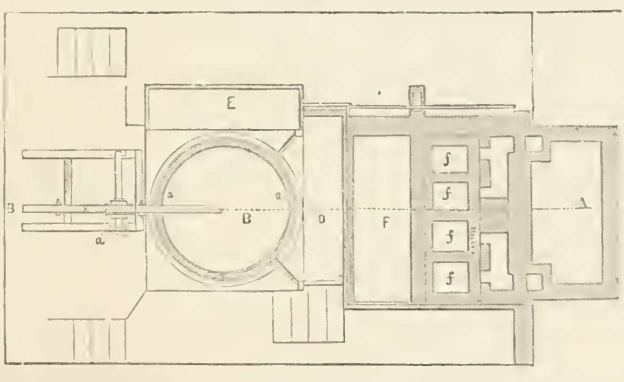
Fig. 3737 is a section representing a boys' and girls' school ventilated (except as regards the windows) in a satisfactory manner: *a a* are the fresh-air openings; *b b*, pipes for heating; *c c*, gratings for entrance of fresh warmed air; *d d*, openings for foul air, leading into a trunk *e*, whence it is drawn down the shaft *f* by the rarefying furnace *g*, whence it is discharged up the shaft *h* into the atmosphere.

This arrangement of a rarefied shaft, continued down to the ground for the purpose of obtaining a quick draught by a heated column, and requiring a down-shaft to connect the ventilating trunk from the top of the building with its lower end, so that the foul air may enter it below the fire, is the same that has been adopted, at very great cost, by Dr. Reid, in the new houses of Parliament. There is a complexity and expense about this arrangement which would seem to be needless. The drawing down to the ground level of the whole of the vitiated air of the building, and then sending it up again; the cost of connecting the main down-shaft with the up-shaft, which circumstances may require to be at a considerable distance; and the trouble of forming air-tight connecting-flues to convey the vitiated air from numerous rooms to one main down-shaft, to say nothing of the double space and materials occupied by the two shafts, would render this plan in numerous cases impracticable. To overcome some of these difficulties the fire has, in many cases, been provided for at the roof level, (*i*, Fig. 3737,) thus relinquishing the down-shaft and the lower part of the up-shaft, and so far has been an improvement; but in many cases the trouble of carrying up fuel and ascending to attend to the fire was too great, and the ventilation was, therefore, uncertain. The best mode of effecting forcible ventilation by a shaft doubtless is, to adopt the last-named arrangement; substituting gas rarefiers for a furnace, as shown in the church, Fig. 3735. By bringing the pipe which supplies gas to the burners to some accessible point near the ground-floor, with a stop-cock at that point, the handle of which should work in a graduated quadrant, the ventilation can be regulated from below with great precision.

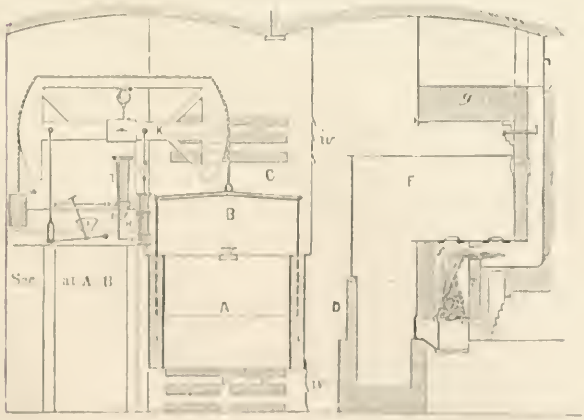
Window ventilation of a kind very frequently adopted in churches and schools, has been introduced into this figure, (*k*, Fig. 3737,) not with a view to represent it as part of Dr. Reid's system, but to illustrate its bad effects, either where it is the sole provision made, or where it is used in combination with a better process. If it be the sole provision made, and the room be heated by a fireplace or stove to 60°, a downward rush of air at 10° (should that low temperature happen to prevail outside at the time) will play upon the heads of those near it. If it be in force, as in the figure, simultaneously with proper means of introducing fresh warmed air, its force will be modified, and partially deflected upwards, towards the egress openings; but whatever cold air thus enters is so much deducted from that which ought to have entered warmed through the proper channel *c*.

Arnott's ventilating apparatus in use in the York County Lunatic Asylum, England.—The apparatus is shown in the annexed engravings, of which Fig. 3738 is a plan, and Fig. 3739 a section, taken through the centre from A to B. It consists of a fixed cylinder, placed in the centre of a room, and which cylinder is about 5 ft. 6 in. diameter and 5 ft. high, with a chamber above and below, each furnished with inlet-valves to receive the air from the fresh-air shaft, and outlet-valves to deliver the air into the adjacent chamber, and thence distributed through the building. The cylinder is made of galvanized iron, is

3738.



3639.



open at both ends, and has an outer case at about 3 inches distance, and the whole depth of the cylinder filled with water, which forms an annular hydraulic joint. Within this cylinder is another cylinder, 5 ft. 9 in. diameter, inclosed on the top, similar to the rising bell of a gas-holder; the rim of this cylinder works up and down in the water contained in the annular rim just described. By this arrangement the communication with the upper and lower compartments is cut off.

The working cylinder is suspended to the end of a movable beam about 10 feet long, and balanced by a weight or bob suspended at the other end, equal in weight to the movable bell, minus a sufficient weight to cause the bell to descend and expel the air in the lower compartment. Now, for the purpose of setting the beam in motion, it is necessary to have some movable power to overcome the friction of the movable parts and the air. For this purpose Dr. Arnott has adopted a single-action water-engine, having a cylinder 2 inches diameter and 12 inches stroke; to be supplied by water from a reservoir placed on the top of the building, 60 feet above the engine. A column of water of this altitude acts with a pressure of about 30 lb. on every movable square inch of the piston; and if the piston be 2 inches diameter, it will be equal in round numbers to 3 square inches, consequently the force of the water acting on the piston will be $3 \times 30 = 90$ lb.; and this is the power with which the Doctor proposes to work the apparatus, and as the engine is single-acting, the cylinder will require about a pint of water for every stroke. Thus, if the engine works 8 strokes per minute, it will require 8 pints of water, or 1 gallon per minute, to keep the beam moving.

This engine is placed so that the connecting-rod is connected with the movable beam at 1 foot from the fulcrum; and if the beam have a radius of 5 feet, and the working cylinder be suspended at the end of the beam, the bell will be elevated 5 feet at every stroke of the engine. When the piston has performed one upward stroke by the pressure of the water, the water is cut off by a slide-valve, and that which is within the cylinder is discharged into an open pipe; consequently, the extra weight of the movable parts will cause the piston to descend, and at the same time the working cylinder will also descend. Now, if we suppose that at the commencement of the working of the apparatus the working cylinder is close down on to the fixed cylinder, the upper compartment will be filled with air, and as it rises it will displace a quantity of air equal in capacity to the cubic contents of the working cylinder, and force it out of the valves that open outwards; and at the same time that the cylinder is rising, the space below is increasing equal in capacity to the cylinder, and a quantity of air rushes in through the valves opening inwards, and fills up the space; and when the bell begins to descend, the lower inlet-valves close and the lower outlet-valves open, and the air that is below is forced out through the outlet-valves of the lower compartment, and at the same time the air is being admitted into the upper compartment, as before described. By this means the action is double, and a constant stream of air is being taken in through either of the inlet-valves, and forced out through the upper or lower outlet-valves into the adjacent chamber, and thence through trunks and cases to all parts of the building.

Now, it has been shown that for every stroke of the engine the working cylinder displaces a quantity of air equal to its capacity in both the bottom and upper compartments; and as the capacity of the working cylinder is equal to 125 cubic feet, it displaces in both compartments 250 cubic feet for every upward and downward stroke of the engine, at an expense of one pint of water, descending from an altitude of 60 feet; and if the engine works 8 strokes per minute, it will displace 2000 cubic feet of air at an expense of 8 pints, or one gallon of water, which is equal to 2,880,000 cubic feet of air displaced by the aid of 1440 gallons of water for 24 hours. These are the proportions proposed by Dr. Arnott for ventilating York Hospital.

For the purpose of feeding the apparatus, pure air is brought down a shaft, the top of which is considerably above the top of the building, and which communicates at the bottom with the chambers before described; and if it be desired that the air be warmed, it is effected by allowing the air, as it is expelled from the chambers on its passage to the trunks, to pass between a series of hollow copper vessels filled with hot water.

The adaptation of the water-engine which Dr. Arnott proposes to adopt is particularly desirable, as it can be worked at comparatively little expense, and the water, after it has done its work in the engine, may be used for domestic purposes. It will also be seen that by this apparatus the whole of the air forced in for ventilation can be accurately measured if a counter be attached to the engine to show the number of strokes the engine has performed during the day.

Literal references.—Similar letters refer to similar parts in each figure.

A is a fixed cylinder, open at both ends with outer case *a*, filled with water, forming an annular hydraulic joint.

B, working cylinder inclosed on the top and open at the bottom; the rim works up and down in the hydraulic joint *a*.

C C′, upper and lower chambers, with inlet-valves *i v* opening inwards to take in the air from the external air-shaft E; and outlet-valves *o v* opening outwards to convey the air to the shaft D, and thence to the building through the trunk T.

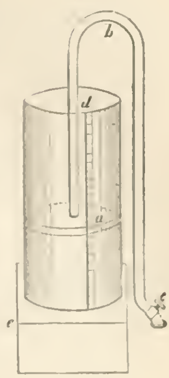
F, furnace-room, in which is placed the boiler with four square fire-boxes *f f f f*, to heat the water for supplying the copper cells *g*, when it is required to warm the air as it is being forced into the building; there are several of these copper heating cells placed side by side, with narrow spaces between for the air to pass through.

H, a water-engine, acted on by a column of water on one side of the piston, which is brought by a pipe *h* from a cistern placed on the roof 60 feet above; *j* is an air-vessel to prevent concussion by cutting off the water suddenly; *k*, geer for opening and shutting the eduction and induction valves; *l*, piston and connecting-rod.

K, balance-beam; at one end is fixed a chain to suspend the working cylinder, and at the other end is another chain to suspend a balance-weight *m*.

WATCHMAKING, or Horology—*the construction of instruments for the measurement of time.* The most satisfactory of the ancient instruments for the measurement of time, was the *Clepsydra* or water-clock; in which the hours were indicated by marks upon the side of a vessel filled with water, from whose bottom a small stream was allowed to flow out. As the water in the vessel ran off, its surface sank; and its height, as shown by the marks, indicated the time that had elapsed. It was soon found that the water does not run from such an orifice with a regular velocity; for, when the vessel is full, the pressure of the fluid is much greater than when it is nearly empty, and its flow will be proportionally faster.

3740



The simplest mode of overcoming the difficulty, arising from the unequal flow of water through an orifice in the bottom of a vessel, is shown in Fig. 3740. This clepsydra consists of a cylinder of glass, furnished with a float *a*, which carries the siphon *b*. When this siphon has been once filled with water, the fluid will run out at the cock *c*, until the whole water in the vessel has been drawn off. The rate at which the water is discharged may be regulated by the cock *c*; and as, by the connection of the siphon with the float, the mouth of the pipe is always at the same distance below the surface of the water, the quantity will always be the same, whatever be the height of the fluid in the vessel; and a scale *d*, on its side, divided into equal parts, will always indicate, by the place of the float, the lapse of equal intervals of time.

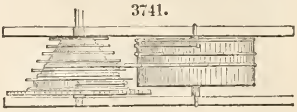
All these instruments, however, were but rude attempts to effect that which is at present accomplished far more perfectly by other means. By the combination of wheel-work (acting upon principles already described) with the *pendulum*, the laws of whose vibration have also been explained, clocks are now constructed, which indicate the passage of time with a degree of accuracy which it would have been thought but a short time since quite impossible to attain. It is to these instruments that the term *Clock* is now restricted. A watch is a portable instrument, in which the same mechanism is employed as in the clock, but in which, instead of a pendulum, there is a balance-wheel, whose vibrations are regulated by a spring. Any clocks or watches might be termed chronometers or time-measurers; but this name is now appropriated to those which are constructed with the utmost attention to the perfection of every part, and with means for compensating certain errors to which they are liable. The most perfect clocks are those constructed for astronomical observations, in which the greatest possible accuracy is required; and hence these are ordinarily termed astronomical clocks. It must be borne in mind, however, that these differ from ordinary clocks in no essential particular; though their appearance is often puzzling to those who see them for the first time, in consequence of the hour and minute hands being fixed on distinct centres, and pointing to different circles, instead of revolving about the same centre, and pointing to the same circle, as in ordinary clocks. Again, the most perfect watches are those constructed for the purposes of navigation, to which they give the most important assistance; and these, being much larger than ordinary watches, though constructed on the same principle, are distinguished as marine chronometers.

General principles—Moving and regulating powers.—The object of clock-work is to maintain the oscillations of a pendulum, by continually communicating to it a slight additional impulse; and, at the same time, to register the number of these oscillations, so as to indicate the passage of time. In order to effect these purposes, a train of wheels and pinions is put in motion by a power acting on the first of them, whilst the last is connected with the pendulum by a peculiar contrivance, termed the *escapement*. In clocks which are to remain stationary, and in which a saving of room is no object, the moving power is a weight, which is suspended by a string coiled round a drum or barrel; this drum carries the first wheel of the clock, and imparts to the train the movement it derives from the gradual descent of the weight. If the whole of this force acted on the wheel-work alone, which it would do if the escapement were taken off, the weight would run down comparatively fast, and the train would be caused to move with great rapidity. But a part of it is expended in keeping up the vibrations of the pendulum; and the connection of this with the wheel work is such, that not a tooth of the latter can advance, unless permitted to do so by the swing of the pendulum. Hence a clock will not go, even when wound up, unless the pendulum be set in motion; but when its vibrations have once commenced, they will continue until the string has been unwound from the barrel by the descent of the weight. In "winding up" the clock, we raise the weight by again coiling its string round the barrel; and thus communicate (as it were) to the machine a power which will keep it in action for a certain limited time. It would not be difficult to extend that time, to any desired amount, by adding to the number of wheels. Ordinary watches, and the commonest kinds of clocks, require to be wound up every day; chronometers for ships, and house clocks, are commonly made to go without winding for a week; many clocks have been constructed which only required winding once a month; and a few have been made to go for a year. It will be easily understood, upon the principle of the wheel and pinion, that the greater the multiplication of velocity, the greater will be the sacrifice of power; so that, the longer a clock is made to go—or, in other words, the more slowly its weight is made to descend—the greater must be the power required to produce the same effect; and the weight must therefore be increased in the same proportion.

In small portable clocks, however, and in watches and chronometers, a weight cannot be thus employed; and motion is given to the wheel work by means of a spring, made of elastic steel, and coiled in a spiral. One end is secured to a fixed point; and the other, in the effort to uncoil itself, will carry round any thing to which it may be attached. Now it is easy to understand, that a spiral spring, in uncoiling itself after having been tightly wound, exercises a much greater degree of force than it will do when it has become slackened; and therefore, if the spring were immediately connected with the wheel work, the impulse which it would give to the train would be much greater at the beginning than at the end of the action. An attempt has been made, in France, to correct this inequality, by making a variation of strength in different parts of the spring itself, so that it shall unwind with equal force, whether it be tight or slack; and if this can be effected, the spring may be made to act at once upon the first wheel of the train, as shown in Fig. 3745 where O P is the spring, of which the outer end O is fixed, so that the inner end, being fixed on the axis or spindle of the wheel N, carries that round in its effort to uncoil itself. But it is found impossible to make such a correction with sufficient accuracy; and a different method is generally adopted.

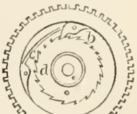
The spring is inclosed within a hollow barrel or drum, to which its outer end is attached; and the inner or central end of the spring is attached to a fixed axle. Hence, when the spring has been coiled up, its elasticity will carry round the barrel, in its attempt to uncoil itself. The barrel, in turning round, pulls a chain, which was previously coiled round a conical axle, which is termed the *fusee.* This axle carries along with it the first wheel of the train. In winding up the watch, we coil the chain round the fusee, and draw it off from the barrel; by which action the spring within the barrel is coiled up and its power becomes very strong. In attempting to uncoil itself, it pulls the chain, which now acts upon the *small* part of the fusee. When it has gradually uncoiled itself, the power of the spring is weakened; but by this time nearly the whole of the chain is coiled upon the barrel, having been unwound from the fusee; and its pull or strain acts upon the *large* part of the fusee. Now upon the principles stated in a former part of this work, the more distant the point to which a force is applied from the central axis, the greater will be its power of giving the required motion. When the spring is acting most strongly, therefore, its power is applied at a far less mechanical advantage than when its power is nearly exhausted; and thus its action on the spindle of the fusee is equalized, so that from a variable power it is made to become nearly as regular as that produced by the descent of a weight.

3741.



The contrivance by which, in winding up a clock or watch, we can turn the fusee without influencing the wheel-work, is shown in Fig. 3742. The first wheel is hollowed out to receive the small *ratchet-wheel d,* of which the teeth are so cut as to slant on one side, but to be upright in the other. In the same hollow, there is a movable click or *ratchet b,* which is pressed down by the spring *c.* Now if the ratchet-wheel be turned in the direction of the slanting sides of its teeth (that is, from left to right in the accompanying figure) it will not carry the large wheel with it; for the ratchet will be lifted by the inclined side of each tooth, and will consequently pass over them all. But if the ratchet-wheel be made to turn in the contrary direction, it will carry the large wheel with it; for the upright side of the tooth will be caught by the ratchet; so that any force applied to the ratchet-wheel will act upon the ratchet, and consequently upon the large wheel with which it is connected. Now the fusee is attached to the ratchet-wheel; and hence, when the fusee is being drawn by the chain in the direction last mentioned, it carries round the large wheel with it, and gives motion to the whole train; whilst, if the fusee be turned in the contrary direction, as it is by the key in the act of winding, the teeth of the ratchet-wheel lift the ratchet, and there is no motion given to the large wheel. The same contrivance is applied in clocks, to the drum round which is coiled the string that suspends the weight. In the better class of time-keepers, whether clocks or watches, there is another contrivance introduced into the fusee, by which the train of wheels is kept in motion during the time when the weight or spring is being wound up; so that the inaccuracy that would be otherwise occasioned by the stoppage of the movement (which any one may observe, who notices the second-hand of an ordinary clock or watch, whilst it is being wound up) is prevented. This contrivance is termed the *maintaining power* or *going-fusee.*

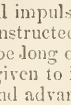
3742.



Having now considered the *moving* power, by which the train of wheels is kept in action, we shall examine the *regulating* power, by which its action is controlled. This, in all clocks now constructed, is the pendulum; whilst in watches and chronometers, it is a wheel termed the balance. The balance of a watch serves the same purpose as the pendulum, having the advantage of occupying much less space, and of acting equally well in almost any position. It consists of a wheel, having an axle which terminates in two very fine pivots, and so exactly balanced, as to be capable of being moved with a very small impulse in either direction. To the axle, however, is attached one end of a very delicate spiral spring; of which the other end is attached to the frame-work of the watch, as shown in Fig. 3747. Now the action of this spring is like that of any other elastic body; it will produce a certain degree of resistance to any change of position of the balance; and the greater the alteration of its place, the greater will be the resistance, until at last the force which set the balance in motion is overcome by it, and the rotation ceases. But the spring has been so much displaced, that it tends to bring the balance back to its original position, with a gradually increasing rapidity; and when it has arrived there, the force which it has acquired will carry it as far on the other side. Again this force is resisted by the spring, and again will this bring back the balance to its former position.

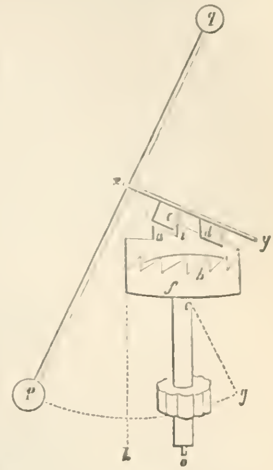
Thus a balance, provided with a spring that possesses perfect elasticity, and uninfluenced either by friction or the resistance of the air, would go on vibrating backwards and forwards without cessation. But three retarding influences really act upon it—want of perfect elasticity in the spring, so that each *reacting* force is somewhat less than the force which acted on it; friction of the pivots; and resistance of the air. Hence, in order to keep up these vibrations, it is necessary that a slight additional impulse should be continually given to the balance, as to the pendulum. When a balance is well constructed, its vibrations become almost perfectly *isochronous,* whether the space through which it moves be long or short; hence it is not much affected by moderate differences in the strength of the impulses given to it by the moving power, and in this respect has even advantages over the pendulum. It is found advantageous to construct the balance-spring of the best chronometers not in the form of a flat spiral, like that of the common watch, shown in Fig. 3747, but in that of a *helix* or cork-screw, as shown in Fig. 3743. And the balance itself is not a complete wheel, but is made in a peculiar form, which will be described hereafter, for the purpose of compensating the influence of heat or cold upon the spring. The time occupied by each vibration of the balance depends upon the strength of the spring—other things being supposed equal; and the strength is influenced by the length. A short spring, of equal thickness with a long one, is very much more elastic; hence, by shortening the balance-spring, we increase its elastic force; whilst by lengthening it, we diminish that force. The greater the elastic force, the shorter will be the vibrations of the balance, and the less will be the time occupied by each of them; consequently the time

3743.



piece will gain when the spring is shortened, and will lose when its length is increased. It is by slightly altering the length of this spring that a time-keeper is *regulated*, so as to go faster or slower than before.

3744.



The contrivance by which the pendulum or the balance is connected with the moving power, is termed the *escapement*. The simplest form of this is represented in Fig. 3744. Let *x y* be the axis on which the balance turns, or from which the pendulum is suspended; projecting from it in different directions are two leaves *c* and *d*, which are termed *pallets*. At *f b* is seen a crown-wheel, turning on a perpendicular axis *o e*; its teeth are cut like those of a saw; and the direction of its movement is from right to left,—that is, *f* moves towards *b*, whilst on the further side *i* moves towards *a*, and *a* comes gradually round to *f*. This wheel, termed the *balance-wheel*, is connected with the rest of the movement by the pinion on its axis, as will be shown hereafter. The pallets are so placed, with regard to the teeth of this wheel, that, as the axle turns from one side to the other by the swinging of the pendulum or the vibrations of the balance, the teeth are permitted to *escape* alternately from each of them, and thus the wheel turns round with an interrupted motion. In the figure, the pendulum or balance is represented as at the extremity of its excursion towards the right, and the movement of the axis has just allowed the tooth *a* to *escape* from the pallet *c*; whilst at the same time the tooth *b* is just about to fall on the pallet *d*. Now, whilst the pendulum or balance is moving to the left, that is, from *p* to *q*, the tooth *b* still presses against the pallet *d*, and is prevented by it from moving further on, until the pallet has changed its position so far towards the left, as to allow the tooth to *escape* from it. During all the time that the tooth is pressing against the pallet, the balance-wheel is communicating to the pendulum or balance, through its means, a part of the power by which it is itself moved; and thus supplies the impulse required to keep its vibrations up to the proper extent. When the tooth *b* has escaped from *d*, the tooth *i*, on the other side of the wheel, will drop against the other pallet *c*; and will remain pressing against it, in like manner, until the return of the pendulum or balance to the position represented in the figure lifts the pallet *c* sufficiently to allow the tooth *i* to escape from beneath it, as *a* had previously done. In this manner, then, the wheel is allowed to advance by an interval of half a tooth at each vibration of the pendulum or balance; and thus, if the wheel have 15 teeth, and the pendulum vibrate seconds, it will make one revolution in half a minute.*

This escapement was in use long before either the pendulum or balance-spring was applied to the regulation of time-keepers.

The escapement first used to connect the pendulum with the clock, precisely resembled that which has just been described. The axis of the crown-wheel was vertical, as in Fig. 3744; and the pendulum was attached to the horizontal axis *x y*. In fact, there was no essential variation from that representation, except that, instead of a cross-bar with weights *p* and *q* at either end, the lower portion only, *x p*, was left, to serve as a pendulum. It was found, however, that the extensive vibrations which a pendulum must make when so hung were injurious to the regular going of the clock; and various contrivances have been devised to prevent this source of error, by constructing the escapement in such a manner that the pendulum shall make shorter vibrations. These have completely superseded the use of this original escapement (termed the *crown-wheel* and *verge*) in clock-work; but it is still used in watches, where, indeed, it is an object to make the vibrations of the balance as extensive as possible. All ordinary watches are constructed upon this plan; and they are distinguished as *vertical* watches, because the last crown-wheel has a vertical or upright position, as seen in Fig. 3745.

The first watches that were made were as imperfect as the early clocks; and differed only from them in being made upon a smaller scale, and in the use of a spring instead of a weight, as the moving power. They had only an hour-hand; and most of them required winding twice a day. The invention of the spiral balance-spring followed the application of the pendulum to the clock, at no long interval; and thus both machines were made to receive the greatest possible improvement in the principles of their construction, at a very short interval. The honor of this invention is claimed by Huyghens, the Abbe Hautefeuille, a Frenchman, and Dr. Hooke. There can be little doubt that it is really due to the last of these; for he was able to produce proof that he had employed the balance-spring, and had applied for a patent for his invention, in the year 1658; whilst the claim of Huyghens was not made until 1674.

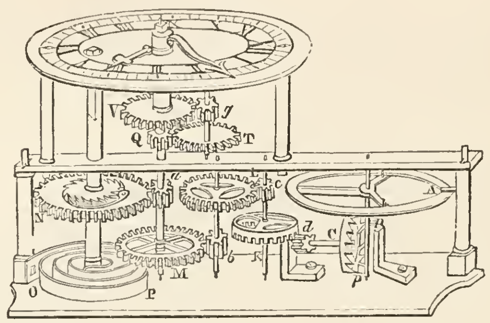
Construction of ordinary watches and clocks.—The general construction of an ordinary watch will now be explained. That of a clock is precisely the same, whether it be large or small; with the exception of the substitution of a weight and barrel for the mainspring and fusee. On opening an ordinary watch-case, we see that the wheel work is for the most part contained between two round plates, which are connected together by pillars. One of these plates is attached to the dial; but there is a thin space between them, which is occupied by the wheel work that connects the motion of the hour and minute hands. On the other plate is a raised portion, beneath which the balance works.

A general view of the work of a common watch, as seen from the side, is shown in Fig. 3745. For convenience of display, the parts are all arranged in one line, instead of being disposed in a circle as they really are; and, in order to make them more distinguishable, the distance of the two plates, between which most of the work is contained, is much increased; as is also the space between the upper

* A crown-wheel of this kind must always have an *odd* number of teeth; else the teeth on the opposite sides would come against the pallets at the same time.

plate and the dial, which really lie close together. The *balance* is seen at A; and on its axis or spindle are the two *pallets p p*, which together constitute what is termed the *verge*. At C is seen the *balance-wheel*, the teeth of which resemble those of a saw. By the vibrations of the balance, the teeth of this wheel are permitted to escape from each of the pallets alternately, as already explained. On the axis of the balance-wheel is a pinion *d*, which is driven round by the crown-wheel K. This wheel is termed by watchmakers the *contrate-wheel*. On the axis of this last is a pinion *c* which works into the *third-wheel* L; and the axis of the third-wheel is another pinion *b* which works into the wheel M, termed the *centre-wheel*, from its position in the centre of the watch, (see Fig. 3746, *e*.) The axle of this wheel passes up through the centre of the dial, and carries the minute-hand; making one complete revolution in an hour. Upon this axle is placed the pinion *a* which works in the *great-wheel* N. This wheel is acted on by the mainspring, which is either fixed upon its own axis, as represented at O P in this figure, or is contained within a *barrel* or circular box, which acts by means of a chain upon the *fusee* which carries the great-wheel, as already explained. Upon the axis of the centre-wheel, between the upper plate and the dial, is fixed the pinion Q; and this drives the wheel T. Upon the spindle of this wheel is a pinion *g* which works into the wheel V. The axis of this last wheel is hollow, so as to allow the axis of the centre-wheel to pass up through it; and upon this hollow spindle the hour-hand is fixed.

3745.



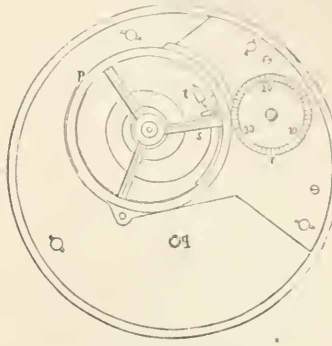
It is seen, then, that in the watch, as in the clock, the moving power acts on a wheel which drives a pinion; that this pinion carries on its axis a wheel, which drives another pinion carrying another wheel; and so on. Hence there is a continual increase of velocity, and at the same time a loss of power. The revolution of the balance-wheel *c* is very rapid in proportion to that of the great-wheel N, but its force is less in the same proportion; so that the slightest interruption (such as a thickening of the oil on the teeth and pivots) is sufficient to check the movement of the former, whilst the power of the latter, communicated to it by the spring, is sufficient to overcome a considerable resistance.

Many different trains may be adopted, to give the required proportions between the times of revolution of the several wheels; since their rates depend not upon their *absolute* number of teeth, but upon the proportion between the teeth of the wheels and the leaves of the pinions. The centre-wheel must, of course, make one revolution in an hour; the balance-wheel is generally made to turn 9½ times in a minute; whilst the great-wheel makes one revolution in about four hours; so that, if the spring can turn it seven times round, the watch will go for 28 hours. The following is the *train* (or arrangement of the number of teeth in the wheels and pinions) usually adopted in common watches. The *great-wheel* N has 48 teeth, and the pinion *a* into which it works has 12 teeth; consequently this pinion will make four revolutions whilst the wheel revolves once; and if the great-wheel turn round in four hours, the centre-wheel will make one revolution every hour. The *centre-wheel* M has 54 teeth, and the pinion *b* has 6 leaves; so that it, together with the third-wheel, turns round nine times, whilst the centre-wheel revolves once, and hence makes nine revolutions in an hour. The *third-wheel* L has 48 teeth, and the pinion *c* has 6 leaves, so that the velocity is again multiplied by 8; and the contrate-wheel which is on the axis of the pinion *c* will make (8×9) 72 turns in an hour. The *contrate-wheel* K also has 48 teeth, and the pinion *d* into which it works has 6 teeth, so that a further multiplication of velocity takes place, to the amount of 8 times; and the balance-wheel C, which is carried round by the pinion *d*, turns (72×8) 576 times in an hour, or about 9½ times in a minute. The *balance-wheel* C has 15 teeth, and *half* of one of these *escapes* with every turn of the balance; hence there are about $(9\frac{1}{2}\times15\times2)$ 305 impulses given to the balance in a minute, so that each of its vibrations occupies 60-305th parts, or about 1-5th of a second.

It is often an object, however, to cause the fourth or contrate wheel to revolve exactly once in a minute; so that its spindle may carry a hand which shall indicate seconds on the dial. This may be done by making the balance perform exactly five beats in a second, and by giving 15 teeth to the balance-wheel, 6 leaves to its pinion, and 60 teeth to the contrate-wheel. The contrate-wheel, in turning once round, causes the balance-wheel to revolve 10 times; and hence the number of escapes its teeth will make is $(10\times15\times2)$ 300 in a minute, or one in every fifth part of a second. Or the balance may be adjusted to beat nine times in two seconds; and then the number of teeth in the contrate-wheel must be nine times that of the pinion it turns—that is, 54 to 6, or 63 to 7. Or the number of beats may be four in a second; and for this arrangement the contrate-wheel must have eight times the number of teeth in the pinion it turns—that is, 48 to 6, or 54 to 7. When the contrate-wheel is to be thus made to turn 60 times in an hour, instead of 72, (as in the ordinary train,) the number of teeth in the centre-wheel and third-wheel, and the number of leaves in the pinions they turn, must be regulated accordingly. The usual plan is to give the centre-wheel 64 teeth, and to the pinion it turns 8 leaves; so that this pinion, carrying with it the third-wheel, revolves eight times for each turn of the centre-wheel. The third-wheel, having 60 teeth, works into a pinion of 8 leaves; and this last, carrying the contrate-wheel, turns $7\frac{1}{2}$ times for each revolution of the third-wheel. Hence the contrate-wheel turns ($8 \times 7\frac{1}{2}$) 60 times for each revolution of the centre-wheel; and as the latter makes one revolution in an hour, so does the former complete one in each minute.

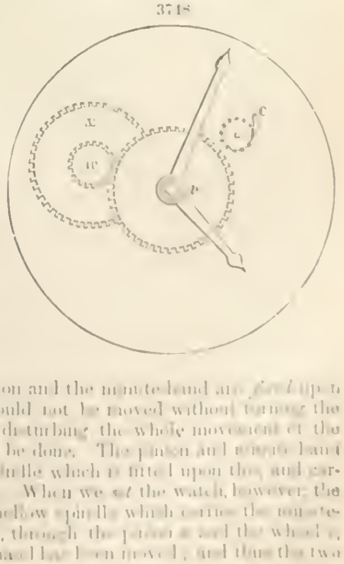
3746.

3747.



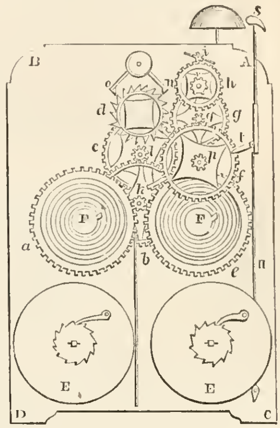
The mode in which the parts of a watch are actually arranged is shown in Fig. 3746, representing the interior of a watch, from which one of the plates has been removed, seen from above. Here *a* is the barrel, containing the mainspring coiled within it. By the elasticity of this, the barrel is made gradually to wind upon itself the chain *b*, which was previously coiled around the fusee, and thus to give motion to that fusee, which carries round with it the great-wheel *c*. The pinion turned by the great-wheel is seen at *d*; and this carries on its axis the centre-wheel *e*. It is the spindle of this wheel which, prolonged through the dial, carries the minute-hand. The wheel *e* turns the pinion *f*, which carries round the third-wheel *g*; and this works into the pinion (which cannot be shown in this view) that carries round the contrate-wheel *h*. This wheel turns the pinion *i*, which carries round the balance-wheel *k*. The balance itself and the verge are supposed to have been removed with the upper plate, which is shown separately in Fig. 3747. This gives a view of the back of the works of an ordinary watch, as seen when the case is opened. The balance is seen at *p*; its spiral spring is shown by *s*; and the end of this is fixed at *t*. In order to regulate the length of this spring, so as to bring the vibrations of the balance precisely to their required number in a minute, there is a movable piece, marked *o*, through a slit in which the balance-spring passes. This piece (which is termed the *curb*) can be made to travel towards one side or the other, by means of a wheel acted on by the circular scale *r*, to which the key is applied for the purpose of regulating the watch. The position of the curb *o* determines the *acting* length of the balance-spring, since the part between *o* and *t* is cut off, as it were, from the rest. Hence, if the curb be moved towards *t*, the acting length of the spring is increased; whilst, if it be moved away from *t*, the spring is shortened. The effect of this alteration has been already explained. At *q* is seen the square end of the spindle of the fusee, to which the key is applied for winding the chain off the barrel. In Fig. 3748 is shown the work which lies between the dial and the plate on which it rests, having for its object to give motion to the hour-hand. The wheel *x* is turned by a pinion on the axis of the centre-wheel, concealed in this figure by the wheel *v*, but shown at *d* in Fig. 3746. The wheel *x* carries round with it the pinion *w*, which gives motion to the wheel *v*; and on the hollow spindle of this last the hour hand is fixed. The number of teeth in these wheels and pinions must be so proportioned, therefore, that the wheel *v* shall turn round with only 1/12th of the velocity of the central axis. Thus, suppose the centre pinion to have 15 teeth, and the wheel *x* to have 60 teeth, the latter will only revolve once whilst the former revolves four times. Again, if the pinion *w* have 20 teeth, and the wheel *v* have 60 teeth, the wheel *v* will turn round once whilst the pinion *w* revolves three times, and the central pinion (3×4) 12 times.

3748



It is not exactly correct to say, however, that the central pinion and the minute-hand are *fixed* upon the spindle of the centre-wheel; for if they were, the hands could not be moved without turning the centre-wheel, and we should not be able to *set* them, without disturbing the whole movement of the watch. There is a very simple provision for permitting this to be done. The pinion and minute-hand are fixed, not to the axis of the centre-wheel, but to a hollow spindle which is fitted upon this, and carried round by friction, so long as there is no opposing resistance. When we *set* the watch, however, the central axis remains unmoved, and we merely turn round the hollow spindle which carries the minute-hand and the pinion. This pinion acts upon the wheel *x*, which, through the pinion *w* and the wheel *v*, turns the hour hand one twelfth of the amount that the minute-hand has been moved; and thus the two are always made to turn conformably to each other whether they be carried round by the going of the watch, or by the action of the key in setting it. If the face of any ordinary watch be examined, there will be seen a small round spindle projecting in the centre. This is the spindle of the centre-wheel Inclosing this is the first hollow spindle, which carries the minute-hand, and which is squared at the top to receive the key; and this is again inclosed in a second hollow spindle, to which the hour-hand is attached. These are seen in Fig. 3745. Precisely the same means are adopted to connect the motion of the two hands in ordinary clocks; but where great accuracy is required, as in clocks used for astronomical observations, it is desirable to avoid unnecessary friction as completely as possible. This is done by making the hour-hand turn on a different centre from the minute-hand; and the former receives its motion from the latter, by means of a wheel containing 12 times as many teeth as the pinion which turns it, and therefore making its revolution in 12 times the period. In astronomical clocks, however, the hour-circle is not unfrequently divided into 24 parts, instead of 12; and the hand requires a whole day and night to traverse it. The object of this is to avoid any mistake, arising from the same numbers being repeated twice between noon and noon, or midnight and midnight. Some clocks have been constructed, especially at Venice, to strike all the numbers, from 1 to 24; but in this there can be no advantage.

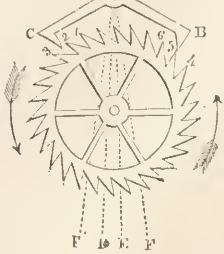
3749.



The mechanism of a portable eight-day clock is represented in Fig. 3749. Of the two barrels, fusees, and trains of wheel-work here seen, the one on the right-hand side alone has for its office the measurement of time. The other is called the *striking-train*, and its office will be separately considered. The works are arranged, as in the watch, between the plates, in which are holes for the pivots of the axles of the various wheels, &c. The front plate is attached to the dial, with an interval in which the hour-hand movement is contained, as in the watch. This interval also contains the mechanism by which the striking is regulated. The dial and the front plate are supposed to be here removed, so as to give an uninterrupted view of the train of wheels. The back plate is shown by the letters A B C D. The springs inclosed in the barrels E E give motion to the fusees F F, as in the watch, either by a chain or a piece of catgut. The main-wheel *a* of the going-train has 96 teeth, and this acts on the centre-wheel pinion *k*, having 8 leaves. This pinion carries with it the centre-wheel *b*; and on the same spindle, as in the watch, the minute-hand is placed. The centre-wheel *b* acts on the pinion *l*; and this carries round with it the third-wheel *c*. This third-wheel, in its turn, acts on a pinion (not seen in the engraving) which carries round the scape-wheel *d*; and this wheel, acting on the pendulum by the pallets *n o* of the escapement, communicates to it the impulse received from the spring, whilst its own motion is entirely determined by the duration of the vibrations of the pendulum. For if, on the very same escapement, we were to hang a pendulum of 9¾ inches, another of 39 inches, and another of 13 feet, the duration of each beat, and consequently the interval between the *escape* of each tooth, would be half a second in the first pendulum, a second in the next, and two seconds in the last.

The number of teeth in the wheels and pinions, therefore, must depend upon the length of the pendulum. Thus, for a pendulum vibrating seconds, the number of teeth in the scape-wheel is usually 30, since, as the wheel only advances to the amount of half a tooth at each *escape*, its revolution is then performed in a minute, and it may be made to carry a seconds-hand. If the centre-wheel and the third-wheel have 64 and 60 teeth respectively, and their pinions have 8 leaves, the multiplication of velocity will be ($60 \times 64 \div 8 \times 8$) exactly 60; so that the scape-wheel will turn round 60 times for one revolution of the minute-hand. Where the pendulum vibrates half-seconds, however, it would be necessary to make the scape-wheel with 60 teeth, if it be required to perform but one revolution in a minute. Small portable clocks, however, such as those designed for a table or mantel-piece, are not made with a seconds-hand; and in these the scape-wheel is made with a small number of teeth, and revolves in a shorter time; the number of teeth in the wheels and pinions which connect it with the centre-wheel being adjusted accordingly. In a clock now before the author, the centre-wheel has 84 teeth. This turns a pinion of 7 leaves, which must therefore revolve 12 times as fast, or once in every five minutes. This pinion carries round with it the third-wheel, which has 77 teeth in it; and the latter drives the scape-wheel by a pinion of 7 leaves, so that a velocity of 11 to 1 is gained. The scape-wheel goes round, therefore, 11 times in five minutes, or once in somewhat less than half a minute. It has 32 teeth; and the pendulum, being not quite eight inches long, allows each to escape in rather less than half a second.

3750.



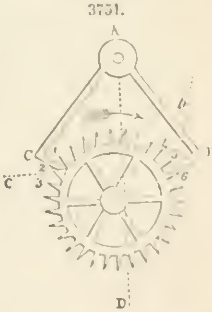
Clock-escapements.—The construction of the anchor-pallet escapement, (so called from its having some resemblance to an anchor,) which is now applied to nearly all ordinary clocks, is seen in Fig. 3750. The scape-wheel has its teeth cut upon its edge, and not raised up as they are in the scape-wheel of a verge watch. The centre from which the pendulum is suspended, is seen at A; and the same point is the centre of motion of the piece of metal A B C, which is termed the *crutch*, the extremities B and C being the pallets. This crutch is usually not fixed to the pendulum, since it is convenient to detach the latter, when the clock is to be moved from one place to another; but it is so connected with it, that, as the pendulum swings from side to side, the two ends of the crutch move up and down. The position of the crutch shown in the figure is that which corresponds with the direction A E of the pendulum. If the pendulum be carried to A F, the end B of the crutch would be raised still more; whilst if it swing to the other side

A F′, the end B of the crutch would sink between the teeth of the scape-wheel, whilst the end C would be raised quite clear of them. The scape-wheel is driven by its pinion in the direction of the arrows; but its motion suffers interruption by the alternate locking and disengagement of its teeth against the pallets of the crutch; and as the movements of these depend upon the pendulum, its time of vibration regulates the period in which the wheel revolves.

In the position of the escapement shown in the figure, the pendulum is to be supposed to be at E, and to be moving towards F. Now the elevation of the pallet B, against whose under side tooth 5 was previously pressing, has disengaged the point of that tooth; and the scape-wheel is consequently at liberty to move onwards. But it is prevented from doing so to more than the interval of half a tooth; for whilst the pallet B was being withdrawn from the space between 5 and 6, the pallet C was sinking into the interval between 2 and 3; consequently the wheel's revolution is checked by the fall of the point of tooth 2 against the upper surface of the pallet C. But as the pendulum continues to swing to F, the pallet C is still further lowered; and it gives a slight backward impulse to the tooth which was resting upon it, and consequently to the whole wheel. This backward movement, termed the *recoil*, may be seen in the seconds-hand of any common clock; this hand being attached to the scape-wheel, and carried round with it. Having completed its swing to F, the pendulum begins to move back again, and in doing so it is assisted by the pressure of tooth 2 against the upper surface of the pallet C. This pallet is gradually withdrawn from the tooth that rests upon it, so that this at last escapes. But in the mean time the pallet B has sunk into the interval between 5 and 4; so that when tooth 2 has escaped from the pallet C, tooth 4 drops against the under side of pallet B. The further motion of this pallet, which continues until the pendulum has reached the position F′, again causes the *recoil* of the wheel; but when the pendulum begins to swing back towards D, it is again assisted by the moving power of the wheel, which tends to make the tooth 4 (now resting on pallet B) press that pallet towards the left. When the pendulum has moved to E, tooth 4 escapes, as 5 had done before; and tooth 1 falls upon the pallet B, as 2 previously did; tooth 5 having in the mean time moved on to 6, and tooth 2 to 3.

The objection to the recoil escapement consists chiefly in this, that the impelling power of the weight, communicated through the train of wheels, is acting on the pendulum, by means of the inclined surfaces of the pallets, during the whole of each of its vibrations. Hence, any inequalities in the moving power are liable to produce a considerable effect on the pendulum, so as to vary its rate of vibration; and such inequalities are continually liable to occur from various causes. It was to avoid this source of error that the *dead-beat* escapement was invented by Graham, a celebrated clockmaker at the commencement of the last century, to whom we owe also the invention of the mercurial pendulum. The peculiarity of this escapement consists in the form of the pallets; the surface of each of which is partly a circle, having the point of suspension for its centre, and partly an inclined plane. The construction and action of this escapement are seen in Fig. 3751. The centre of suspension is at A; whilst A B and A C are the two legs of the crutch, moving from side to side with the vibrations of the pendulum, whose line of direction is shown by A D. The scape-wheel moves in the direction shown by the arrow; and the position of the whole is seen to be such in Fig. 3751, that the pendulum having nearly reached the limit of its vibration on the left hand, the tooth 6 has *escaped* from the pallet B, having just slid off the inclined portion of its surface, of which the dotted line *b* shows the direction. The tooth 2 now drops against the pallet *c*, and the further motion of the scape-wheel is thereby checked. The pendulum then begins to vibrate towards the right, carrying with it the crutch; so that the pallet B enters the interval between the teeth 5 and 6; whilst the pallet C is drawn out from the interval between 1 and 2. During this movement, however, the scape-wheel remains at rest; for so long as the tooth 2 bears upon the circular part of the pallet C, it does not either advance or recede, and its moving power is not communicated to the pendulum. But as soon as the pallet C has been sufficiently withdrawn for the edge of the tooth 2 to press against the inclined plane, of which the dotted line *c* is a continuation, the wheel is allowed to move forwards; and it communicates an impulse to the pendulum, which aids it in its vibration.

3751.



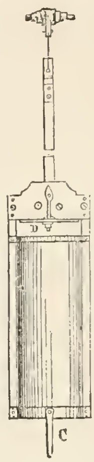
When the pallet C has been completely withdrawn by the continued motion of the pendulum, the tooth 2 is entirely disengaged from it; and the wheel would move onwards, but for the check it receives on the other side. Whilst the pallet C was being withdrawn, the pallet B was entering the interval between 5 and 6; consequently, just as the tooth 2 is disengaged from the former, tooth 5 falls upon the upper surface of the latter.

The pendulum, having completed its vibration towards the right, commences its return; and whilst it is moving in that direction, the tooth 5 remains at rest, and the whole wheel is consequently stationary, until the pallet B has been withdrawn far enough for the tooth to rest against the inclined portion of its surface. When it does so, the wheel again begins to move onward, and gives the pendulum a fresh impulse, in a contrary direction to the first. When the pallet B shall have been completely withdrawn, and the pendulum have arrived at D, the tooth 5 will be disengaged and will take up the position of the tooth 6 in Fig. 3751.

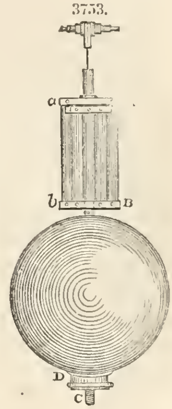
Hence, during a large part of each vibration of the pendulum, the scape-wheel is stationary, in consequence of the resting of its teeth upon the circular portion of the pallets; and it is only whilst they are sliding down the inclined plane, which action occupies but a small proportion of the whole time, that the wheel moves on. Its movement, therefore, as indicated by the seconds-hand, is a succession of jerks, very different from the recoiling movement of the scape-wheel of the ordinary clock. As the dead-beat escapement is the one now universally adopted in this country for the best kind of clocks, whether those designed for astronomical purposes or for *regulators* of time, such as almost every watch maker possesses,) and also in many large public clocks, most of the readers of this description may ob tain the opportunity of observing its action.

Compensation pendulum.—Although every part of a clock may be constructed with the greatest perfection, its performance will be very inaccurate, unless it be provided with the means of compensating for those changes which result from an alteration of temperature. A very minute difference in the length of a pendulum will produce a decided influence upon the rate of going of a clock. For if this alteration be so trifling as to cause an increase or decrease of the time of each vibration by 1-1440th part of its whole length, it will occasion the clock to lose or gain a minute in every twenty-four hours—a minute being the 1-1440th part of a day. The alteration in length required to produce a difference of a second a day will therefore be almost inconceivably small, and such as a trifling variation in the temperature of the air would be sufficient to produce. The amount will vary with the material employed. If the pendulum-rod be of dry varnished deal, an alteration of the temperature to the amount of 10° (Fahr.) will only affect its going by one second a day. But if iron wire be employed, the alteration is three times as great; and it is increased to five seconds by employing brass. Hence, to insure the accurate going of a clock, some means must be devised to compensate for this source of error.

3752.



3753.



This compensation is sometimes effected in clocks by the apparatus termed the *mercurial pendulum*, the form of which is shown in the annexed drawing, Fig. 3752. The rod of the pendulum consists of a flat piece of steel, which is formed at the bottom into a kind of stirrup, to carry a glass jar securely fixed to it. This jar is partly filled with mercury, which serves as the weight or bob of the pendulum. When a change of temperature causes the steel rod to expand downwards from its point of suspension, it also occasions an expansion of the mercury upwards from the bottom of the jar; and as the expansion of any given bulk of mercury is many times greater than that of the same bulk of steel, the rise of the mercury in the jar counteracts the lowering of the whole jar by the expansion of the rod; so that the place of the centre of oscillation remains the same, and the rate of vibration continues unaffected. The quantity of mercury requisite for the purpose can only be accurately determined by experiment; but in general it will be found that the height of the column should be about 6·7 inches. If the column is not high enough, its expansion will not counteract that of the steel rod; if it be too high, the pendulum will be over-compensated, so that heat will cause it to gain, and cold to lose,—contrary to the usual rule. Of course what has been said of the mode in which the two expansions balance each other, equally applies to the contractions which will take place, in the steel rod and in the mercury, from the operation of cold. The absolute length of the pendulum is adjusted by a screw at D, by turning which the stirrup is raised or lowered upon the rod. At C is a projecting index, which points to a circular scale below, by which the pendulum's arc of vibration may be observed from time to time.

A very simple compensation pendulum, which may be applied to any clock at the most trifling expense, consists of a wooden rod, dried and varnished; carrying at its lower end, by way of bob, a hollow leaden cylinder, which rests on a screw at the bottom of the rod. If the rod be made about 46 inches long, and the lead cylinder about 14 inches long, it will nearly vibrate in seconds, (since the centre of oscillation will be at about the middle of the leaden cylinder, and therefore at about 7 inches from the end of the rod;) and the expansion of the lead upwards is sufficient, or nearly so, to counteract that of the rod downwards. There is another very ingenious compensation pendulum, which was invented by Harrison, to whom we are so much indebted for his improvements in chronometers. This is termed, from its form and aspect, the *gridiron* pendulum. (See Pendulum.) Many other contrivances have been devised for the same purpose; but they are not superior to these.

The regular going of a clock will partly depend also upon the steadiness with which it is fixed; and it is therefore desirable that a clock for scientific purposes should be as firmly supported as possible. After all, however, there is one source of error for which it does not seem easy to devise a remedy;—this is the varying density of the air, which will produce a variation in the resistance to the motion of the pendulum. When the air is dense, as shown by a rise of the mercury in the barometer, the resistance is increased, and the clock will go slower; the contrary result occurs when the pressure of the air is diminished, as shown by a fall of the mercury. An attempt has been made to correct this error, by attaching small barometers to the sides of the pendulum; it being intended that the rise of the mercury in the tube, by slightly raising the centre of oscillation, should counterbalance the effect of the increased resistance. This ingenious idea has not yet been properly applied to practice. To show the perfection at which clockmaking has arrived, it may be mentioned that several clocks are now going, whose errors are less than 1-10th of a second daily.

Watch escapements.—As in the clock it is desirable to remove the pendulum as much as possible from the *constant* influence of the moving power, so is it desirable in the watch to withdraw the balance from the same influence, slight variations of which (such as must be continually occurring from various causes) must otherwise greatly affect its regularity. In order to effect this, various kinds of escapements have been devised.

The vertical escapement is the oldest escapement of all, which, after having first been adopted in clocks, was applied in the construction of watches. Its nature is explained by Fig. 3754, (*a* contrate-wheel, *b* escape or wheel, *c* the verge, *d* the balance.) That which is here called the balance-wheel was, when originally applied in a horizontal position to the primitive clocks, termed the crown-wheel evidently from its resemblance to a crown: this same wheel, when employed in the watch, (supposing the latter to be placed on its face or back,) obviously revolves vertically to the plane of the horizon; hence, watches made with this escapement are termed vertical. Watches are still manufactured on this principle, which has its conveniences, as it is understood in every part of the world where a man pretends to repair watches, and is the cheapest of all movements, and perhaps for this reason will never be wholly superseded.

In this escapement, as in the common recoil escapement of clocks, the teeth of the balance-wheel are continually pressing on the pallets, in such a manner as to be exercising a constant influence over the vibrations of the balance; and a fresh impulse is communicated at each vibration. In all the improved escapements, the balance is so *detached* from the train of wheels, that it only receives a momentary impulse from the moving power; and in the intervals, the whole train of wheels is checked. In general this impulse is communicated only at every second vibration of the balance; that is, the balance, after receiving one impulse, completes its vibration in that direction and returns to the same point again, before it receives the next.

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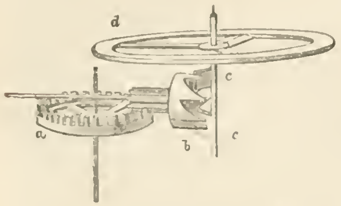

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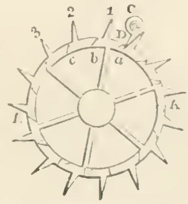

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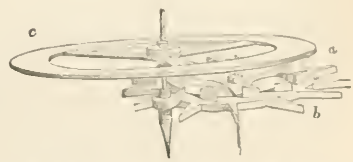

One of the contrivances by which these objects are fulfilled, is that known as the *duplex* escapement, so named from the escapement-wheel having two sets of teeth on its rim; the action of which will be easily comprehended by reference to Figs. 3755 and 3756. A A represents the scape-wheel, which is provided with two sets of teeth;—1, 2, 3, &c., projecting from its sides, and termed the teeth of repose;—and *a b c*, &c., rising from the surface of the wheel, and termed the teeth of impulse. On the axle of the balance there is fixed a piece C D, termed the impulse-pallet; this stands just above the surface of the scape-wheel, so that the teeth *a b c* must strike the projecting portion D, when the wheel revolves. On the same axis, but placed a little below it, so as to be on the level of the teeth 1, 2, 3, &c., is a small roller made of ruby; this has a notch cut out of one side of it, as seen in Fig. 3755. The scape-wheel is constantly being urged, by its connection with the going-train, in the direction from 3 to 1; and consequently, in the position represented in Fig. 3755, the tooth *a* is just about to strike the impulse-pallet D. The impulse being given, the balance moves round, and the tooth *a* escapes from the pallet. The next tooth *b* does not immediately fall against it, however; since, before it can do so, the tooth 1 has been stopped against the ruby roller. There it is held, during the vibration of the balance and its return, until the roller comes back into the position shown in Fig. 3755, which will permit the point of the tooth 1 to pass by the notch; so that the tooth *b* may fall on the pallet D, and give the balance a renewed impulse just as its next vibration is commencing. Thus it is seen that the teeth *a b c* are those which give the impulses to the pallet; whilst by means of the check which, in the intervals, the points of the teeth 1, 2, 3 receive against the ruby roller, the train is kept in repose.

Fig. 3756 is a perspective view of this escapement, the cogs *a* being placed upright nearer the centre, while the long teeth *b* are in the plane of the wheel; hence arises a *double* action: *c* is the balance. This escapement is of English invention: watches having it are perhaps to be ranked next to the chronometer in value, particularly as regards the length of time which they will continue to perform without cleaning, or requiring a fresh application of oil.

To this movement there are, it must be acknowledged, some objections. It is of very delicate construction, and if not made and put together by a workman of superior talent, the watch is liable to stop in the pocket.

This escapement is not so commonly employed, however, as the one known under the name of the *detached lever*. This essentially consists of the dead beat escapement, applied to the balance in such a manner, that a straight piece prolonged from the anchor or crutch, on the other side of its centre of motion, shall give a momentary impulse to a ruby roller fixed on the axle of the balance, each time that either of the pallets escapes.

Neither of these, however, is equal in perfection to that known, after the name of its inventor, as Earnshaw's detached escapement. This is the one at present universally employed for chronometers and the most accurate time-keepers; and nothing but the delicacy of its construction, and its consequent expensiveness, prevents it from coming into general use. Its action will now be explained by the help of Fig. 3757. A A represents the scape wheel, the teeth of which, 1, 2, 3, 4, &c., are considerably *undercut* on the side or face towards which they move. At B B is shown the steel roller or main pallet, which is fixed on the axle of the balance. This has a large notch cut in it; and the side of this notch nearest the tooth 1 is guarded by a thin plate of ruby, on which the points of the teeth strike as they pass it. The same arbor carries the small lifting pallet *q*, which has a projection on one side, that lifts the end E *p* of the locking lever or detent next to be described. This lever E E has its centre of motion at *c*, where it is attached by a screw to a stud S, which is firmly fixed to one of the plates of the chronometer. Near this stud, the lever is made thin and elastic, so that it has a springing power which keeps it pressing towards the scape wheel, unless removed from that position. It is prevented from pressing too far, however, by the screw *d*, which is fixed into the stud D; for the head of this screw acts as a *stop* to the lever, and prevents it from

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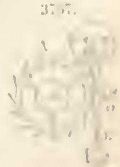

moving further towards the right than the place in which it is seen. At the other end of the lever is an extremely delicate spring *p*, which extends a little beyond the extremity of the detent. In the middle of the lever is the pin *o*, which serves to stop the teeth of the scape-wheel, when the detent is in the position represented in Fig. 3757, which is that of repose.

The following is the mode in which these parts act upon one another. The tooth 5 of the scape-wheel is seen to be resting against the pin *o*; whilst the tooth 1 is nearly ready to advance and strike the ruby face of the main-pallet B B B, but is prevented from doing so by this locking of the wheel. The balance, however, being in motion from right to left, (by the elasticity of its spring,) carries round with it the lifting-pallet *q*, the projection on which acts against the end of the lifting-spring; and this spring, pressing against the end of the detent E E, raises it a little from its place, towards D, so as to withdraw the pin *o* from the point of the tooth 5. The wheel being thus unlocked, the tooth 1 strikes against the ruby face of the main-pallet, and gives the balance an impulse, which increases the extent of its vibration. Before the tooth has entirely escaped, however, from the ruby face, the lifting-pallet *q* has completely passed the point of the lifting-spring *p*; so that the detent is at liberty to fall back into its place, which it is caused to do by the spring at its fixed end. Hence, by the time that the tooth 1 has escaped from the main-pallet, the pin *o* will be in a position to check the next tooth 6, which advances against it; and the whole train of wheels, therefore, again comes to repose. The balance, having completed its vibration forwards, begins to return, by the elasticity of its spiral spring. In this return, the lifting-pallet *q* has again to pass the end of the lifting-spring *p*; but it now merely separates this from the end of the detent, and does not move the detent itself. The locking of the scape-wheel still continues, therefore, until the balance has completed its return vibration, and again begins to move forwards; the lifting-pallet will then again raise the detent and set free the scape-wheel; the balance will receive a fresh impulse from the action of the teeth upon the ruby face of the main-pallet; and the detent will again lock the wheel, as soon as the tooth has escaped. All this complex action, which occupies so long in the description, is really repeated in every half-second,—that being the time in which the balance is usually made to perform its double vibration.

Compensation balance.—It is essential to the accurate going of a chronometer, that it should be furnished with some means of compensating the action of heat or cold upon the balance-spring, analogous to those by which compensation is made for the effect of change of temperature upon the pendulum. This is here also effected, by taking advantage of the unequal expansion of different metals; so that the change produced in the length of the spring may be antagonized by a change in the form of the balance, producing a variation in the amount of force necessary to move it. From what has been formerly stated of the principles of the lever, and wheel, and axle, it is evident that, the nearer the chief weight of the balance is disposed to the centre of motion, the less amount of force will be required to turn it. Consequently if—when the action of heat upon the balance-spring has weakened it, by increasing its length—the same action can be made to cause the weight which the spring has to move to approach nearer the centre, a perfect compensation may be effected. In the same manner, the spring being shortened by cold, and thereby rendered more powerful, the weight ought to be carried further from the centre, so as to require a greater moving power.

These objects are accomplished by the compensation balances represented in Figs. 3758 and 3759. The principle of both is the same; and the only difference consists in this, that the necessary weight is given in Fig. 3759 by a single piece W on each arm of the balance; whilst in Fig. 3758 it is distributed among the four screws 1, 2, 3, 4, which are inserted into each arm. These balances are not made in the

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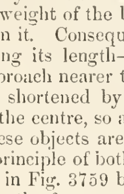

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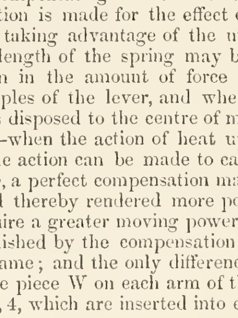

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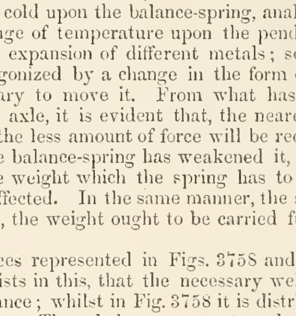

form of a complete wheel; but are composed of the cross-bar A B attached to the axis, and of the two circular arms carried by its ends. Each of these circular arms is a compound bar of brass and steel, the brass being on the outside. As brass expands by heat much more than steel, the effect of a rise of temperature is to cause the curvature of the bars to increase, so that their ends *a a* curl in, as it were, towards the cross-piece A B, carrying inwards the weights W W, Fig. 3759, or the screws 1, 2, 3, 4, Fig. 3758; hence the balance will be more easily made to revolve, and the weakened action of the spring will be compensated. On the other hand, the effect of cold will be to make the brass contract more than the steel, and thus to diminish the curve of the circular bars, rendering them straighter, so as to increase the distance of the weights from the centre, and thereby to increase the power requisite to move them; thus counterbalancing the increased power given to the spring by its own contraction.

There is much difficulty in exactly adjusting this compensation to the error it is desired to correct. It may be that it is too great; in which case the chronometer will gain by heat and lose by cold. This is corrected by shifting the weights W W, Fig. 3759, towards a part of the circular bars nearer to their attachment, so that they may be less influenced by the alteration of the curvature of the bars; and the same result is obtained in the other form of the balance, Fig. 3758, by drawing out the screws 4, 4, and screwing in 1, 1. On the other hand, if the compensation be not sufficient, the weights must be shifted towards the ends *a a* of the circular bars, so as to be more altered in place, when the curvature of the bars is changed by an alteration of temperature. The screws C C are obviously not affected by these changes of curvature, since they pass into the ends of the straight bar A B; but the effect of screwing them in or drawing them out, is to alter the rate at which the balance will vibrate; for if the moving power remain the same, and a portion of the weight be carried to a greater distance from the centre—as it is by partly drawing out the screws C C—the vibrations will be rendered slower; and the contrary effect will be produced by screwing them in. Now in finally adjusting a chronometer, it is found undesirable to alter the length of the balance-spring, after the point has once been ascertained at which its vibrations are isochronous, or nearly so. Hence, in order to bring it to the proper rate, it is found advantageous to make it go faster or slower as required by slightly altering these screws, which are hence called, to distinguish them from the others, *mean-time* screws.

The chronometer.—Fig. 3760 shows the balance-wheel of a chronometer; *a* is the balance-spring, the elastic force of which, when wound up by the motive power, acting through the escapement, into a state of tension, gives motion to the balance *b*. The elastic force of this balance-spring varies by change of temperature, producing an error of six minutes in twenty-four hours in the time indicated by the chronometer, for 68° of Fahrenheit. This irregularity is corrected by the balance *b* varying its diameter, much in the same manner as the balls of a steam-engine govern that machine; with this exception, that while the balls of a steam-engine act by gravity and centrifugal force, the effect is here mechanically produced from the different metals (brass and steel) expanding and contracting differently under a change of temperature, thus varying the diameter, and consequently the inertia of the balance in accordance therewith. It must be recollected that no chronometer can keep a uniform rate unless the tension of the balance-spring has an invariable ratio to the inertia.

Heat renders the balance-spring *a* weaker, while the inertia of the compensation balance *b* is decreased, thus compensating the loss occasioned by the relaxation of the spring.

The compensation balance, by which the error is compensated, may be thus explained: The compensation, as already observed, is produced by the variation in the diameter of the circle *b*. The internal part of the rim *c* is of steel, while the external part *d* is of brass; these are united by heat, causing a partial fusion of the brass, and consequent union with the steel. The degree of expansion of these metals upon application of the same degree of heat varies; the brass expands *more* than the steel, and as it cannot release itself from this, so neither has it the power of expanding itself in length, being restrained by the steel: consequently an increase of curvature is produced by the brass forcing the steel to change its original circular form, the inertia or power of the compensation balance hence varies, and compensates for the loss or gain in the balance-spring occasioned by a change of temperature. The rim of the balance is cut open at *e*, to admit of this variation in its form; the screws *f* can be inserted in any of the holes *g*, and according to their position in one or the other, these screws are moved more or less in towards the centre by the increase of curvature of the rim before mentioned, thus contributing to vary the inertia of the balance in a small degree, but admitting of original adjustment for this purpose—giving that finish to the principle of this contrivance on which the exquisite accuracy of the chronometer in great measure depends. This principle of compensation is the same in all watches to which a compensation balance is applied, viz., to those of the duplex and lever kind. The escapement used in the chronometer, as seen in Fig. 3761, is termed a "detached" one, which means, that the vibrations performed by the balance are nearly detached from the pressure of the motive power during the greater part of its arc of vibration; one great advantage is, that it requires no oil. This escapement is of French invention, but improved by English artists.

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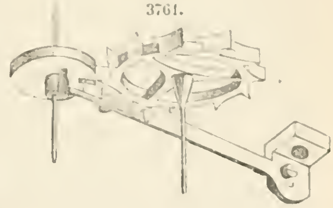


These are the principles on which the excellence of a time-keeper depends. In their application to practice, however, every thing depends on the perfection with which the machine is constructed; and the minuteness of the conditions required for the good going of a chronometer may be judged of from the fact with which practical men are familiar—that, of two chronometers, constructed upon the same plan, and finished with equal care in all respects by the same hand, one may go very well, and the other comparatively badly, without any discoverable difference between them. In finally adjusting a chronometer no attempt is made to keep it exactly to *mean time*; that is, to make it continue to point, day after day, and week after week, exactly to the correct hour; for it is just as advantageous to allow it to gain or to lose a few seconds a day, provided that the gain or loss be *regular* in its amount; since the real time may be known with equal accuracy from that which the chronometer indicates. Thus, suppose that we have a chronometer which was set 36 days ago, since which time it has been gaining 5 seconds a day; if its gain have been regular, its whole gain during that period will be (5 × 36) 180 seconds, or three minutes; and three minutes being deducted from the time to which the hands point, we shall have the real time. This regular amount of gain or loss is called the *rate* of a chronometer, and it is thus expressed: When the chronometer is said to have a rate of + 2·5, we understand that it is gaining 2½ seconds per day; but if its rate is — 3·2, we know that it is losing 3⅕ seconds per day. The more closely it keeps to this rate the better the instrument will obviously be; but if it vary much from its rate, even though its errors should be sometimes on one side, and sometimes on the other, so as to compensate one another, and make the general average the same, the performance is bad, and cannot be relied on.

When the minuteness of the parts of a chronometer is considered, and the variety of disturbances to which it is exposed, the accurate performance to which it may be brought is most wonderful. For it must be remembered how very trifling a cause, if constantly acting, (such as a slight thickening of the oil,) will greatly alter the result. Thus, as there are 1440 minutes in a day, any cause which makes each vibration of the balance (of which there are five in a common watch) take place in 1-7200th part less or more than its usual time, will cause the time-keeper to gain or lose a minute a day. And as there are 86,400 seconds a day, any cause which makes each vibration of the balance of a chronometer (which usually occurs 4 times in a second) take place in 1-432,000th part less or more than its usual time, will cause it to gain or lose a second a day—an error of very considerable magnitude. When it was first supposed that chronometers could be made sufficiently perfect to give important assistance in the determination of the longitude at sea, (the mode of doing which will be explained hereafter,) a parliamentary reward of £10,000 was offered in 1714 to any one who should construct a time-keeper capable of doing so within the limit of sixty geographical miles; £15,000 if to forty miles; and £20,000 if to thirty miles. Now a chronometer that has so much changed its rate as to have gained or lost, in a few weeks, two minutes more than it was estimated to have done, would gain the highest of these rewards; so that the utmost degree of accuracy which was contemplated as possible, at the beginning of the last century, when this act was passed, is far surpassed at present.

The reward was gained by John Harrison, who, in 1736, completed the first chronometer used at sea, after many years of patient study and laborious experiment. He gradually improved his machine; and in 1761 the first trial was made of it, according to the regulations of the act of Parliament, by a voyage to Jamaica. In consideration of his advancing years his son was allowed to take this voyage instead of himself. After eighteen days' navigation the vessel was supposed by the captain to be 13° 50′ west of Portsmouth; but the watch giving 15° 19′, or a degree and a half more, was condemned as useless. Harrison maintained, however, that if Portland Island were correctly marked on the chart, it would be seen on the following day; and in this he persisted so strongly, that the captain was induced to continue in the same course, and accordingly the island was discovered the next day at seven o'clock. This raised Harrison and his watch in the estimation of the crew; and their confidence was increased by his correctly predicting the several islands as they were passed in the voyage to Jamaica. When he arrived at Port Royal, after a voyage of 81 days, the chronometer was found to be about 5 seconds too slow; and finally, on his return to Portsmouth, after a voyage of five months, it had kept time within about one minute and five seconds, which gives an error of about 18 miles. This amount was much within the limits prescribed by the act; but Harrison did not receive the whole reward until a second voyage had been made; and large as the sum appears, it cannot be regarded as more than equivalent to the devotion of extraordinary talents, with unwearied perseverance, during 40 years, to the attainment of an object whose importance can scarcely be estimated too highly.

As an illustration of the improvements which have been since made in the construction of chronometers, the following circumstance, mentioned by Dr. Arnott as having occurred to himself, is of great interest. "After several months spent at sea," he says, "in a long passage from South America to Asia, my pocket chronometer and others on board announced one morning that a certain point of land was then bearing north from the ship at a distance of fifty miles; in an hour afterwards, when a mist had cleared away, the looker-out on the mast gave the joyous call of 'Land ahead!' verifying the report of the chronometers almost to one mile, after a voyage of thousands. It is allowable at such a moment, with the dangers and uncertainties of ancient navigation before the mind, to exult in contemplating what man has now achieved. Had the rate of the wonderful little instrument, in all that time, been quickened or slackened ever so slightly, its announcement would have been useless, or even worse; but in the night and in the day, in storm and in calm, in heat and in cold, its steady beat went on, keeping exact account of the rolling of the earth and of the stars; and in the midst of the trackless waves which retain no mark, it was always ready to tell its magic tale, indicating the very spot of the globe over which it had arrived."

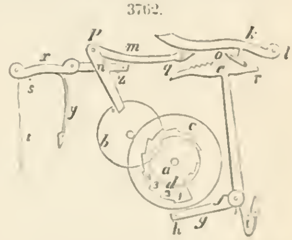
It is surprising that, in spite of the great advantages resulting from the use of chronometers in navigation, many ships are sent to sea without them, even for long voyages. Not unfrequently must it occur that the knowledge of the exact position of the ship, which may be obtained by the chronometer, produces a great saving of time, as well as contributes to the avoidance of danger. A remarkable instance of this was mentioned to the author, a few years since, as having just then occurred. Two ships were returning to London about the same time, after long voyages, one of them provided with chronometers, the latter destitute of them. The weather was hazy, and the winds baffling; so that no ship, whose position was uncertain, could be safely carried up the British Channel. Confident in his position, however, the captain of the first ship stood boldly onwards, and arrived safely in the Thames, whilst the other ship was still beating about in uncertainty near the entrance to the Channel. The first ship discharged her cargo, took in another, set sail on a fresh voyage, and actually, in running down the Channel, encountered the second ship still toilsomely making her way to her port!

Of the degree of accuracy which chronometers are capable of exhibiting, some idea may be formed from the following statement, kindly communicated to the author by a gentleman practically conversant with them. A chronometer made by Molyneux had its daily rate determined, in August, 1839, to be a loss of 7 seconds per day. It was then placed in a ship which traded to the coast of Africa, and was consequently exposed to great variations of temperature. Yet when again placed under careful observation in November, 1840, (sixteen months afterwards,) its daily loss had only changed to 6·7 seconds, being a difference of only 3-10ths of a second a day. As opportunities for ascertaining the real position of the ship, without chronometers, frequently occur at sea, any error in these may almost always be detected before it has accumulated to any great extent; but even supposing that no such opportunity had occurred for six months, and that the alteration of the rate had taken place at once, and had been entirely unknown, the whole error would have been under a minute of time, and consequently less than 15 miles of space. Another chronometer, constructed by Muston, which had made the same voyage, and been out about the same length of time, had its previous gaining rate of 1·9 seconds a day increased to 2·3 seconds; the difference being here 4-10ths of a second. It is customary for two or more chronometers to be carried by the same ship, that they may check one another; for if one alone were trusted to, an accidental irregularity in its going might lead to great error. The average of several—their errors counterbalancing each other—will be most likely to give the real time with great exactness.

Striking apparatus.—The apparatus for striking the hour is somewhat complex; but we shall endeavor to make its action intelligible, as it is a very beautiful specimen of ingenious mechanism. The form which will be described is that which is adopted in the best English clocks: a simpler plan is adopted in the cheap German clocks, which are now so largely employed in this country; but they are very liable to get out of order. The difference consists, however, only in the apparatus by which the striking is regulated, as to time and number of strokes; the mechanism by which the hammer is made to strike the bell is the same in both cases. It consists of a train of wheels and pinions, put into action by the spring contained in the barrel E, Fig. 3749, which turns the fusee F. The fusee carries round with it the main-wheel *e*, which has 84 teeth; this drives the pinion *p* of 8 leaves, which carries on its axle the *pin-wheel f*, having 64 teeth. In the rim of this pin-wheel are 8 pins, which lift the hammer *s* by acting on its tail *t* when the train is in motion. The hammer being gradually lifted by each pin, is at last let go by it, and is made to strike the bell by the spring *u*. The pin-wheel drives a pinion *q* of 8 leaves, which carries round the *pallet-wheel g* of 56 teeth: as the pin-wheel has 64 teeth, it turns the pallet-wheel pinion 8 times for each revolution of its own, consequently this pinion makes one revolution for every stroke of the hammer, an arrangement of which the use will be presently shown. The pallet-wheel acts on a pinion *z* of 7 leaves, on which is the warning-wheel *h* of 48 or 50 teeth, and this last turns the fly-pinion *i*. The object of this part of the train is only to equalize the motion which is principally effected by the constant resistance of the air against the surface of the plate (termed the fly) which is whirled very rapidly round by the highest pinion. If it were not for this addition, the pin-wheel would move onwards with a jerk, after each pin had escaped from the tail of the hammer.

The striking-train remains completely at rest during each hour's movement of the going-train, and is only allowed to act at the conclusion of one hour and the commencement of the next. The mode in which it is restrained in the intervals, and its action at the proper time permitted and regulated, will now be explained. The mechanism by which this is effected is shown in Fig. 3762. It is situated immediately behind the dial. The axis of the centre-wheel, as already mentioned, is prolonged through the dial, to bear the minute-hand. In the striking clock this also bears a small wheel *a*, which gives motion to another wheel *b* of the same size and number of teeth; hence this wheel, like the former, revolves once in each hour. On the centre of this wheel is a pinion of 6 or 8 leaves, which turns a wheel *c* with a hollow axle, moving on the same centre as *a*, but at a different rate, as in the watch. This wheel has 12 times the number of teeth that the pinion contains, and therefore moves at only 1-12th of the rate. To it the hour-hand is affixed; and it also carries a peculiarly shaped piece of metal *d*, which is called the *snail*. The edge of this snail is cut into 12 steps, each of which is a twelfth of the circle of which it forms a part; but the distance of each from the centre increases regularly from 1 to 12. At *e* is seen a circular *rack*, fixed to the end of a bent lever *e f g h*, whose centre of motion is at *f*. By the action of the bent spring *i* this rack will be made to fall towards the left, when permitted to do so; but the amount to which it shall fall is governed by the position of the snail, against the edge of which the pin *h* will be brought to bear. This spring is prevented from forcing the rack out of the position shown in the figure, by means of the projecting piece on the lever *k*, which turns on the centre *l*, and drops by its own weight into the teeth of the rack. The form of these teeth is such, that when the rack is moved from left to right, the catch is lifted by them and allows them to pass; but, so long as it is allowed to drop between the teeth, it completely prevents the motion of the rack from right to left. The lever *k*, with its catch, may be lifted by the bent lever *m p n*, whose centre of motion is at *p*: and this is acted on by a pin in the circumference of the wheel *b*, which is seen in the figure, close against the tail of the lever.

3762.



Only one other part remains to be described—that which is known as the *gathering-pallet*. The axle of the pallet-wheel *g*, Fig. 3749, projects through the front plate; and is furnished with a projection, seen at *o*, resembling one leaf of a pinion. This works into the teeth of the rack in such a manner that, as the axle turns round, the rack is *gathered up* by it, to the amount of one tooth for each revolution. When the machinery is in the position shown in the figure—which it has during the whole time that the striking-train is at rest—a projection on the gathering pallet rests on a pin which projects from the rack, as seen at *r*. It is this which keeps the striking-train from acting; for, so long as this projection from the axle of the pallet wheel bears upon the pin, so long must the pallet-wheel, and consequently the whole remainder of the striking train, be prevented from running on.

But when the time of striking is nearly come, the pin on the wheel *b* acts on the tail of the lever *n p m*; the end *q* of which raises the lever *k l*, and consequently lifts its catch out of the rack *o*, which is thus set free. The spring *i*, therefore, pressing upon the projection below *f*, causes the rack to fall towards the left; and therefore sets free the projection on the gathering pallet, by withdrawing the pin on which it rested. Hence the whole striking train would be set in action by its weight; if it were not that, at the same time that the gathering pallet is freed, another check is provided. The end *q* of the bent lever *m p n* bears a projecting piece, which, when the lever is raised, stops a pin placed on the circumference of the warning-wheel *h*, Fig. 3749. So long as the lever remains in this position, therefore, the striking train is prevented from acting. The amount of motion given to the rack is determined by the place of the snail. In the position represented in the figure, the pin *h* would be stopped by the second step; and thus the rack would only be permitted to move to the amount of two of its teeth. If the position of the hour wheel were such, that the twelfth step of the snail corresponded with the end *h* of the rack lever, then the pin would not be stopped so soon; and the rack would fall towards the left to the amount of twelve teeth. This preparatory action is usually made to take place about 3 or 5 minutes before the expiration of the hour, and it is called *giving warning*.

The machinery remains in this position until the minute-hand points to XII., at which time the wheel *b* has so far advanced that its pin escapes from under the end of the lever, and thus allows it to fall, so that the end *q* no longer checks the pin on the warning-wheel. The striking-train is now set entirely free; the weight or spring that moves it produces a rapid revolution of its wheels; and the pins on the pin-wheel, acting on the tail of the hammer-lever, cause the successive strokes on the bell. This movement goes on until it is checked by the action of the gathering-pallet on the rack. It has been already mentioned that the pallet-wheel, from the axle of which the gathering-pallet projects, turns round once for every stroke given to the hammer; and in each turn it gathers up one tooth of the rack, causing it to move towards the right, so as to regain its original position. The projecting catch of the lever *k l* drops between the teeth at each advance, and prevents the rack from being moved back by the spring *i*. This goes on until the rack has been completely brought back to its first position, and then the projection on the gathering-pallet will be again checked by the pin *r*, and the striking-train would be brought to rest.

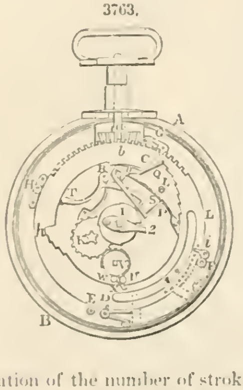
It is evident, then, that the number of strokes will be determined by the number of revolutions which the gathering-pallet is allowed to make; this depends upon the number of teeth on the rack which have to be gathered up by it; and this number is regulated by the extent to which the rack is permitted to fall, by the bearing of the pin *h* against the edge of the snail. It is almost impossible for any error to be committed by a movement so constructed; but the striking-train of the common German clocks, now so largely imported into Britain, is regulated by an apparatus of simpler construction, which is very liable to give wrong indications. It principally consists of a large wheel, (termed the *count-wheel*,) usually placed at the back of the clock, on which are cut 78 teeth; this is so connected with the striking-train, that it moves on one tooth for each stroke. The number 78 is the sum of all the strokes which the clock should make in 12 hours; consequently, after all these strokes have been made, the wheel returns to the same place again. From the surface of the wheel, near its edge, there projects a rim, in which are cut a series of notches, at intervals corresponding with the number of strokes. Thus, between the first and second notches there is an interval amounting only to one tooth of the wheel; between the second and third notches an interval of two teeth; and so on up to the twelfth notch, the interval between which and the first is 12 teeth. The use of these notches is to receive a catch or projection, which keeps the striking-train at rest during the hour, and regulates the number of strokes. When the clock gives warning, this catch is lifted out of the notch; but there is a temporary check applied to the warning-wheel as in the last case. When this check is removed, the train immediately begins to move, and continues in action until it is stopped by the falling of the catch into the succeeding notch. The number of strokes is determined, therefore, by the number of teeth which the count-wheel shall have moved on before the catch falls into this notch—or, in other words, by the number of teeth between each notch and the succeeding one.

The advantage of this last plan consists in its simplicity, and the facility with which the apparatus may be constructed. Its disadvantage consists in the readiness with which it may be put out of order. For it will be easily seen that if, from any cause, the clock be made to strike at an improper time, the count-wheel advances, and the number of strokes made will be one more than the last; so that, when it should next strike the hour, the number of strokes is one too many. Or if any cause (such as neglecting to wind up the weight of the striking-train) should prevent the clock from striking at the proper time, the count-wheel remains stationary; and when the clock next strikes, it gives the number succeeding the one which it last struck, which may, of course, be altogether wrong. On the other hand, in the more perfectly constructed clock, the striking may be repeated any number of times within the hour, or it may be made to cease for a time altogether; and yet, when the clock next strikes the hour, it shall do it correctly. For the number of strokes, as just explained, is dependent upon the position of the snail, which is carried round by the hour-wheel whether the clock strikes or not; and which must, therefore, always correspond with the place of the hour-hand. In some clocks of this construction, there is a simple contrivance for causing the hour to be struck at any time. This consists of a lever *x*, to one end of which the string *t* is attached, whilst the other carries a pin that raises the lever *m*. The action of this lever is checked by the two pins *s* and *z*, which prevents it from being moved too far in either direction. When the string *t* is pulled the lever *m* is lifted, and all those changes take place which have been described as occurring in the ordinary *warning* of the clock. When the string is let go, the lever is made to return to its place by the spring *y*; the lever *m* falls, the warning-wheel is released, and the proper number of strokes is made. Such a contrivance is convenient to those who desire to know the hour during the night.

Where a clock is made to strike the quarters as well as the hours, a third train of wheels is required. The mechanism is the same in principle with that which regulates the striking of the hours. The axle of the minute-hand carries round a snail cut into four steps; and on a wheel corresponding to *b*, and revolving therefore in an hour, there are four pins, one of which lifts the lever that sets free the rack every quarter of an hour. The rack has four teeth, corresponding with the four steps of the snail; and the passage of each tooth permits one stroke on the quarter-bell. Most frequently the quarter-stroke is made upon two bells; and this is accomplished simply by having a set of pins on each side of the pin-wheel, of which one set acts on one lever, and the other set (acting a little afterwards, so that the two strokes may not be made at the same moment) on the other lever. In clocks constructed for purposes in which great accuracy is required, it is necessary to dispense altogether with the striking apparatus; since a certain degree of force is required to set it in action, that would derange the very regular movement of a delicate and perfect clock, in which the power of the weight ought to be no more than is requisite to keep the pendulum in action.

The same apparatus has been applied to watches; but when made on so small a scale and carried about in the pocket, its action is extremely liable to become deranged, and it is therefore of little use. The ordinary repeating-watches are made, not to strike the hours regularly, but merely to indicate them when desired to do so. In order to effect this, it is not requisite that the watch should be furnished with a second barrel and fusee with a distinct striking-train of wheels, for it is easy to apply a power sufficient to produce the strokes every time that the watch is applied to for this information. This is usually accomplished by pushing in the *pendant*, or projecting portion to which the chain is attached; and by this a spring is compressed, which sets in action the mechanism that produces the strokes. The number of strokes is regulated by a snail, resembling that employed in clocks. The ordinary repeating-watches are still very complex in their construction; and we prefer describing one invented some years ago by Mr. Elliott, of Clerkenwell, in which the number of parts is greatly reduced by the combination of several into one. The striking portion of this watch is represented in Figs. 3763 and 3764. The most important part of it is a flat ring or centreless wheel, of nearly the same diameter with the watch, supported in its place so as to admit of a circular motion, by four grooved pulleys round its external circumference. In Fig. 3763, A B represents the plate to which the dial is attached; and the flat ring C D, with the rest of the striking mechanism, lies between this plate and the dial. The four pulleys are seen at E F G H. This ring has teeth cut in the part of the outer edge *b* nearest to the pendant, and the rack may be thus turned by the wheel *a*, to which motion is given by turning the pendant. At the lower part of this ring is a series of projecting pins, which, in the position shown in Fig. 3763, act upon the projecting pallet *i*; whilst in the position shown in Fig. 3764, they act upon the pallet *r*. Of these, the former is destined to strike the hours, and the other the quarters. The internal edge of the ring is cut into two series of *steps*, of which the one seen on the left-hand side of each figure contains twelve, and regulates the striking of the hours; whilst the one on the right contains only four, and regulates the striking of the quarters. When the ring has had its position changed by turning the pendant, it is brought back again by a spring contained in the box or barrel V; the action of this spring is communicated to the ring by a chain which winds off the barrel, passes between the pulleys U and W, and is attached to the ring at X. Hence, in whichever direction the ring is turned, the chain will be drawn off the barrel, and the spring put on the stretch, as seen in Fig. 3764; and the elasticity of the spring will tend to bring back the ring to its previous position, shown in Fig. 3763.

3763.



3764.

The regulation of the number of strokes is effected by means of a snail, exactly resembling that of a clock. At I in either of the figures is seen the quarter-snail, placed on the axis of the minute hand, so as to revolve every hour, and cut into four steps. The same axle carries a projecting piece 2, which acts on the star-wheel 1, Fig. 3764, in such a manner as to push it on to the amount of one-twelfth of a circle at each revolution of the minute-hand; consequently the whole star is made to turn once in the twelve hours. To this wheel is attached the hour-snail, as seen in Fig. 3764; the common centre on which they turn is marked at L, Fig. 3763. The hour snail acts upon the bent lever P O Q, whose centre of motion is at O; and the end P is always kept against the step of the snail by the spring seen in Fig. 3763. In the position in which the lever is there shown, the snail having been removed, the end Q of the lever is pressing against the last or lowest step of the flat ring, and consequently the ring cannot be moved. But supposing the end P to be lifted by the snail to the 2d, 3d, 4th, or any other step, the end Q will be raised to exactly the same amount, and will permit the ring to be turned from right to left, until it is stopped by the contact of Q with the corresponding step of the ring. In exactly the same manner the quarter snail acts upon the steps cut in the inner edge of the ring at *h*, by means of the bent lever S R T, whose centre is R.

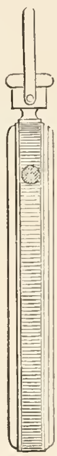
Now when it is desired to ascertain the hour, the watch is held in one hand and the pendant turned from right to left with the other. This causes a corresponding motion in the ring; and every pin, as it passes the pallet *i*, gives an impulse to the hammer, which causes a stroke upon the sounding body. The extent to which the ring may be turned, and consequently the number of pins allowed to pass the pallet, depends upon the position of the lever P O Q; and this, as just explained, is determined by the position of the snail. Hence the ring is stopped just when as many pins have passed the pallet as correspond with the step of the snail against which the end P of the lever is resting. After the hours have been struck, the ring is brought to its original position by the spring contained in the barrel V, and the pendant may then be turned in the opposite direction, so as to cause the other set of pins to act upon the pallet *k* and to strike the quarters. Its motion in this direction is governed by the position of the lever S R T, of which the end S rests upon the quarter snail, whilst the end T checks the steps cut in the ring at *h*. In the position represented in Fig. 3764, the ring has been turned as far as possible in this direction; for the end S rests upon the highest step of the snail, and has lifted the end [illegible] so high that the motion of the ring is not checked until it stops at the last step, by which time four pins have passed the pallet, and four strokes have been made.

Dent's new patent watch without a key.—There are two improvements which have recently been made in the construction of watches, and patented, which will now be described. The daily recurrence of the act of winding up our watch, and its imperative necessity, renders it obviously desirable that the power of doing this should be facilitated as much as possible; and that whatever may be the situation in which we may be placed, whether travelling, or in the dark, that we should be able to perform this operation with the greatest ease and certainty: now the use of a key detached from the watch, and requiring to be applied to a small hole, which must be seen to be used, is dispensed with by the improvement alluded to, so that the winding up of the watch may be effected in the dark by simply turning part of the pendant, by which the watch is attached to the chain to connect it with our person.

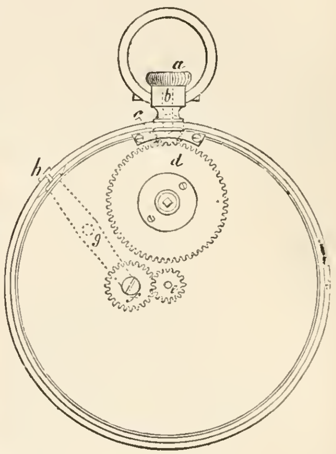
But this improvement is not the only one now made: thus much has been partially accomplished by former artists, who, while they rendered the watch independent of a *key* for winding it up, suffered the necessity for this adjunct, for the purpose of adjusting the hands, still to exist, and thus did not make the machine quite independent of appendages of any kind. By a simple contrivance, which will now be described, it will be seen that the adjustment of the hands can also be effected by the motion of the pendant at the pleasure of the wearer, and that with a greater latitude than could be done under ordinary conditions.

In Fig. 3765, *a* is the knob next to the pendant-ring, but in the improved watch independent of it, and movable with a rotatory motion like a common watch-key: on the axis *b* of this knob there is a bevelled pinion which acts by means of an intermediate wheel *c* on a larger one *d*, which is carried on the axis of the main-spring; this completes the arrangement for simply winding up the watch: that for setting the hands consists of a pinion *e* attached to the arbor of the minute-hand. This pinion, it must be observed, is free of the wheel *d*, or, in technical language, not in *geer* with it; but it can be put so by means of another and equal pinion *f*, which is carried on an arm, or lever, moving on a centre at *g* and terminating in a stud *h*, which projects through the rim of the case; if this stud is moved by the finger *from* the pendant, the pinion *f* will obviously be brought into geer with *d*, and thus will impart the motion of that wheel to *e* when the hands require setting; but when the stud *h* is released, a spring removes the pinion *f* from *d*, and the winding-up part is detached as before. It must be mentioned, that as it is requisite to be able to move the hands either backwards or forwards, the wheel *d* is made to admit of motion from the knob *a* in either direction, for this purpose. Since the winding up must always take place in the same constant direction, there is a ratchet and click of the usual principle connected with the wheel *d* to admit of this double motion: by this arrangement also, the injury to the watch produced by over-winding is guarded against.

3766.



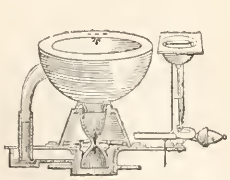
3765.



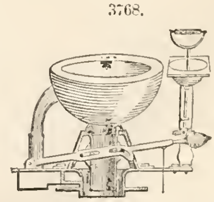
It will be inferred from the foregoing description that the frequent necessity for opening the watch is done away; hence results another, and not the least improvement effected by the contrivance: in the old construction of the watch-case, dust will penetrate to the interior of the watch, however seldom it may be opened, through the number of passages necessarily consequent on the existence of hinges in the case; these being dispensed with in the watch now described, the glass and case are as nearly air-tight as possible, while the dust which makes its way in the ordinary watch to the works each time the case is opened for the purpose of winding up, or of setting the hands, is now altogether excluded; thus cleaning the watch will not be so frequently required as heretofore.

WATER-CLOSET—By G. Jennings. This closet is intended to remedy the defects of the pan and valve closet. It has neither the usual metal pan or valve, so that no chamber is required, which prevents displacement of pure air when used—an evil so justly complained of in pan or other closets.

3767.



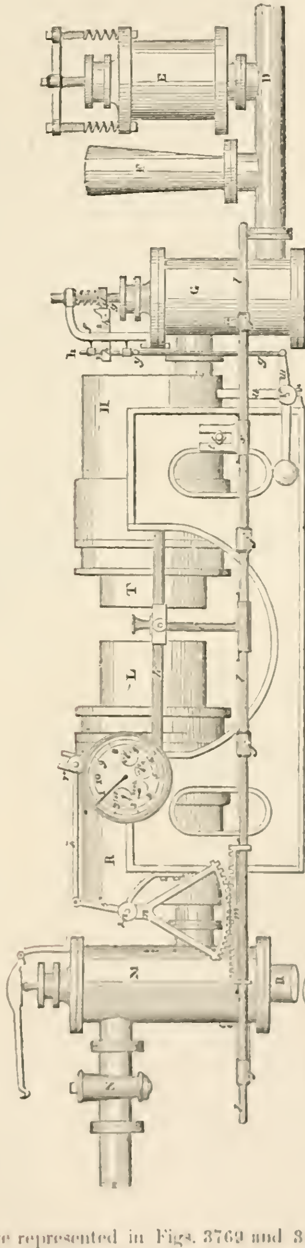
3768.



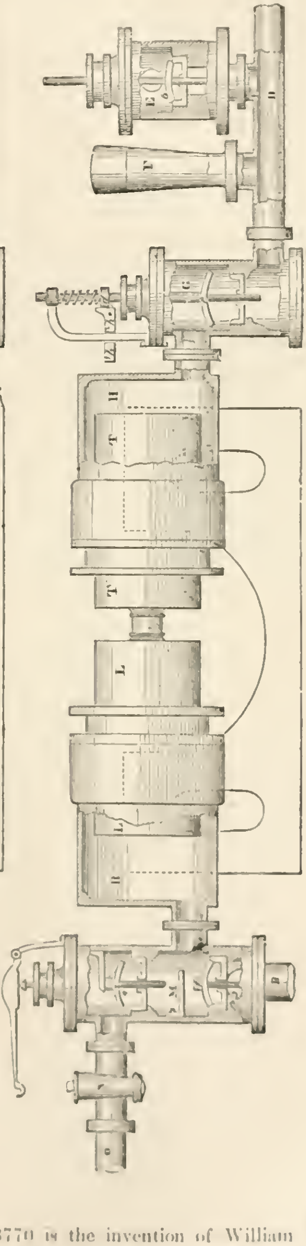
The raising of the handle, as shown in Fig. 3768, causes the water to fall from the cistern to the closet, and suddenly discharges the contents of the basin with all its force through a four-inch India-rubber pipe, flushing, as it is termed, the trap and soil-pipe each time the closet is used. The lowering of the handle, as shown in Fig. 3767, compresses the tube, and retains the water in the basin. The surplus water passes off through the overflow pipe, which also regulates the proper quantity of water to be retained.

This closet in its action is perfectly silent, as the metal-flaps fall without noise against the India-rubber tube. It is also free from all *complication;* and a fresh piece of India-rubber tube, if ever needed, will make the closet as good as new.

WATER-METRE—By W. H. Lindsay. The invention of an instrument that will, on inspection, show accurately the amount of water evaporated during any given time—as, for instance, during a voyage—by a steam-boiler, is a desideratum which has long been sought after.



3769.



3770.

The water-gage represented in Figs. 3769 and 3770 is the invention of William H. Lindsay, constructing-engineer, New York, who has, after a large outlay of time and money, succeeded in producing a durable and critically accurate instrument, and is the only one yet brought into practical operation which can lay claim to that title. It has been subjected to the most thorough and repeated trials, under the supervision of many of our most distinguished engineers, and a board of officers appointed by the Navy Department to examine and report upon its merits. The trials took place after it had been in operation more or less every day for the previous five months. On measuring accurately the quantity of water passed through it, in the tanks that received it, and comparing the amount as indicated by the instrument, the difference on nine experimental trials, under different or varying circumstances, was found not to exceed 30 cubic inches in one hundred thousand.

By the use of this instrument on board steam-ships, the owners will be enabled to place themselves in as advantageous a position, in a pecuniary point of view, as that of the Cornish mine-owners, who some years since adopted the system of registering the duty performed by their engines, and the amount of fuel consumed; in other words, the *work done* in relation to the *fuel consumed* is registered. This object is accomplished there by means of a counter, which merely registers the number of strokes made by the engine; but this expedient will only answer where the load upon the engine is constant and easily measurable, but is of no avail in a steam-vessel, where the load is continually varying; which can only be done by measuring and recording the quantity of water evaporated by the boilers, and converted into steam, which is the measure of the power exerted by the engines.

The best proof of the saving in fuel derivable from the plan of registering the duty performed by steam-engines, consists in the enumeration of the wonders it has already done. According to a report made by a committee of the House of Commons appointed to investigate the matter, it appears that the Cornish mine-owners, even in their limited operations, are saving the sum of $400,000 per year, by the simple expedient of registering the duty of their engines. If such a saving can be realized by this system out of the contracted sphere of Cornish engineering, the results that would ensue by its adoption in our ocean steam-ships are incalculable. Such a practice insures a rigid attention to their duties on the part of the engineers and firemen, as any negligence will be sure to tell to their disadvantage. Its adoption puts all the engineers upon their mettle, and induces an emulation, out of which improvement cannot but spring, with corresponding advantages resulting to the owners. Yet the saving of fuel in the case of steam navigation, important as it would be, is not the greatest benefit that would be derived. The powers of steam navigation would be extended, and its profits correspondingly augmented. Requiring a less amount of fuel to perform the same duty, they could carry more cargo, and the growth of our steam marine would just be in proportion to the extension of the limit which now hinders its development. It is needless, however, to dwell further on the advantages derivable from the system of registration, as they must be conspicuous enough to every one who gives attention to the subject, the acknowledgment of which has been made by its adoption in the naval service, by order of the Navy Department. A series of experiments will shortly be commenced at one of our navy yards with one of these instruments, by a board of officers appointed by the Department, for the purpose of establishing a standard of evaporation due the different varieties of coal used for the generation of steam, for the use of the naval and mercantile marine; also to institute a series of experiments to ascertain the relative merits of boilers of different construction, which may lead to the solution of the problem, what are the true principles which should govern their construction in every respect; and determine, beyond all cavil, the best-constructed boiler in use at the present time. The results that may be arrived at by the use of this instrument will be a subject of much importance to all concerned in steam navigation.

Having given an outline of the use of this important invention, we will proceed to give a description of the figures, &c.:—Fig. 3770 is an elevation. Fig. 3769, sectional do. The figures are lengthened out, with the view only of showing the metre's general arrangement, without reference to the economy of space that may be attained by a compact arrangement of its several parts.

Literal references.—D, connecting pipe from the feed-pump of the engine to the drop-valve chest, G; E, an overflow-valve chest bolted on the pipe E; F, air-chamber; G, drop-valve chest bolted to the forcing metre-chamber or cylinder H; T, plunger or ram working in the cylinder H; R, metre-cylinder; L, plunger working in the metre-cylinder—the two plungers being connected by a coupling-rod; M, metre valve-chest bolted to the cylinder R; N, stop-cock on the pipe O leading to the boiler; R, feed-pipe from the hot well bolted to the bottom of the valve-chest M, for supplying the metre-chamber R; P, side-frames, to which the cylinders H and R are bolted.

b, valve in chest E, loaded by means of the springs attached to the cross-head on the valve spindle; *c*, drop or cut-off valve in the chest G; *g*, cut-off valve spindle passing through a stuffing-box on the cover or bonnet of the drop-valve chest; *d*, stud keyed on the spindle *g*; *e*, an inclined slide receiving motion from the connecting link *y*. It works in a slot in the slide-piece that springs in under the stud *d*. When the valve *c* rises, and when it is drawn down by the rod *y*, it draws back the slide-piece from under the stud *d*, thereby allowing the valve *c* to fall on its seat, and prevent the return of any more water from the forcing-cylinder H through the pipe D into the engine feed-pump, during its exhaust stroke. h^2 h^2, seat on the frame *f*, on which the drop-valve slide (not shown) works, and through which, at the back part, the inclined slide *e* also passes; *f*, stand for the seat h^2 h^2, its lower end being bolted on the bonnet of the chest G. Its upper end is curved, the valve-rod *g* working through it, which confines the valve-rod to its place. There is a spring not shown fastened to the inside of the frame in its curved portion, the lower end of which being in contact with a small stud on the slide-piece working on the seat h^2 h^2, springs it under the stud *d*. When the valve-rod *g* rises, by the water lifting the valve *c* on its passage to the cylinder H, the slide-piece retains the valve *c*, leaving a free passage for the water to and from the cylinder H and the engine feed-pump during the force and exhaust strokes of the feed-pump plunger, until such time as the plungers T and L have completed their required amount of force and exhaust travel, when, by the motion-rod *l*, on which is keyed the bracket *s*, in the slot of which is adjusted the pin *t*, coming in contact with the arm *u*, thereby giving motion to the arm *w*, the connecting link *y*, and the inclined slide *e*, the slide-piece is withdrawn from the under side of the stud *d*, and the valve *c* drops on its seat, having arrested the motion of the plungers T and L. It remains at rest until the feed-pump plunger again commences its force stroke, when the valve rises as before, and is again locked by the slide-piece. The motion-rod has the same motion as the plungers T and L, being worked by a cross-arm from the plunger coupling-rod, (not shown,) the end of which works on the guide-rod *k*. The arm *i* being bolted to the cross-arm at the upper end, and keyed to the motion-rod at the lower, the travel of the plungers is recorded by means of the rack, keyed on the rod *b*, giving motion to the segment *n*, which works freely on the spindle n^2, on which the arm is keyed. The motion of the arm is communicated by the link *h* to the counter arm *r*, which has a slot in it, by which the required length of counter arm may be obtained by means of a pin having a nut on the back. 1, feed-valve in metre-chest; 2, delivery-valve in same.

On reference to the sectional figure, it will be perceived, that by the drop-valve *c* and the delivery-valve 2 being open, that the cylinder H is receiving water from the engine feed-pump during a force stroke, and that the metre-cylinder R is discharging, by the advance of the plunger L into it, a quantity of water through the valve 2 and the pipe O, provided the stop-cock N is not closed, equal to its area of surface and length of travel. But, supposing all the parts in the position as represented, that the stop-cock should now be closed, there being no passage for the water from the cylinder R, the plungers are at once brought to a state of rest, the water from the feed-pump finds an escape by lifting the loaded valve *b*, and passing off by the overflow-pipe; so in like manner if the stop-cock N is only part open, the plungers T and L will only move a distance equal to the quantity of water received into the cylinder H, the rest going to waste by the valve *b*.

On the engine feed-pump plunger commencing its exhaust stroke, the delivery-valve 2 having closed, the pressure of the water from the hot well causes the feed-valve 1 to rise, admitting of a supply to the cylinder as the plunger L recedes, by reason of the plunger T being acted on by the vacuum caused by the exhaust stroke of the engine feed-pump plunger, and the pressure of the water from the hot well on the plunger L, by the plunger T following the vacuum, the water in the cylinder H during the previous force stroke of the engine feed-pump is returned to it on the exhaust; and in case that only a part of the water discharged by the feed-pump during its previous force stroke should have entered the cylinder H, by reason of the stop cock N being partly closed, the rest having escaped by the valve *b*, then the cylinder H first returns all it received, the valve-rod *g* is disengaged, the valve *c* drops, and the deficiency is supplied to the feed-pump by the feed-pipe from the hot well.

From the above, it will be seen that the travel of the plungers L and T is dependent on the quantity of water received during each stroke of the engine feed-pump by the cylinder H, and the quantity of water displaced from the cylinder, and thence into the boiler, is dependent on the area of surface and length of travel of the plunger L; from which it follows, that if the travel of the plungers is correctly recorded, we can at any time ascertain, by inspection of the counter-face, the actual amount delivered.

WATER-PRESSURE ENGINE. The first engine erected in England with cylinder or piston-valves, was that put up in the Alport mines, Derbyshire, in the year 1842. This was a single cylinder engine. Its success was complete, and others were erected on the same plan. But in 1845, a *combined cylinder engine* was designed, and erected by the same engineer, which is found practically to have several advantages for such large supplies of water as that consumed by the pumping-engine, of which we subjoin accurate reductions of the working-drawings.

3773.

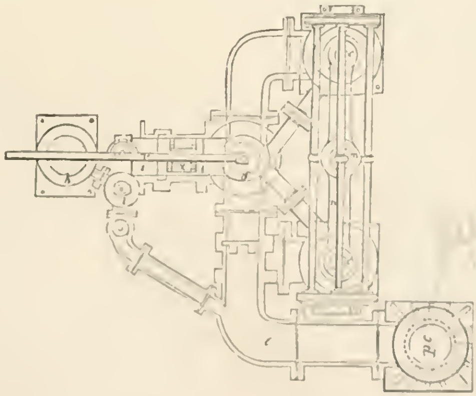
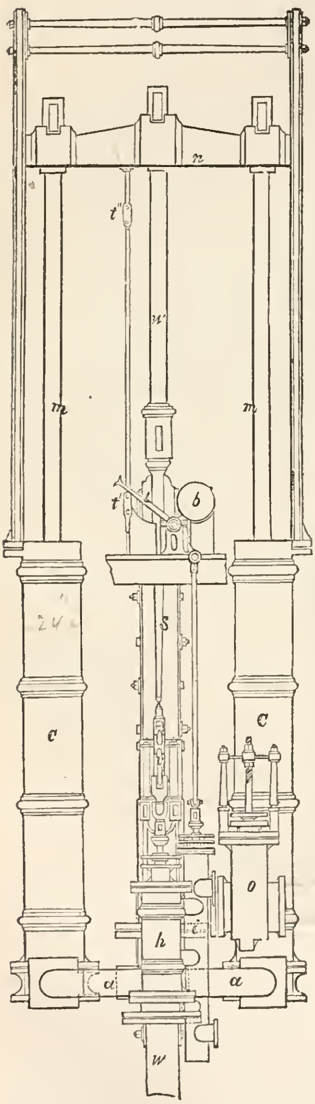


Fig. 3771 is a front elevation of the combined cylinder engine. Fig. 3772 is a sectional view, and Fig. 3773 is a general plan. PC is the bottom of the pressure column, 130 feet high, and 24 inches internal diameter. C C are the combined cylinders, each 24 inches diameter, open at top, with hemp packed pistons *a*, Fig. 3772, and piston-rods *m*, combined by a cross head *n*, working between guides in a strong frame. The admission throttle-valve is a sluice valve, shown at *o*, Fig. 3771, and between the letters *b* and *c* in Fig. 3773. The main or working valve, is a piston *g*, 18 inches in diameter, Fig. 3772, with its counter or *equilibrium piston* above. The orifice for the admission of the pressure water is between the two pistons. The intermediate pipe *a* is a flat pipe, into which numerous apertures lead from the valve-cylinder, seen immediately under *g*, Fig. 3772. The valve piston is in the position for discharging the water from the cylinders through the pipe *e*, Fig. 3772, by the sluice-valve *k*.

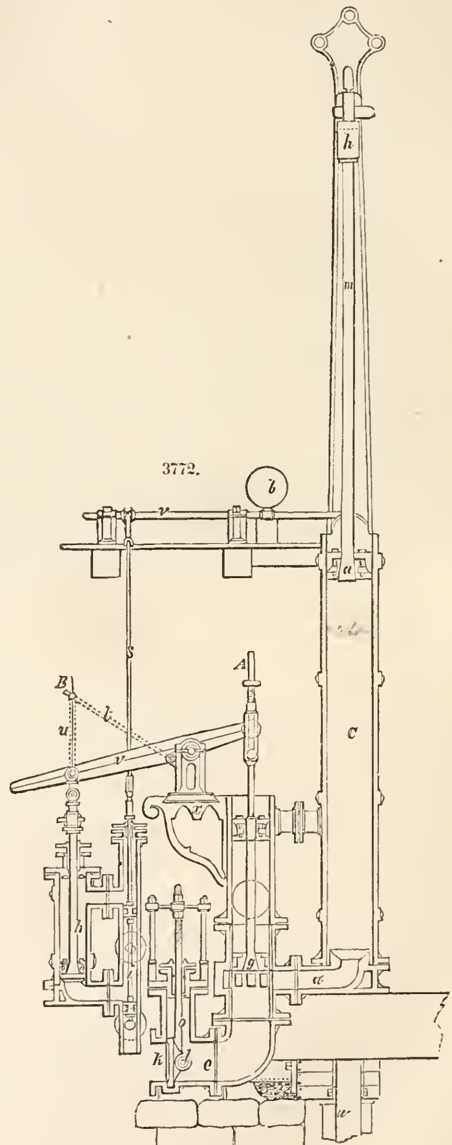
The valve-geer is worked by an auxiliary engine *h*, by means of the lever *r*. The auxiliary engine valves, are piston-valves in the valve cylinder *i*, Figs. 3772 and 3773, communicating with the pressure pipes by a small pipe, provided with cocks, as shown in Fig. 3773. The motion of the auxiliary engine-valves is effected by a pair of tappets *t' t''*, set on a vertical rod attached to the cross head *n*. These tappets move the fall-bob *b*, by means of the canti lever *t*, Fig. 3771, the other end of the lever being linked to the rod *s*, Fig. 3772, (*s*, Fig. 3771, is misplaced,) which again is linked to the auxiliary piston valve rod.

The play of the machine is now manifest. It is in every respect analogous to the Harz and Huelgoat engines, described by Weisbach. The average speed of the engine is 140 feet per minute, or 7 double strokes per minute. This requires a velocity of something less than $2\frac{1}{2}$ feet per second of the water in the pressure-pipes; and as all the valve apertures are large, the hydraulic resistances must be very small. The engine is direct-acting, drawing water from a depth of 135 feet, by means of the spear *w w*, Figs. 3771 and 3772. The "box," or *bucket* of the pump, is 28 inches in diameter, so that

3771.



3772.



the discharge is 266 gallons per stroke, or when working full speed, 1862 gallons per minute. The mechanical effect due to the fall and quantity of water consumed is nearly 140 horse-power. The mechanical effect involved in the discharge of the last-named quantity of water is nearly 74 horse-power, so that supposing the efficiency of the engine and pumps to be on a par with each other, the efficiency of the two being $\eta_1 = 71·15$, the efficiency of the engine alone $\eta = \frac{1 + \eta_1}{2} = \frac{1 + ·71}{2} = ·85$, or in the language of Cornish engineers, 85 per cent. is the duty of the engine.

WATER-WHEELS—Theory and Construction of. Although in localities where mineral reservoirs of motive power are convenient, the ever-available steam-engine has much diminished the importance of hydraulic movers, these must always continue to be the most economical, and therefore the most frequently resorted to, in situations where the liquid element can be attained in sufficient abundance, and under the necessary circumstances to answer the conditions contemplated. A waterfall is rendered available comparatively without labor, and furnishes its supplies without the intervention of human aid The energies of the steam-engine, on the contrary, can be commanded in any situation, only by the influence of the miner; and in localities much removed from sources of fuel, can only be sustained at an expense which falls heavily upon the operations to which they are subservient. That expense, it is true, is continually being diminished, and by means of the steam-engine itself, in its character of a carrier; but no happy discovery, no possibility, can reduce it to the minimum at which our water-runs are maintained.

But while water-power has the advantage of economy, where it is abundant and constant, in other localities where it is more immediately dependent upon the condition of the seasons, it is under the disadvantage of being less certain, and less under control, than the more artificial agency developed in the steam-engine. It is this independence of time and season, of circumstances and locality, which mark the great superiority of this potent creation of engineering skill, and which, in its multiform applications and applicability, have invested it with an importance and an interest which success seems only to stimulate and render more intense. The complexity of parts, and the diversity of combination, offer a scope for the exercise of ingenuity, alike highly inviting to the theoretical and the practical mechanic. The steam-engine, even as a stationary power, is, moreover, of recent origin; and contemplating the phases which it has already assumed, in connection with the general feeling that its energies have not yet been fully developed, it is not matter of wonder that it has diverted attention from the less inviting problem which we are about to discuss. Water-power is an old, if not an antiquated subject, on which the light of modern improvement has been but feebly reflected since the days of Smeaton. With a few exceptions, it has been abandoned to the management of those who recognize in it no principle, and no scope for improvement; and whose practice is not more opposed to improvement than it is empirical and opposite to all true principle.

The fact that water-power is an agency which cannot be augmented at pleasure, and which, in most situations where it is employed, has a full share of duty imposed upon it, renders it desirable that the best means of economizing it be adopted. This implies a knowledge of some of the fundamental principles of hydraulics, in addition to that acquaintance with the general laws of mechanics which every engineer is assumed to possess. It is with the view of placing the subject in a distinct and concise form, and of pointing out precisely those principles which ought to guide the practice of the engineer in his dealings with this agency, that we undertake a brief exposition of the general problem. Under the title assumed, is implied the economy of water-power, and the various means of rendering it available for purposes of industry. Without avoiding those abstract questions which beset the subject, and which imply some acquaintance with elementary analysis, we shall endeavor to keep in view that theory is valuable only in its relations to practice.

Characteristic varieties of water-wheels, and the theory of their action.—By far the most numerous, and, therefore, important order of hydraulic movers, are those which come under the denomination of *vertical wheels*, from their movement being in vertical planes, and their axis of rotation consequently horizontal. Of these we have three varieties—named according to the points at which the water is received upon the periphery—*overshot*, *undershot*, and *breast wheel*. This last is further distinguished as *high* and *low breast*, according as the water is received upon the wheel above or below the horizontal plane of the axis. When the point of reception approaches the lowest point of the circle, it becomes an *undershot-wheel;* and on the contrary, when the water is *laid on* within a few degrees of the summit, it takes the name of overshot.

A second order, of which the varieties are more numerous, and even less distinct, come under the denomination of *horizontal wheels*, because they move in planes parallel with the horizon, and consequently have their axis of rotation vertical. Of these, the best known types are the *reaction-wheel*, the *turbines* of Burdin, Fourneyron, and Jonval, the *tub-wheels* of America, (the *moulines à cuve* of the French,) and the *wheelets* common in the south of France (in Provence and Dauphiné), and which consist simply of a series of spoon-shaped (and sometimes flat) paddles or floats, set on the periphery of a strong wooden axis, and against which the water is projected from a conical adjutage. The *danaide*, better known to theory than practice, belongs to the same order.

The effects of these different varieties of wheels arise from three sources—weight, impulse, and reaction. But in stating these as the primary and simple elements of hydraulic power, it is to be remarked that we very rarely find the effect reducible to a single mode of action; more commonly we find two, and sometimes even the three acting simultaneously, and not unfrequently in nearly equal degrees. Centrifugal force is also an element which in most forms of wheels requires to be appreciated, and in some constructions—the reaction wheel, for example—it is the most difficult influence which enters into the calculation of the ultimate effect.

Directing our attention, in the first instance, to the element of weight, it is easy to prove that when a given volume of water descends through a known height H, its effect, as a mechanical agent, will be expressed by the product of the weight into the height H fallen through. As a familiar illustration, in lieu of a more precise demonstration, take the case of a horse drawing a load upon a horizontal road, and suppose that the movement is uniform over a certain distance: the constant effort exercised by the horse may manifestly be measured by a dynamometer placed between the horse and the load. Supposing this done, and that the number of lbs. indicated by the instrument as the force expended by the animal in moving the load is P, and that the distance travelled over is D feet; the product $P \times D$, or simply P D, will be a measure of the amount of effort exercised by the animal in passing over the given distance D. Now if, in place of the horse, we suppose a weight of W lbs. to be attached to the load by a rope passing over a pulley fixed in the mouth of a pit, of the depth H, equal to the length D, the pulley being assumed to have no friction, and the rope no weight, (conditions which can be virtually attained,) the weight W, which is a measure of the constant effort exerted by the animal, will descend and drag the carriage along the level road with the same uniform velocity, and arrive at the bottom of the pit at the same moment that the horse would have arrived at the extremity of the distance D. In both cases, the carriage passes over the same space and with the same velocity; the weight W is therefore capable of effecting all that the horse had done; as a prime mover, it is therefore identical. It has given the same quantity of action $W \times H$ or $W H = P D$ in the same time. Its dynamical effect may therefore be expressed in terms of the power of the horse, as a known unit. And in general the power developed by any mover, animate or inanimate, may in like manner be measured by that of a weight W descending through a certain height H, and expressed by the product W H.

Keeping this principle in view, it is further obvious that the greater the height through which the weight descends, the greater will be the effect produced. But as a current of water may be regarded as a continuous succession of weights, descending from the higher to the lower level, it is necessary to ascertain the rate of succession—in other words, the measure of the weight which descends in a given unit of time. Let that unit be 1 minute, and let the quantity of water flowing be 500 cubic feet, which multiplied by 62½, the weight in lbs. of a cubic foot of water, gives 31,250 lbs. as the weight which has descended in a minute. Further, let it be supposed that the whole height H, through which it descends, that is, the whole height of the *fall* or *head*, is 120 feet; if this quantity of water be made to act upon the circumference of a gigantic overshot-wheel, so constructed as to be free from all those detrimental influences to be hereafter considered, and the wheel be attached by a suitable connection to a train of carriages upon an incline, which by experiment is found to require the application of a force (measured dynamometrically) of 31,250 lbs. to move it through 120 feet in a minute, then, the power and resistance being equal, the water will give motion to the wheel, and descend with it through the height of a fall equal to 120 feet in the same time that the load is moved through an equal distance upon the incline. In this case we have manifestly $W H = P D$, since $W = P$, and $H = D$. The first of these conditions only is necessary to establish an equality of dynamical action. Let us assume the height of the fall to be reduced to 30 feet, and the force necessary and sufficient to drag the train of carriages up the incline, with a velocity of 120 feet a minute, to be only 7812½ lbs., the other conditions remaining unchanged, the quantity of water constantly in action upon the circumference of the wheel will be ¼th of 31,250 lbs. = 7812½ lbs., since the rate of descent is 120 feet per minute; and the distance ¼th of 120 feet, or 30 feet. In this case, $D = 4 \times H$, and $W = 31{,}250$ lbs. of water expended in the unit of time is equal to four times the load moved; but $\frac{1}{4} W \times H = \frac{1}{4} P \times D$ is $W H = P D$, by cancelling the common multiplier ¼.

The dynamical force of a current of water is therefore correctly represented by W H lbs. per minute; and since the height of fall H feet is independent of the time, W lbs. must express the weight of water which descends in a minute. A stream on which there is a fall of 30 feet, with a supply of 500 cubic feet of water per minute, will afford the same amount of power as another stream of 1000 cubic feet with a fall of 15 feet, the product W H of the two factors being the same, whether we take $30 \times (500 \times 62\frac{1}{2})$, or $15 \times (1000 \times 62\frac{1}{2})$.

In thus estimating the motive force of a current of water, the height H is the difference of level between the surface of the water at the higher and lower points between which its power is developed. This is termed the fall, and is either real or fictive: it is real when the fluid descends abruptly from a higher to a lower level, and fictive when it acts in virtue of a velocity of motion due to that height. Thus if a current, flowing in an inclined channel, be ascertained by experiment to have a uniform velocity of 12 feet in a second, then we know, from the laws of falling bodies, that the fictive head is 2·25 feet nearly, and is found from the formula $V = \sqrt{2 g H}$. In this formula, V expresses the velocity of the current in feet per second, and $g = 32{\cdot}2$ feet the velocity communicated to a falling body by gravity at the end of the first second, when it falls freely. H is the height capable of generating the velocity V, and is therefore represented by $\frac{V^2}{2 g}$ $0{\cdot}0155\, V^2$; and if s be the area of the cross section of the fluid current in square feet, then the weight of water passing a given point in a second will be $62{\cdot}5\, s\, V$; and therefore the whole dynamical force in a second will be expressed by

$$62{\cdot}5\, s\, V \times 0{\cdot}0155\, V^2 = 0{\cdot}97\, s\, V^3,$$

and this result multiplied by the number of seconds in a minute, the unit assumed in speaking of the dynamical value of a real fall of H feet, gives $W H = 58{\cdot}23\, s\, V^3$.

In illustration: let the mean velocity of a current be 10 feet per second, the mean depth 2 feet, and the mean width 15 feet; then $V^3 = 1000$, and $s = 30$ square feet;

$$\therefore W H = 58{\cdot}23 \times 30 \times 1000 = 1746900,$$

the dynamical force of the current, of which the fictive head is $0{\cdot}0155\, V^2$, equivalent to 1·553 feet, and the quantity of water flowing per minute is 1,125,000 lbs.

The fictive head of a stream flowing in an inclined channel may then be determined in terms of a real or vertical head, and measured accordingly. They are, indeed, mutually convertible; and were it not that the expression W H is arithmetically more convenient than $58{\cdot}128\, s\, V^3$, we might in every case determine H in terms of V, and employ the latter formula in our calculations of the power of a waterfall. Thus generally $H = \frac{V^2}{64{\cdot}4}$; therefore, if H be known, the value of V can be readily determined; and conversely, if V be ascertained, the corresponding value of H may in like manner be found.

We have hitherto employed these expressions abstractly; but in speaking of the dynamical force of a fall of water, it is found convenient to introduce a unit of comparison by which the amount may be more readily conceived. The mind does not readily apprehend the value of a product, even of such magnitude as 1,746,900; and it is often necessary to deal with much higher results. In this, as in all other estimates of mechanical power on a large scale, the unit adopted is the *horse-power*, reckoned at 150 lbs. raised through a height of 220 feet in a minute, or 33,000 lbs. 1 foot high per minute—as from the bottom of a mine by a rope passing round a pulley. This is the unit introduced by Watt in rating his steam-engines, and is supposed to have been taken as the maximum work of the London dray horses. The estimate is found to be a third part too high, as applied to draught horses generally; but as a measure of dynamical force, when applied to inanimate sources of power, it is unexceptionable on that account. The object is served by a definition of the unit; and *horse-power* is a name less objectionable than any others which have been proposed, unless we are to except the *cheval vapeur* of the French writers.

We have already shown that the magnitude of the individual factors of the product W H may relatively change without affecting the result. Now, in the estimate of the *horse-power*, we have taken 150 lbs. = W raised (or descending) through 220 feet = H in a minute; but these numbers will manifestly give the same product by multiplication as 33,000 lbs. = W, raised (or descending) through 1 foot = H in a minute. This affords the simpler enunciation, and is that uniformly adopted.

To estimate, therefore, the moving force of a current of water in units of this kind, it is only necessary to divide the product W H by 33,000, and the quotient will indicate the equivalent in *horse-power*. Thus in the example above, we find W H = 1,746,900 dynamic units; which divided by 33,000 gives 52·936 as the *horse-power* of the current.

The same result may, of course, be obtained by taking the reciprocal of 33,000 = ·000030,303 as a multiplier. And if we take Q to represent the number of cubic feet of water supplied in a minute, we shall have $W = 62·5\ Q$, and, therefore, $\frac{62·5\ Q\ H}{33,000} = \frac{Q\ H}{528}$ ·0018,939 Q H will express the horse-power of the current. Thus in the preceding example, the fall due to a velocity of 10 feet per second is 1·553 feet = H, and the quantity of water supplied per minute will be $(2 \times 15 \times 10) \times 60 = 18,000$ cubic feet = Q. Then $·0018939 \times 18,000 \times 1·553 = 52·94$ horse-power as before determined.

It may also be here observed, that 33,000 lbs. raised a foot in a minute being the same as 550 lbs. raised to the same height in a second, if we take *w* to represent the weight of water supplied in the smaller unit of time, then will $\frac{W\ H}{550} = ·00182\ W\ H$ represent the horse-power of the stream. Thus in the preceding example, $w = 300 \times 62\frac{1}{2} = 18,750$ lbs.; and H = 1·553; therefore, $\frac{W\ H}{550} = 52·94$ horse-power as before.

Also, since 550 lbs. = 8·8 cubic feet of water, if *q* be the number of cubic feet furnished per second, then $\frac{q\ H}{8·8}$ will in like manner represent the horse-power of the current.

As all calculations of the velocity are referred to a second as the unit of time, these forms of expression will sometimes be useful in our subsequent investigations, and may be borne in mind.

We have hitherto spoken of the power of the water; but in the application of a motive power by means of machinery, we in no case realize the theoretical effect. To produce an effect by a machine, is to overcome the resistances continually and periodically reproduced in a direction opposed to the direction of the moving force during the time of its action; but in this a certain loss invariably occurs. Thus, confining our attention to the agency under consideration, *all* the force W H of a current of water directed upon the buckets of a water-wheel does not take effect. A part of the water W commonly escapes, especially in low breast and undershot wheels, between the wheel and the *arc* by which the water is confined; and a part of the head H is also lost, both on the entrance of the water upon the wheel and on its leaving it. To these sources of loss we must generally add the amount of motive force annihilated by the counteraction or *back lash* of the water in striking the buckets, and the contraction of the stream at the *penstock*. These circumstances, to which we shall return, prevent the transfer of a certain amount of the power possessed by the water to the wheel; but there are, besides, absorbing influences which diminish the useful effect of the power actually developed. In the machine itself, we have the friction of the journals; and if the velocity be high, as in horizontal wheels working under high falls, the resistance of the atmosphere becomes a sensible quantity. At the geering by which the power is transmitted to the working points, another loss takes place by the friction and shocks of the teeth—individually very small, it is true, but being constantly and often repeated, the sum becomes an appreciable quantity.

These resistances, which for our present purpose it is sufficient to indicate, being in some part essential to every arrangement of mechanism, have in consequence obtained the name of *passive resistances*, in contradistinction to *active resistance*, by which we understand the useful effect developed. The sum of the two—that is, the whole resistance overcome by the machine, active and passive, useful and non productive—is its *dynamic effect*, and is less than the *dynamical effect* of the water expended by the amount of loss incurred by the factors $W \times H$.

From what has been observed, respecting the development of mechanical power, its measurement being the force requisite to elevate a given weight through a known space in a defined unit of time, it is manifest that the higher the velocity of the machine, the greater will be its efficiency, supposing always the resistance overcome to preserve the same intensity. If, therefore, we put *w* to represent the weight equivalent to the useful or active resistance, and *v* the velocity with which it is overcome, also $w' \times v'$ to denote the same quantities in respect of the passive resistances, we shall have as the expression of the whole dynamical effect of the machine, $w\,v + w'\,v'$. But as all resistances, active and passive, upon the machine are reducible to the common velocity v, we may put W to represent their entire sum; and, therefore, denoting by E the whole dynamical effect, we shall have $E = W\,v$. In words: the effect of the mover is equal to the resistances overcome.

From this, we observe that the effect does not depend upon the magnitude of the individual factors, but upon that of their product. By means of geering, the working speed may be made a hundred or a thousand times greater or less than that of the first mover; but when this is the case, the weight elevated will be correspondingly diminished or increased in amount, agreeably to the maximum universally recognized in mechanics, that whatever is gained in speed is lost in force, and *vice versa.*

The factor v is in practice easily ascertained by observation; but W being the sum of resistances opposed to the movement of the machine, and often consisting of many particulars imperfectly ascertained, and only ascertainable by direct experiment, usually of some difficulty, this factor, and consequently the whole effect E, does not always partake of that certainty which is desirable, in comparing the work done with the power expended. But this last, which we have represented by W H, being always greater than E, we know that whatever may be the efficiency of the wheel, these forces must have the relation $E = m$ W H, in which m is a fraction less than 1, but different in different cases and conditions, and only determinable by direct experiment. Taking the force expended, viz., W H = 1, the coefficient m will express the ratio of the effect realized in the active and passive resistances of the mover to that force. It can never equal 1, for then the whole moving force would be realized by the wheel, which cannot possibly happen by any adaptation hitherto discovered; much less can it exceed 1, which would imply that the power realized is greater than that expended. The values which it bears in particular cases will be subsequently investigated at considerable length, taking as the basis of discussion the numerous experiments which have been directed to its determination. In the mean time, it will be sufficient to observe, that it very rarely exceeds 0·80, and not unfrequently, in undershot-wheels, it falls below 0·25. In wheels coming under the denomination of high breast and overshot, the common value ranges from 0·75 to 0·66.

The formula $E = m$ W H is general; it applies to any hydraulic mover under any circumstances, and, therefore, the effect and producing cause may always be thus compared. When the fall is fictive, we have seen that it may be determined in terms of H, from the known relations of the velocity V generated in the current, to the generating head H. But in the case of an undershot-wheel acting by a fictive head, although the formula of ultimate comparison remains the same as for an overshot-wheel acting under a real head, the mode of action is different, and requires a separate consideration. Taking a case of the most simple kind, in which the wheel is furnished with radial floats, and acts in a confined rectilineal course, in which the current of water flows with a velocity of V feet per second, it is obvious that the motion of the floats must, under the supposition of the wheel being burdened, be less than V when impelled by the current; since it is clear that the fluid could have no effect upon them if they moved at the *same* velocity, and would retard rather than impel the wheel at any higher velocity. Moreover, in impelling the floats at a given velocity v, there must remain in the water, after it has passed the wheel, a certain velocity which is always greater, and cannot manifestly be less than v. If, according to the supposition, the floats so completely occupy the watercourse that no particle of the fluid can pass without acting upon them, the velocity retained by the current would evidently be the difference between the initial velocity V, and that imparted to the surfaces opposed to its motion. But this condition, although not actually, is virtually fulfilled in every case analogous to that assured, however imperfect the arrangements in scheme and construction. Although a highly mobile fluid, there is a certain cohesion among the particles of a current of water, by which an equilibrium of motion is, if not uniformly maintained, at least quickly established in cases of disturbance. The interruption offered to one portion of the mass is speedily communicated to the whole. The uninterrupted particles, by the mutual cohesion existing in the mass, act upon those to which the interruption has occurred, and thereby reciprocally communicate and lose a portion of the velocity which they possessed. An equilibrium may not be thus instantaneously established. Like other ponderous bodies, the fluid particles possess inertia, and, therefore, require time to receive and communicate motion; but the action is no less certain and essential to the conditions assumed. We may, consequently, without risk of error, presume that in all cases the velocity retained by the water after it has acted upon the float of the wheel, will be fairly expressed by $V - v$. This velocity is, moreover, lost as respects the efficiency of the wheel: it has produced no effect. Now, from what has been before stated, we know that the head equivalent to the initial velocity V of the current may be expressed by $\frac{V^2}{2g}$; and extending the same principle to the velocity v communicated to the wheel, the head equivalent will be expressed by $\frac{v^2}{2g}$; and the head lost in consequence of the unemployed velocity $V - v$ will, in like manner, be represented by $\frac{(V - v)^2}{2g}$. The vertical section of the stream being, therefore, designated as before by s, the whole weight of water acting upon the wheel, in a second of time, will be represented by 62·5 s V, and this multiplied by 60 will be the quantity acting in a minute = W. The dynamical effect of the impulse will, therefore, be expressed by

$$W\left(\frac{V^2}{2g} - \frac{v^2}{2g} - \frac{(V - v)^2}{2g}\right) \text{ reducible to } \frac{W}{g}(V - v)\,v$$

by performing the operations indicated. And designating by $h\,h'\,h''$, the heights of head due to the three velocities V, v, and $V - v$, we have the equivalent expression

$$W\,(h - h' - h'').$$

The two last terms in the parentheses manifestly diminish the effect produced. Were they *zero*, this effect would then be Wh, which is the whole dynamic force of the current, since h represents the total head due to the velocity V. In order that the first of the two last terms may be *zero*, it is necessary that $v = 0$; and on this supposition, the whole expression vanishes, showing that no effect is realized—which is manifestly the case where the wheel has no velocity. The expression further shows that the velocity preserved by the water after it had acted upon the floats depends upon the relation of V and v, and in order that $V - v = 0$, the wheel must have the same velocity as the current. In this case also the whole expression vanishes, or the power realized is nothing; for then the whole force of the water will be absorbed by its own velocity, and could only turn the wheel at an equal velocity when the burden (including its own weight and passive resistances) of the wheel is nothing. The formula is therefore, consistent with itself in the most extreme cases, and may be accepted as a fair representation of the effect realized in all intermediate conditions.

There are other modes of establishing the rule, which it may be at least satisfactory to state, more especially as it will be necessary to resort to them in a subsequent part of the inquiry. According to a well-known notation in dynamics, the weight of a body divided by gravity g is called the *mass;* and the mass multiplied into the velocity in feet per second is denominated the *quantity of movement*, or *pressure* of the body.

Adopting this notation, and denoting the weight of fluid which flows in a second by w, and its velocity by V; then the mass will be represented by $\frac{w}{g}$ and the quantity of movement or pressure by $\frac{w}{g}V$. But the floats of the wheel are assumed to recede from the impulse with a velocity of v feet per second; the pressure exercised upon them will therefore be reduced to $\frac{w}{g}(V - v)$; but the space passed through by the wheel, impelled by this pressure, is v feet per second; consequently the dynamical force (the product of the pressure and velocity) will be $\frac{w}{g}(V - v)\,v$ per second; or taking $W = 60\,w$, it will be $\frac{W}{g}(V - v)\,v$ per minute. But as before observed,

$$\frac{W}{g}(V - v)\,v = W\left\{\frac{V^2}{2g} - \frac{v}{2g} - \frac{(V - v)^2}{2g}\right\}$$

as may be found by reduction of this last expression.

From the principle formerly adverted to of the relation of the velocity possessed by a falling body, to the height through which it must have fallen to acquire that velocity, it follows that the weight being w pounds, and the velocity V feet per second, there must be accumulated in the body a number of units of dynamical force represented by the former $w\frac{V^2}{2g}$ as before shown. After it has passed from the velocity V to the less velocity U, there will be accumulated in it the number of units of force represented by $w\frac{U^2}{2g}$. There will therefore have been taken from its dynamic force a number of units represented by $w\frac{V^2}{2g} - w\frac{U^2}{2g} = \frac{W}{2g}(V^2 - U)^2$. Now this must be equally true of a current of water or of any other body; consequently, if the velocity with which it meets the floats of the wheel be V, and it escape with the reduced velocity U, the force lost by its action will be expressed by

$$\frac{W}{2g}(V^2 - U^2).$$

But this force has been lost by impulse upon the floats, and ought, theoretically, to have been entirely communicated to them. On this assumption, if v denote the velocity of the wheel in feet per second, and p the pressure overcome, then will $p\,v = \frac{W}{2g}(V^2 - U^2)$.

But on the assumption that the water meets the floats of the wheel without shock, it will leave them with a velocity, as before shown, of $(V - v = U)$ feet per second; consequently, putting for U^2 its equivalent $(V - v)^2$ and reduce our formula by performing the operations indicated, we find

$$p\,v = \frac{W}{2g}(V^2 - (V - v)^2) = \frac{W}{g}(V - v)\,v$$

2 D

which is the same expression which resulted from the preceding modes of investigating the question.

In the case of purely under-shot and other impulsive wheels, we may therefore assume the effect,

$$E = m\left\{\frac{W}{2g}(V - v)\,v\right\}$$

in which, as before, m is coefficient determined by experiment, and W the weight of water in pounds per minute; and V and v are respectively the velocities of the water, and of the periphery of the wheel in feet per second.

This formula was first given in all its precision and generality by Borda, in his memoir on water-wheels, presented to the French Academy in 1767. Having called z the velocity with which the wateabandons the machine, and $\frac{P}{g}u^2$ the sum of the losses of *vis-viva* sustained by the fluid, he gives, as a general corollary to the principles demonstrated in his memoir, the relation,

$$p\,v = P\left(h - \frac{z^2}{2g}\,\frac{u^2}{2g}\right)$$

which is exactly the same as that above established, p being the pressure overcome by the wheel, v its velocity in feet per second; P the total pressure due to the weight of water, and h the head real or fictive; $u = V - v$ the difference of velocity of the current and of the periphery of the wheel. Deceived by his formula, he, however, remarks that in the case of the greatest effect $u = 0$ and $z = 0$; whence $p\,v = P\,h$, which in plain language signifies that the wheel being at rest, the whole power of the stream is realized. This is evidently absurd; but the absurdity is in the interpretation, not in the formula. When u and z are respectively *zero*, no power is realized, but the floats of the wheel entirely obstruct the passage of the water, and sustain the whole pressure Ph. But pressure without motion is not power. The error has, however, been reiterated until it has assumed the position of an established principle. Thus every writer since Carnot has laid it down, as the basis of the theory of hydraulic machines, "that in order that the machine may produce the greatest possible effect, it is necessary that the water shall arrive and act upon it without shock, and quit it without velocity." That the maximum effect be obtained, it is admitted that there must be no percussive action; the fluid must lose its velocity by insensible degrees; but to suppose that it shall quit the wheel without velocity, is to suppose that the wheel itself has motion equal to that of the stream, and consequently produces no mechanical effect. The doctrine is, however, true, if, instead of velocity, we read "relative velocity." In this case no water will escape that has not given up a certain amount of its movement to the wheel, and it will clearly possess the least quantity of motion consistent with its action upon the floats, namely, an absolute velocity equal to theirs. On this condition we shall have $v = V - v$ and therefore $v = \frac{1}{2}V$, which implies that the wheel ought to take half, and only half, the velocity of the current.

We shall hereafter find that this conclusion requires modification; but in the mean time it is sufficient to intimate the mode of calculation, and to point out the theoretical conditions which form the basis of inquiry.

It now only remains in this place to indicate the general principle of the reaction of water. According to Newton's third law of motion, action and reaction are equal in amount and opposite in direction. This proposition assumes the character of an axiom, when the mind is directed to the reciprocal action of solids, since it is clear that any body acting upon another by pressure, for example, must itself experience a reaction equal and directly opposed to the action which it exercises. In the same manner, whenever a force, as that of gravity, pressing upon a fluid, causes it to issue through an orifice formed in the side of a containing vessel, a force equal and contrary to that with which the stream issues will, in consequence, be expended upon the side of the vessel opposite to the orifice of escape. To explain this very briefly: when a part of the weight of a fluid is expended in producing motion in any direction, an equal pressure is necessarily deducted from its pressure in the opposite direction, for the gravitation employed in generating velocity cannot at the same instant be causing pressure. Supposing an orifice to be made in the bottom of a vessel filled with water, a column of the fluid will descend through it, and will expend during its descent a quantity of pressure equal to a column of twice the depth of the fluid in the vessel, and having an area equal to the least section of the stream. For example: suppose the vessel to be 16 feet deep, and to be kept constantly full, the velocity of the stream will be 32 feet in a second; and, therefore, a column of 32 feet of length will pass through the orifice in each second, with the whole velocity derivable from its weight acting for the time. It is therefore clear that an equal amount of the pressure of the fluid in the vessel must be expended in producing that velocity, and must of course be deducted from the weight of the whole fluid—that is, from the entire pressure which it would otherwise exercise on the bottom of the vessel. Now, what is true with respect to vertical descent, is equally true when the motion is in any other direction. When the orifice is formed in the side of the vessel, the pressure upon that side will be diminished by as much as the pressure employed in producing the motion; and the effect of the diminution of the pressure in that direction will be the same as if the vessel were subjected to an equal pressure of any other kind in an opposite direction. And, moreover, the pressure being lateral, and therefore perpendicular to the only direction in which a vertical force, like that of gravity, can itself act, it must be derived from reaction of the opposite surface of the vessel upon the moving particles of the fluid, and may be assimilated to the constant pressure of a spring interposed between the moving particles and the part of the vessel immediately opposite to the orifice. In this position the spring must needs act in a direction exactly contrary to that of the movement impressed upon the fluid, and with an intensity exactly equal to the hydraulic pressure—that is, to the force due to the volume of water issuing by the orifice. Now, if s be taken to denote the cross sectional area, in square feet, of the stream, and h the depth of the water above the centre of the orifice, then the quantity of water discharged in a second will be $s\sqrt{2gh}$ cubic feet, and the weight $62{\cdot}5\,s\sqrt{2gh}$. But the hydraulic pressure due to this volume of water will be $62{\cdot}5\,s \times 2h$, which is the weight in pounds which would be necessary and sufficient to prevent the vessel from receding in a direction opposite to that in which the water issues. To approach the actual conditions: suppose a vertical cylinder with two hollow tubes inserted near its base, and projecting laterally at right angles to its axis; that these tubes are closed at their outward extremities, and communicate freely with the interior of the cylinder; that an orifice is pierced near the extremity of each on opposite sides of their common axis, and in a plane passing through that axis perpendicular to the axis of the cylinder. If this apparatus be placed on a vertical axis, round which it is free to revolve, it will constitute that variety of hydraulic machine known as Barker's Mill, and may be considered a type of those machines which derive their power from the reaction of fluids. Water being let in to fill the vertical cylinder, it will flow into the horizontal tubes, and issue by the lateral orifices, but in thus finding vent into the atmosphere through the (contrary) sides of the tubes, these will be made to recede in a direction opposite to that in which the water flows out, and thereby produce a circular motion of the apparatus round the axis by which it is confined.

To arrive at a general notion of the power developed by the revolution of the machine, let us denote the depth of the cylinder above the level of the orifices by H, and the sum of the cross-sectional areas of the jets by S; if the cylinder be kept constantly full of water to the depth H, then the weight which must be applied in an opposite direction to that in which the machine tends to revolve, and at the same distance from the axis of revolution as the centres of the orifices, to prevent the machine from getting into motion, will be $62\frac{1}{2} S \times 2H$ lbs., this being the hydraulic pressure due to the quantity of water $S\sqrt{2gH}$ cubic feet discharged each second. Otherwise expressed, the weight necessary and sufficient to balance the hydraulic pressure, and thereby to prevent the machine from revolving, is that of a column of water equal in length to twice the head, and having an area of base equal to the sum of the cross-sectional areas of the two jets. This is found to agree with experiment, and it may be determined from *a priori* reasoning. In every body falling freely, the velocity acquired in a given unit of time is such as would carry it through double the space which it has fallen during the next equal unit of time, supposing gravity to cease to act upon it. There must, therefore, have issued by each of the orifices of the machine, a column of water equal to double the height of the surface above the orifices, that is, 2 H, and the weight of such column is manifestly $62\frac{1}{2} S \times 2 H$.

This will then be the condition of the machine held in a state of rest by a weight balancing the hydraulic pressure of the water discharged by its orifices. But when it is allowed to get into motion another important condition is superadded. Centrifugal force is brought into action, and increases the pressure of the water at the orifices, and thereby augments the quantity discharged in a given time, and also the intensity of the reaction, exactly as if the head-pressure or depth of the cylinder were correspondingly increased.

A common expression for the centrifugal force of a body revolving in a circle at a distance x from the centre of motion is $\frac{w}{g}\omega^2 x$, in which ω is the angular velocity at the distance x, and is $= \frac{v}{x}$ when v expresses the absolute velocity in feet per second, at the distance x. Now, if the mass $\frac{w}{g}$ of the body advance in the direction of the radius outwards, through the element of space dx, in an instant of time, the quantity of action (*vis viva*) created by the centrifugal force will be $\frac{w}{g}\omega^2 x\, dx$. But this being true of a solid body, will be equally true of the molecules of water in the arms of the machine. If, therefore, these arms commence at a distance r and extend to a distance R (the centres of the orifices) from the centre of rotation, we shall have, by integrating for the space between r and R, the length of each arm,

$$\int_r^R \frac{w}{g}\omega^2 x\, dx = \frac{1}{2}\frac{w}{g}\omega^2 (R^2 - r^2).$$

And since $\omega = \frac{v}{R}$, if we take the quantity of water $w = 1$, we have, as the pressure at the orifices due to the velocity of rotation,

$$\frac{1}{2}\frac{w}{g}\omega^2 (R^2 - r^2) = \frac{v^2}{2g}\left(1 - \frac{r^2}{R^2}\right).$$

If, therefore, we add this to the initial head-pressure H, we shall have as the whole pressure at the orifices of the machine,

$$H + \frac{v^2}{2g}\left(1 - \frac{r^2}{R^2}\right).$$

Now, under this pressure, the expenditure of water will be increased as

$$\sqrt{2gH} \text{ to } \sqrt{2gH + v^2\left(1 - \frac{r^2}{R^2}\right)}, \text{ that is,}$$

$$\text{as } 1 \text{ to } \sqrt{1 + \frac{v^2}{V^2}\left(1 - \frac{r^2}{R^2}\right)},$$

putting V for the velocity due to the initial head H; and supposing the permanent head H to have been increased by the quantity $\frac{v^2}{2g}\left(1 - \frac{r^2}{R^2}\right)$, by directly increasing the depth of the cylinder, it is plain, from what has before been stated respecting the force of reaction, that the weight which would just be sufficient to keep the machine from getting into motion, would be

$$62{\cdot}5\, S \times 2\left\{H + \frac{v^2}{2g}\left(1 - \frac{r^2}{R^2}\right)\right\} \text{lbs.}$$

This, then, is the whole pressure of reaction due to the increased head $H + \frac{v^2}{2g}\left(1 - \frac{r^2}{R^2}\right)$, but the reaction due to the fictive part $\frac{v^2}{2g}\left(1 - \frac{r^2}{R^2}\right)$ is obtained in consequence of the rotatory motion of the machine, with a velocity of v feet per second; a portion, therefore, of the whole reaction due to the quantity of water expended, must have been consumed in communicating that velocity to the volume of water discharged in that second of time. The pressure thereby withdrawn from that due to the condition of rest will be expressed by the mass $\times$ into the velocity, that is, by

$$\frac{62{\cdot}5\,S\sqrt{2\,g\,H + v^2\left(1 - \frac{r}{R^2}\right)}}{g} \times v;$$

and this pressure being subtracted from the pressure due to the whole force of reaction, there remains the whole effective pressure, that is, the resistance or load which the machine can overcome at the given velocity, v feet per second. The operation being performed, we obtain

$$\frac{62\frac{1}{2}\,S}{g}\left\{2\,g\,H + v^2\left(1 - \frac{r^2}{R^2}\right) - v\sqrt{2\,g\,H + v^2\left(1 - \frac{r^2}{R^2}\right)}\right\}$$

But the weight of water discharged in a second is

$$62\tfrac{1}{2}\,S\sqrt{2\,g\,H + v^2\left(1 - \frac{r^2}{R^2}\right)} = w;$$

therefore,

$$62\tfrac{1}{2}\,S = \frac{w}{\sqrt{\left\{2\,g\,H + v^2\left(1 - \frac{r^2}{R^2}\right)\right\}}}$$

If, then, we put for $62\frac{1}{2}$ S in the foregoing expression this equivalent, and reduce, we obtain the convenient formula,

$$\frac{w}{g}\left\{\sqrt{2\,g\,H + v^2\left(1 - \frac{r^2}{R^2}\right)} - v\right\}$$

Now, this being the pressure acting upon the machine, and the velocity being v feet per second, the power transmitted, supposing no loss, will be

$$\frac{w}{g}\left\{\sqrt{2\,g\,H + v^2\left(1 - \frac{r^2}{R^2}\right)} - v\right\}v;$$

and putting $V = \sqrt{2\,g\,H + v^2\left(1 - \frac{r^2}{R^2}\right)}$, the formula takes the form

$$\frac{w}{g}(V - v)\,v,$$

in which $w =$ the weight of water discharged in a second; V the velocity of the issuing jets, and v the absolute velocity of the machine, in feet per second. The theoretical rule thus agrees with that established for wheels which derive their efficiency from the impulse of the stream, thereby verifying the doctrine that action and reaction are equal. There still remains, however, to determine the value of the experimental coefficient m, with which this expression must likewise be affected to render it available in practice; but this being different for differently constructed machines, we cannot pursue the inquiry in this place.

The rule may be otherwise established thus: The whole laboring force, or mechanical efficiency of the water, expended under a head-pressure of $H + \frac{v^2}{2\,g}\left(1 - \frac{r^2}{R^2}\right)$ feet, will be

$$\frac{w}{2\,g}\left\{\sqrt{2\,g\,H + v^2\left(1 - \frac{r^2}{R^2}\right)}\right\}^2 = \frac{w}{2\,g}\left\{2\,g\,H + v^2\left(1 - \frac{r^2}{R^2}\right)\right\}.$$

But of this efficiency there is consumed in giving rotatory motion to the water, and thereby raising the head-pressure $\frac{v^2}{2\,g}\left(1 - \frac{r^2}{R^2}\right)$, the quantity $\frac{w}{2\,g}v^2\left(1 - \frac{r^2}{R^2}\right)$, which consequently falls to be deducted from the entire efficiency of the fluid.

Again, the water leaves the machine with a certain amount of velocity remaining in it, namely, a velocity equal to the difference between that with which it issues from the orifices under the virtual head $H + \frac{v^2}{2\,g}\left(1 - \frac{r^2}{R^2}\right)$, and the velocity of the machine measured on the tangent to the circle through which the orifices revolve; this difference of velocity will be expressed by

$$\sqrt{2\,g\,H + v^2\left(1 - \frac{r^2}{R^2}\right)} - v,$$

and the quantity of laboring force due to it will be

$$\frac{w}{2\,g}\left\{\sqrt{2\,g\,H + v^2\left(1 - \frac{r^2}{R^2}\right)} - v\right\}^2$$

This likewise falls to be deducted from the laboring force due to the water expended under the head $H + \frac{v^2}{2g}\left(1 - \frac{r^2}{R^2}\right)$, leaving the efficiency communicated to the machine

$$wH - \frac{w}{2g}\left\{\sqrt{2gH + v^2\left(1 - \frac{r^2}{R^2}\right)} - v\right\}^2 = \frac{w}{g}\left\{\sqrt{2gH + v^2\left(1 - \frac{r^2}{R^2}\right)} - v\right\}v,$$

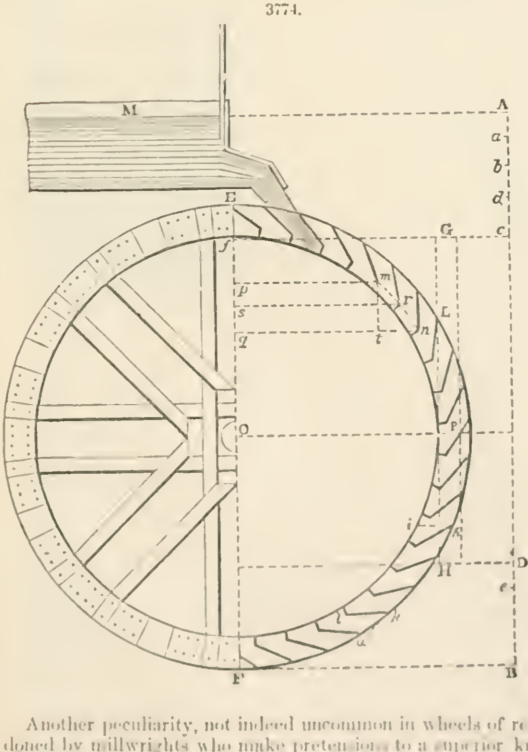
which is the same formula as we obtained by the preceding investigation, and which, it may be well to observe, would correctly represent the action of the machine, were it not that it is liable to modification by certain incidental influences, which remain to be examined when we come to treat of the details of construction, and other circumstances by which the efficiency of the machine is affected.

We now pass to the examination of the different varieties of wheels before indicated, and shall take them nearly in the order given, but under a somewhat more convenient division.

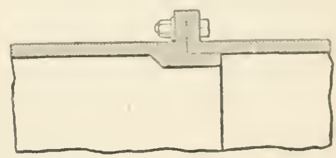
Bucket-wheels.—Under this head we include those nominal varieties of vertical wheels—overshot and breast—which are provided with buckets upon their peripheries for the reception of the water, and which, therefore, derive their efficiency chiefly from the weight of the fluid received into the buckets. This form of wheel, at whatever point the water may be received upon its circumference, is the most obvious in its action. No hydraulic machine could be more simple: a given weight descends from a given height; a known power is thus expended, to which the work performed ought to bear an assignable relation.

The older bucket-wheels which we encounter are constructed of wood; but that material, once of almost universal use in constructive mechanics, is fast giving place to iron, and in a few years hence we may expect that a wooden water-wheel will be as rare, and as much an object of antiquarian interest to those who take pleasure in reviewing the progress of the industrial arts, as wooden geering has already become. Many of those wheels still continue to exhibit in their constructive details a very superior style of workmanship, and an attention to durability which, in several instances within the knowledge of the writer, the lapse of a century has hardly conquered. The best specimens, no doubt, only remain of the truly old construction, while those of an inferior grade have disappeared and been replaced by wheels of modern construction, in which iron, if not the sole material, holds at least a prominent place.

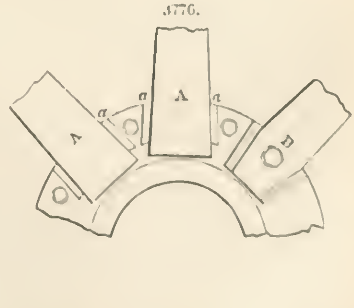
3774.



3775.

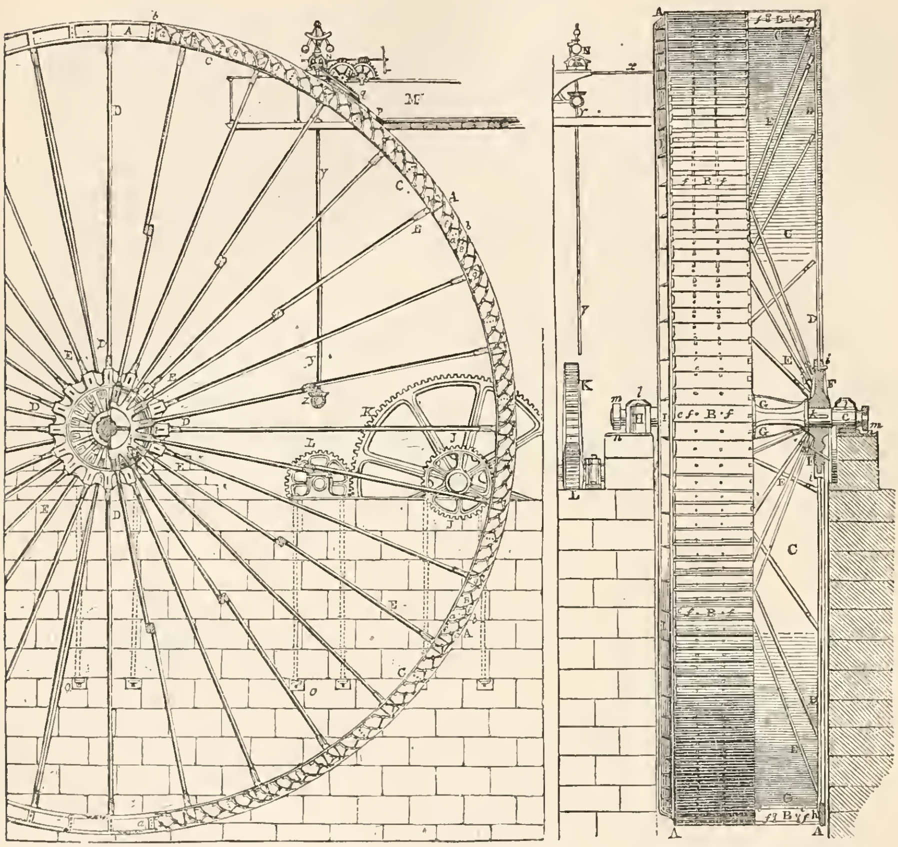


3776.



Another peculiarity, not indeed uncommon in wheels of recent construction, although generally abandoned by millwrights who make pretensions to a superior knowledge of the principles which ought to govern the transmission of hydraulic power, unless the conditions be dictated by extraneous circumstances, consists in passing the water over the summit of the wheel into the buckets in the manner represented in Fig. 3774. This arrangement constitutes literally an overshot wheel; but while we have preserved the name, it is no longer deemed necessary to apply it literally. In the present acceptation of the term, nothing more is implied than that the water is received into the buckets near the summit of the wheel; and, in ordinary practice, these wheels reckoned as overshot, by strict definition some under the designation of high-breast wheels. One of the finest specimens of this construction yet erected is that represented in Figs. 3778 and 3779, in which the height of the fall bears to the diameter of the wheel the relation of 9 to 10. In the purely overshot-wheel this relation, as we shall immediately have occasion to show, is very nearly inverted.

3778. 3779.



In the construction of wheels of this class, the technical points which remain to be considered, after determining the diameter and breadth of the wheel from the height of fall and quantity of water furnished by the stream, are the axle and its journals, the arms and their connections, the shrouding, sole, and buckets.

The subject of the axle and journals has already been very fully noticed when treating of shafts in the article on GEERING, (which see;) but it may be here added that in iron wheels of great weight and breadth, in which the axle is consequently of corresponding diameter and length, and especially when the wheel is to be transported to a considerable distance from the work at which it is constructed, it is not uncommon to make the axle of two, or even of three parts. When the axle is formed in this manner, the parts are fitted together by turning, and are secured by bolts in strong flanges cast upon the contiguous extremities. Fig. 3775 will convey an idea of this arrangement in its best and most enduring form—that in which it is least liable to objection. But no force of ingenuity can render it safe; the constantly changing position of the weight ultimately, and sometimes, indeed, very speedily, acts injuriously on the bolts, thereby relaxing the joint, which it is all but impossible to refit with any prospect of durability. This result is greatly delayed by boring the bolt-holes in the flanges, and turning the bolts exactly to fill them. In fitting the parts together permanently the bolts ought to be inserted hot and have the nuts fully screwed up before they have contracted to their normal length. As a further precaution, the bearing surfaces may be rusted together by washing them immediately before they are put together with a dilute solution of sal-ammoniac.

In wheels composed entirely of wood, the eight principal arms are commonly disposed in parallel pairs, crossing each upon the axle to which they have no positive attachment. The arms at the points of crossing are bolted together in sets of four, and the two frames thus formed are set apart upon the axle at a distance from each other, determined by the intended breadth of the wheel, and are bound together by tie-rods, and not unfrequently by diagonal struts when the breadth of the wheel is considerable, yet not sufficient to require the introduction of an intermediate set of arms and partition shrouding

The framing is further secured in its place upon the axle by wedging. The material used for this purpose is commonly oak, which, on being driven as firmly as the nature of the material will admit, is interspersed with thin iron wedges to give further compactness and solidity to the joint, and to prevent the packing from relaxing. These crosses of four arms each thus fixed in position sustain the two lateral shroudings between which the buckets of the wheels are inserted. They are termed the master, main, or principal arms; and in wheels of very small diameter—14 feet and under—there are no other employed. But when the diameter of the wheel exceeds the limit at which the arcs of the shrouding would be safely supported at that minimum number of points, a series of auxiliary arms are introduced, in sets of four, on each side of the wheel. These secondary arms do not cross each other at the axle as the principal arms do, but are simply made to abut against its faces, where they are secured by filling blocks, laid in in different ways, according to the number of auxiliaries introduced. They are further secured by bolts to the master-arms, which they are always made to cross in the manner represented.

When the wood is sound, and no particular circumstances intervene to increase the strain upon the wheel, the strength of the arms may be computed by the ordinary rules applicable to the kind of wood employed in the construction. In a very elegant specimen of 48 feet diameter the arms at the base are 8 inches square, and taper to 6 inches at the extremities.

In wooden wheels of more modern construction, instead of the arms being framed together upon the axle in the manner just described, their bases are inserted, and generally fixed by wedges in iron centres previously fitted upon the axle. This is a much more elegant and substantial arrangement, and is applicable to all the varieties of vertical wheels, and to all diameters; but it does not always happen that the mode of fitting is the best adapted for durability or convenience of repair. Very commonly the centres are solid castings, with recesses in the periphery corresponding in number and size to the arms which they are intended to receive; and when the arms are formed of malleable-iron bars, this arrangement is all that could be desired. But for wooden arms, the recesses ought to be considerably more in breadth than the butts to be inserted into them; and these ought to be fixed, not with iron, but by wooden keys, and without the aid of bolts. If the outside cover be cast separately as a loose ring, and bolted upon the centre after the butts of the arms are fitted, it will allow of the recesses to be formed widest at bottom, and the butts to be made dovetail-shaped, and secured by parallel keys *a a*, in the manner represented by the arms A A, in Fig. 3776. These recesses, when the work is of a superior character, would be planed on all the bearing surfaces, and the cover might be fitted by turning.

This mode of fitting is equally suitable for cast-iron arms, except that the keys are in that case rendered unnecessary by the butts being made to fill the recesses, and are carefully fitted by planing. They are also secured by bolts, and it is not often that any cover is employed.

When the wheel is of small diameter the centres and arms are sometimes, and advantageously, formed of one casting. In this case no fitting is required; and although the moulder's labor is greater, there is an ultimate economy, when the diameter does not much exceed 12 feet, which more than balances the excess of foundry cost. In one small example we have observed the principle extended to the shrouding; each side of the wheel consisted of a single casting, and the two were simply bound together by a few tie-rods, and the sheet-iron plates, of which the buckets were composed.

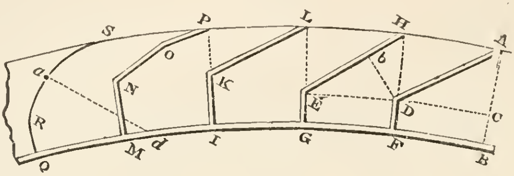
The shrouding is formed of two annular plates, which, in wooden wheels, are composed of plank, of 3½ inches to 7 inches thick, shaped and jointed together similarly to the felloes of a carriage-wheel. Instead, however, of the joints being formed by simply abutting the extremity of one piece upon that adjacent, the extremities are checked to half their thickness upon opposite sides, and overlapped. Sometimes also the joints are made by scarfing, when not opposite to the arms, and strengthened by plates of iron laid into recesses flush with the general surface. The other joints which receive the extremities of the arms are half-checked on the exterior surface, and are connected by the palms, which are usually counter-checked on the inner face, to fall flush into the recesses prepared for them in the ends of the pieces which they are intended to connect. With the old millwrights it was not uncommon to form the joints of the better class of wheels by mortise-and-tennon, and sometimes by joggles—a method which seems to us equally efficient and less expensive.

In the older wooden wheels the shrouding is usually of a greater depth than is consistent with modern practice. At present we meet with few examples in which the shrouding is more than 12 to 15 inches deep, whereas a depth of 20 inches was formerly not uncommon. This is a subject, however, which will require to be considered subsequently, as also the width of the wheel or distance between the shrouds.

The width of the wheel determines the length of the buckets. These extend between the shrouds, except in very broad wheels, in which an intermediate or partition shrouding is sometimes introduced to give support to the buckets at the middle of their length. This is usually resorted to in wooden wheels when the breadth exceeds 8 feet, but it is not uncommon to find iron wheels of double that breadth without any partition shrouding. In this class of wheels it is, indeed, an excepted case in which we find this arrangement adopted in the entirety exhibited by the older specimens. In these the partition shrouding was, in all respects, a duplicate of the lateral shrouds, and was like them attached upon arms radiating from an independent centre, placed intermediate to the two others upon the axle of the wheel. Besides giving additional rigidity to the struction, it served to carry the medial extremities of the buckets, which being formed of plank, did not admit of that ready mode of staying, so convenient with sheet iron buckets, as exemplified in Fig. 3778 and elsewhere.

The shrouds being properly adjusted and fixed in relation to the axis of motion, a circular runner of plank having a transverse section of 3 × 3 inches, is attached by wood-screws to the interior face of each of the shroud plates, and upon this the ends of the sole-planks are supported. We speak of the best form of construction; but more frequently the sole-planks are simply fitted and fixed upon the interior circumference of the shrouding; and this arrangement has its advantage in the facility which it allows for the repair of the sole, as the planks may be taken off without disturbing the buckets in their vicinity. When the sole is completed the wheel has the appearance of a large drum with radial flanges, between which the buckets are to be fixed. The extremities of the planks of which the buckets are formed are commonly received into mortises cut in the contiguous faces of the shroud-plates; or into grooves formed by narrow runners of wood nailed upon the plates. A still better mode of fitting is to sprig the buckets in their places, or to mark off their form and positions upon the inner surfaces of the shrouding, and fill in the spaces between them by plates of board cut to the proper form. When the first method is adopted it is necessary to insert the radial part D F of Fig. 3780, before fixing the sole-planks; but by forming grooves according to the latter methods, the sole may be completed previous to any part of the bucketing being prepared. When the method of mortising is adopted it is, on the contrary, more convenient to make the bucketing precede the application of the sole-planking. It is of little moment which of these methods be adopted in practice, and the circumstances of the particular case will invariably determine that which may be resorted to with most advantage; but it is of the utmost importance that in the process of *cleeding* the wheel be not thrown out of truth. To avoid this, the operations ought to proceed from at least two points; and if the wheel be of large diameter it will give a better chance of correctness to distribute the operations over the four quadrants of the wheel, taking alternately that immediately opposite and contiguous as the next in succession to be operated upon.

3780.



Each bucket consists usually of two plates placed at a determinate angle A D F, Fig. 3780; and sometimes of three, as in the form indicated at P M. The bucket is an essential part of the wheel, which ought to be determined not by the rule-of-thumb practice admissible in some of the less important details, but from a competent regard to the conditions involved. Upon their form depends, in a great measure, the efficiency of the wheel as a hydraulic motor; and although with wood the true conditions which lead to the best effect can only be very distantly approximated, it may still be of advantage to indicate these as nearly as the circumstances will admit.

Having determined the diameter of the wheel and the depth of the shrouding—the rules for which will be hereafter adverted to at length—let portions of their circles A S and B Q be described from a common centre, as O in Fig. 3780. Let the depth A B of the buckets be divided into three equal parts and with a radius to C, making B C = ½ A C describe the arc C D E of the third circumference upon which the centre of gravity of the water contained in the buckets will always be found, at least very nearly. This radius, marked O *r* in Fig. 3774, is termed the *dynamic radius* of the wheel, and it is of importance that it be correctly defined. The distance of one bucket from that succeeding it is measured upon this last circumference, and may be taken generally at 12 to 13½ inches. The common practice is to divide the circumference into four equal parts, and in each quarter is inserted the same number of buckets, the distance being made to vary slightly with the size of the wheel. But it also follows from this practice that the number of buckets will not be exactly proportional to the diameter. An approximate rule is to double the number expressing the diameter of the wheel in feet, and call that or the next higher number divisible by 4, the number of buckets.

Thus the diameter	being	12 feet,	the number of	buckets	24.
"	"	17 "	"	"	36.
"	"	21 "	"	"	44.
"	"	25 "	"	"	52.

In greater diameters, the proportion increases thus:

Diameter, 28 feet	Buckets, 60	Diameter, 40 feet	Buckets, 92
" 32 "	" 72	" 42 "	" 96
" 38 "	" 84	" 46 "	" 108

We do not instance these as examples to be copied, but simply in illustration of a practice not yet quite obliterated, of referring the most vital conditions of the question to a haphazard empiricism, which pretends to no better foundation than its affording an easy approximation. The proper elements from which the capacity of the buckets ought to be determined are the quantity of water to be used and the angular velocity of the wheel, subjects which will be subsequently considered in relation to this and other questions of equal importance.

The circumference described by the dynamical radius of the wheel being divided into equal parts, C, D, E, &c., in number equal to the number of buckets which the wheel is intended to have, the radial lines C B, D F, E G, &c., will determine the direction and breadth of the *starts* of the buckets. The *flats* A D, H E, &c., are determined by regard to the condition that the angle H E G, comprised between the start and flat of the same bucket, ought to open as little as possible, in order that the bucket may retain its water as long as possible; but at the same time the angle must be sufficiently great that the water shall have free admission through the space D *b*, otherwise a portion of it would be thrown back chiefly by the action of the air confined in the bucket—an evil now almost entirely remedied by the system of ventilation introduced in the construction, but which in wooden wheels could only be effected very imperfectly. In all cases it is essentially and obviously requisite that the space between the flats be considerably greater than the thickness of the sheet of water which is thrown upon the wheel. It is true, that by increasing the breadth of the stream, its thickness may be diminished at pleasure. Still it is necessary to give to D b a minimum of 5 to 6 inches, to insure free ingress to the water in all positions of the bucket, while receiving its charge. This condition is attained by giving to the angle H E G a value of 110° to 118°, supposing the wheel to have a diameter not less than 15 feet. Under this arrangement, the flat will have an inclination to the interior circumference—rather to a tangent drawn to that circumference from the point of intersection with the exterior circumference—of about 31°, and not more than 33°. This angle is indicated by the tangent in Fig. 3774.

Some millwrights have endeavored to lessen the evil experienced in the water being thrown out of the buckets by increasing the breadth of the starts, as in the bucket L K I, in which I K = ½ I P. And as an approach to the more modern curved bucket, the form P M has been employed, in which the flat is composed of two parts, P O, O N, joined together at an angle of about 150°. This form has an advantage in so far as it retains the water longer; but besides increasing the labor and difficulty of fitting and repairing the buckets, it has the further effect of contracting the space through which the water is received into the bucket, which, under the very imperfect system of ventilation practicable in wood wheels, is an evil more than equivalent to the advantage secured Even the mode of fitting the two plates of the bucket together by a bevel-joint, as at D, is considered by some millwrights as an unnecessary technical difficulty, which they avoid by fitting the start-board at an angle of 90° with the flat-board. This practice has an advantage in point of simplicity of construction, and it does not seem liable to any serious theoretical objection. But the difficulty complained of is more effectually removed by the introduction of sheet-iron buckets, which is not now uncommon, even in wheels principally constructed of wood. The usual practice is to curve the plate into the form S Q, in which the start to the point R on the dynamical circumference approaches the circumference of the wheel at an angle of 90°, and the extremity S meets that circumference at an angle of not more than 5°. In this mode of bucketing, which, when introduced, was reckoned an improvement of much value, and which in modern practice is the simplest that can be adopted, the buckets carry their water to the lowest point of the revolution of the wheel; but like that previously noticed, although it has an advantage in this respect, it has been considered liable to the objection of affording a less ready admission to the water in filling. In early practice, and, indeed, until very recently, the necessity of facilitating the escape of the air from the buckets, when receiving their charge of water at the summit, was not understood. The importance of making the buckets of a form to carry the water to the lowest point of the revolution of the wheel was obvious; but when this was accomplished, it was usually found that the wheel neither received nor parted with the water freely. The late Professor Robinson seems to have been the first to give a full explanation of these circumstances, and to have pointed out at least a partial remedy. In reference to the first, he observes that "the half-taught millwright attempts to retain the water a longer time in the buckets, but finds that it gets into them with a difficulty for which he cannot account, and spills it about even after they have ceased to receive any from the spout. This arises from the air, which must find its way out to admit the water, but is obstructed by the entering water, and occasions a great spluttering at the entry. This obstruction is vastly greater than one would imagine, for the water drags along with it a great quantity of air, as is evident in the water-blast described by many authors."

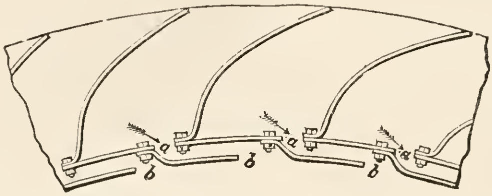
After observing that "this evil may be entirely prevented by making the spout considerably narrower than the wheel, and thereby leaving room at the two ends of the buckets for the escape of the air," he proceeds to consider the circumstances attending the emptying of the buckets. He observes, "There is another very serious obstruction to the motion of an overshot or bucketed wheel, especially when it revolves in backwater. It is not much resisted by the water on account of the slowness of its motion; but it lifts a great deal of the water in the rising buckets. In some particular states of backwater the descending bucket fills itself completely with water; and in other cases it contains a very considerable quantity of air of common density, while in some rare cases it contains both water and air in a compressed state. In the first case, the rising bucket must come up filled with water, which it cannot drop till its mouth gets out of the tail water. In the second case, part of the water goes out before this; but the air rarefies, and therefore there is still some water dragged or lifted up by the wheel, but (which is as detrimental to its performance) the descending side is employed in condensing the air; and although this air aids the ascent of the rising side, it does not aid it so much as it impedes the descending side, being (by the form of the bucket) nearer to the vertical line drawn through the axis."

Without acquiescing in the correctness of the objection and explanation contained in this second case, it is not difficult to perceive that if the bucket be quite air tight, and of such a form as to carry its charge of water to the bottom of the circle of revolution, in the process of emptying itself against the atmospheric pressure, and in a direction contrary to the direction of motion of the wheel, there will be a partial vacuum formed in the bucket, and to that extent the effect of the wheel will be diminished. If the bottom segment of the wheel be immersed in tail water, which is a very frequent circumstance, the evil will be greatly increased, for then the bucket cannot relieve itself until its mouth has ascended above the water level; and in consequence of the resistance offered to the descent of the water, the bucket will have ascended considerably higher before it is entirely relieved of its load.

The earliest remedy applied to the removal of these difficulties, and which has been continued to some extent to the present time, was to bore holes in the starts of the buckets. As respects the admission of the water, this contrivance is of little value, as the escape of the contained air by the holes is prevented by the presence of the water in the interior bucket. But its success in promoting the easy discharge of the water from the buckets soon became obvious, from the increased efficiency of the wheels in which it was adopted. And besides its effect in facilitating the relief of the buckets by the admission of the air to replace the water discharged, it has the further advantage of preventing the troublesome and often dangerous effect of *bucketing* when the works are stopped as the small quantity of water escaping by the sluice and falling upon the wheel runs through the air-holes without accumulating in the buckets of the wheel, and starting it into motion at intervals.

Mr. Fairbairn, of Manchester, to whom we owe the present improved system of ventilation, relates in a paper submitted to the Institution of Civil Engineers, that about twenty years ago he constructed a wheel for Mr. James Brown, of Linwood, near Paisley, "which in floodwaters, when the wheel was loaded, every bucket acted as a water-blast, and threw the water and spray to a height of six to eight feet above the orifice at which it entered. This was complained of as a great evil; and in order to get rid of the difficulty, incisions were made through the sole-plates, and small interior buckets were attached to the inner sole-plates, as represented in Fig. 3781. The air made its escape by the openings

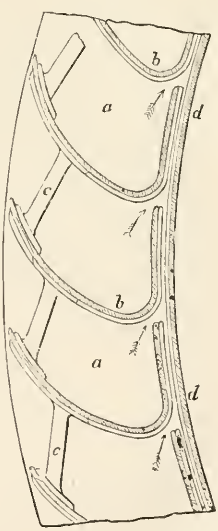
3781.



a a a into the interior buckets *b b b* inside of the wheel during the time of filling; and, when working in backwater, it presented the same facilities for its emission before even a partial vacuum could be formed in the ascending bucket when rising through the tailwater. The changes which this remarkable alteration effected can scarcely be credited; the wheel not only took and parted with the water with perfect freedom, but an increase of power of nearly a fourth was obtained. The wheel is still in the same state, and continues in all states of the water to perform an apparent and satisfactory amount of duty."

This was an important advance on the scheme of piercing the starts of the buckets; and although in this case applied to an iron wheel, it admits of easy application to wooden wheels, by making a species of internal sole, and dividing it off into portions answering to the small buckets *b b b*, and of course equal in number to the number of main buckets in the wheel.

3782.



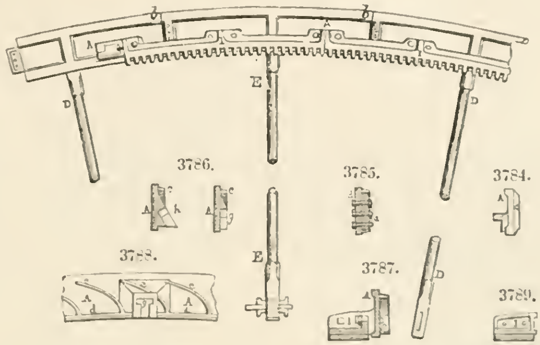
The improvement effected upon Mr. Brown's wheel subsequently induced Mr. Fairbairn to extend the principle of ventilation; and instead of waiting to ascertain the action of the wheel when started, to apply it as a fundamental requisite to be provided for in the construction. The primary form of the contrivance, although very effective, is manifestly liable to objection in respect of the additional workmanship which it required; and besides, if thoroughly carried into effect, would tend to weaken the sole-plate of the wheel. To obviate these objections, Mr. Fairbairn introduced the elegant arrangement depicted in Fig. 3782, by which the integrity of the sole is preserved, and in which, with very little additional cost of construction, the object is most effectually accomplished. The method consists in forming the buckets—each consisting of a single plate—with independent soles, which are applied parallel with the sole of the wheel, leaving between the two contiguous surfaces a vacant space of about an inch, for the escape of the air into the superior bucket during the process of filling, and which will obviously serve to readmit the air to replace the water when the bucket begins to empty itself towards the lowest point of its revolution and begins to ascend. When it has attained this position, it ought manifestly to be entirely relieved of its burden; but it has been already intimated that, in certain conditions of backwater, this can be accomplished only by some contrivance for admitting the pressure of the atmosphere upon the water in the bucket immediately on its beginning to ascend. If the atmosphere be then excluded, and the bucket be full of water, a certain amount of weight will be made to act adversely to the motion of the wheel, and to that extent will diminish its efficiency. This takes place more commonly with iron than with wooden buckets destitute of provision for their ventilation, on account of the more contracted form of the inlet passages produced by the curvature of the flats of the former.

On this subject Mr. Fairbairn remarks, that "water-wheels constructed entirely of iron, and having thin plates instead of wood for the buckets, give decreased facilities for the admission of the water, and for the escape of the air contained in them. So great difficulty is experienced in effecting the discharge of the air in a close bucket through the same orifice, and at the same time that the water is being admitted, as in some wheels almost entirely to prevent the entrance of the water; and in cases where the buckets are closely formed, the wheel is deprived of almost half its power by the reaction of the inclosed air. This defect is most obvious in water-wheels having contracted openings—which may be easily accounted for in every case where the water is discharged upon the wheel in a larger section than the opening between the buckets. Under these circumstances the air is suddenly condensed, and again reacting by its elastic force, throws back the water upon the orifice of the cistern, and thus allows the buckets to pass without being more than half filled."

These remarks are intended to show the extent of the difficulties which have been removed by the introduction of the ventilated bucket, and to induce the adoption of that system, which, we may remark is always applicable, and presents none of those constructive objections which are so often fatal to the introduction of technical improvements in hydraulic machinery. This has, indeed, been acknowledged by the almost universal adoption of the principle by those engineers capable of appreciating its advantages; but examples in which it has been disregarded—possibly through ignorance of its use—have fallen under our notice very recently, and in more than one instance very fully illustrated the danger of dealing with hydraulic power on mere empirical rules.

When the wheel is wholly constructed of iron, the buckets are usually supported at their extremities on narrow flanges, cast of the intended form upon the inside faces of the shrouding, and secured by small bolts, (usually half inch in diameter,) for which the holes are cast in the flanges, and bored in the bucket-plates. They are further supported upon each other by intermediate stays, cast with palms of opposite curvature at their extremities, to meet the interior and exterior surfaces of the buckets which they are intended to connect. The details are fully illustrated in Figs. 3783 to 3795.

3783.

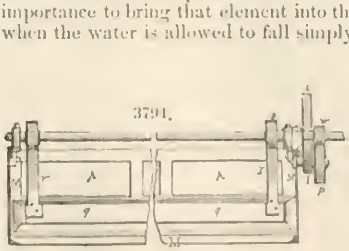


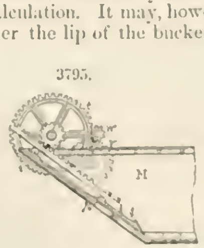
3786. 3785. 3784. 3788. 3787. 3789.

3790. 3791.

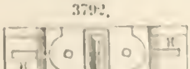
It is, however, to be remarked that, except in the undershot-wheel of M. Poncelet, no attempt has hitherto been made to give the buckets a definite form with reference to the action of the water upon them on its admission; and possibly under the system now generally adopted, of introducing it below the summit, and under as small a head-pressure as can be obtained, consistently with the volume to be used, it is of little importance to bring that element into the calculation. It may, however, be remarked that, in strictness, when the water is allowed to fall simply over the lip of the bucket, the curve ought

3794. 3795.





3793. 3792.

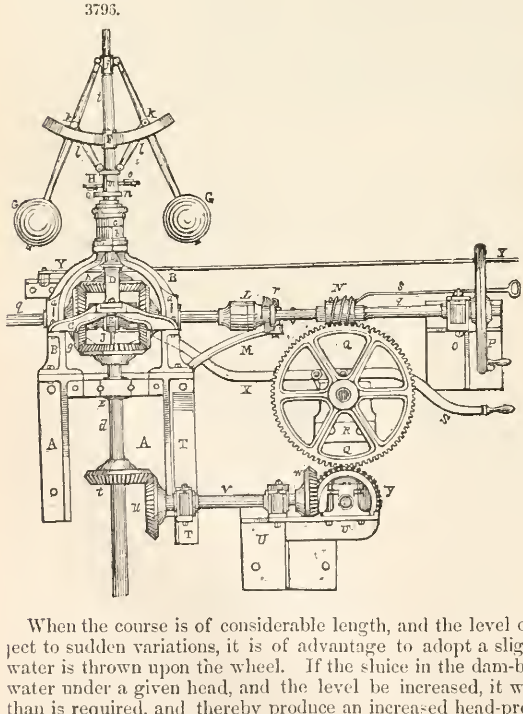


to be that of quickest descent; and in no case ought it to descend from so great a height that its reaction upon the under side of the succeeding bucket shall be sensibly felt. This appears to be well illustrated by the well known experiments of Mr. Smeaton, to which we shall hereafter have occasion more particularly to advert. His overshot model was 24 inches in diameter; and when the whole descent of the water was 27 inches, the maximum effect of the wheel was 76 per cent. of the power of the water but when increased to 35 inches, the ratio fell to 52. In other words, the head being increased in the ratio of 7 to 9, the increase of effect is only in the ratio of 81 to 84, and, consequently, the increase of effect is not 1-7th of the increase of perpendicular height. From this he concludes, and correctly, as respects purely overshot-wheels, "that the higher the wheel is in proportion to the whole descent, the greater will be the whole effect." But the explanation which he offers is founded entirely on the opinion "that the effect of the same quantity of water, descending through the same perpendicular height, is *double* when acting by its gravity upon an overshot-wheel, to what the same produces when acting by its impulse." It is unnecessary, in the mean time, to examine this proposition, as it is sufficient for our present purpose to intimate that a high velocity of the current entering the buckets is attended with a loss of effect, and that at least a portion of that loss seems to us to result from the reaction of the water against the sole of the bucket into which it is received, and against the bottom of the next succeeding bucket; and it is obvious that any impulsive force expended on these surfaces must proportionally resist the motion of the wheel in the contrary direction.

As respects the mode of supplying the water to the overshot-wheel, the arrangement is sometimes made to differ slightly, according as the level of the water in the reservoir or dam is nearly constant, or varies between wide limits. In the first case, especially if the dam be close at hand and the duty of the wheel nearly constant, the channel is simply formed of the proper width to bring forward the maximum quantity which is intended to be employed upon the wheel; and a sluice is placed at the origin of the channel in the dam-breast to regulate the quantity drawn off for immediate use. From this sluice, the channel—often formed of wooden troues—follows the most direct line over the summit of the wheel, and is terminated by a spout inclined at an angle sufficient to throw the water perpendicularly upon the start of the second or third bucket counted from the summit. The *apron* or sole of this spout is usually from 18 to 24 inches long, and declines from the bottom level of the channel at an angle of 12 to 18 degrees, forming an incline plane on which the water attains the required velocity before entering the buckets, and which ought to be at least equal to that of the circumference of the wheel; otherwise it is struck, and some portion of it thrown off by the flat-boards of the buckets as they successively come into position with the current.

When the dam is at some considerable distance, rendering it inconvenient to have recourse to the sluice there situated, on every occasion that it may be necessary to modify the power of the wheel, a second sluice or *shuttle* is placed contiguous to the spout, and which, in the common class of wheels, is usually set by hand at the required height, often directly, but sometimes a simple contrivance, consisting of a weighted lever, intervenes, by which the shuttle can be adjusted by a cord brought inside of the building. In the higher class of wheels, and especially when great steadiness of motion is required, the shuttle is worked by a self-acting apparatus—shown in its most complete form in Figs. 3796 to 3803, with all the improvements and appliances of modern mechanism, as applied to the large wheel at Greenock.

3796.



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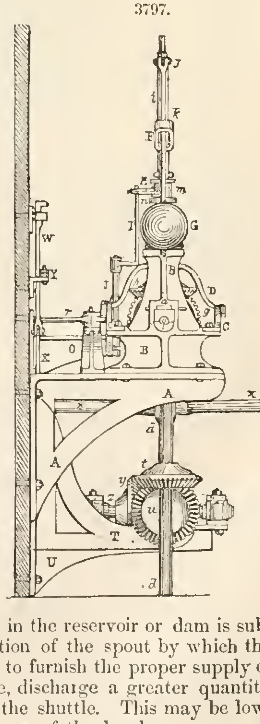

When the course is of considerable length, and the level of the water in the reservoir or dam is subject to sudden variations, it is of advantage to adopt a slight modification of the spout by which the water is thrown upon the wheel. If the sluice in the dam-breast be set to furnish the proper supply of water under a given head, and the level be increased, it will, of course, discharge a greater quantity than is required, and thereby produce an increased head-pressure upon the shuttle. This may be lowered to diminish the quantity thrown upon the wheel; but, in consequence of the head-pressure accumulated in the course, the velocity of efflux would be increased often to such an extent as, without precaution, to throw the water entirely over the buckets. To prevent this, and, at the same time, to take advantage of the increased impulse of the water, the spout is provided with a cover inclined to the axis of the orifice, and connected, water-tight, with the back-plate of the shuttle. The spout has thus the outline of a truncated pyramid, of which the faces converge towards the extremity at an angle of 6 to 7 degrees with the axis, which is directed towards the superior surface of the start of the bucket immediately in advance of it. The direction of the current upon the wheel is thus preserved under any variations of head-pressure upon the shuttle; and the impulse being directed as nearly as possible in the line of motion of the point impelled, its value becomes an increment to the force of gravity of the water, and, to some extent, economizes a power which would otherwise act injuriously in projecting the water beyond the proper range. The horizontal dimension of the orifice, under this arrangement, and especially when the system of ventilation is incomplete, ought to be a little less than that of the buckets, and the height perpendicular to the axis ought not, in general, to be more than four inches, and it is almost always better to be less.

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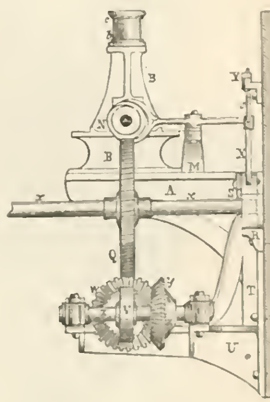

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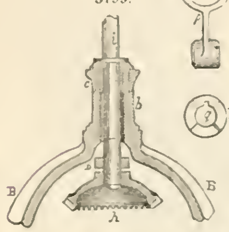

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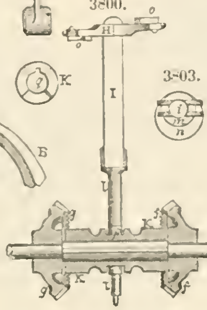

3803.

This form of spout is represented in Fig. 3774. It has not been in very general use in this country, although examples are still met with; but it is still very commonly employed in Europe, especially in France, where it bears the significant name of "duck's-bill." In some cases, also, the spout is attached to the feed-box or small reservoir formed over the wheel in some works, where the water is brought forward from the main dam by a large pipe or covered conduit passing along the surface of some intervening ground situated on a lower level than the summit of the wheel, and sometimes entirely under ground, when it is necessary to keep the surface free of interruption for any particular reason, as the crossing of a road and the like. In this arrangement, there is always a certain amount of loss of head incurred by the passage of the water through the conduit, which must be taken into account in the construction of the wheel. The effect of this diminution of head-pressure is to prevent the water from rising to the same level in the feed-box as in the reservoir, by diminishing the force of the current; and this loss, which is also a loss of fall upon the wheel, and consequently a loss of moving force, without any compensating advantage, except the convenience afforded under particular circumstances, must be deducted from the height of the fall in determining the diameter of the wheel.

The natural situation for the opening to the culvert for carrying away the tail-water is on the side opposite to that at which the water is received by the wheel; for, in that case, should the lower arc of the wheel dip, which it almost invariably does, from the desire entertained by the millwright to economize the fall as much as possible, the run of the water will impede it less than if its motion were opposed to the motion of the wheel. When the wheel is kept entirely above the level of the tail-water, this arrangement may, of course, be reversed. It is then immaterial at what point the culvert opens into the wheel pit, except that the water will rise higher when the direction of its motion is changed from that impressed upon it by the motion of the wheel, and consequently a greater amount of tail-clearance must be allowed when the escape is retarded by a change of movement. This is, therefore, always avoided as much as possible; but in situations where the lead of the water is determined by circumstances of locality, and the direction of the motion of the wheel by circumstances of convenience, we commonly find that when these conditions conspire to render the common arrangement inapplicable consistently with economy, that, instead of the water being led over the summit of the wheel, it is thrown upon that side to which the current approaches, the spout of the shuttle being deflected sufficiently backwards to reverse the motion of the current, and direct it upon the circumference at some distance below the summit. It is easy to perceive that under this arrangement, which at first was resorted to rather as an artifice to avoid an inconvenience, very severely felt in cases where the direction of the waste-water culvert was fixed by local circumstances, and in which the wheel-pit was liable to be flooded with backwater, allows of the wheel being made of any desired diameter even greater than the height of the fall. It also requires less of the head to be sacrificed between the shuttle and the point of the wheel at which the water is received, and is, therefore, more economical than the primary arrangement from which it was considered a deviation merely allowable in obedience to the local conditions of the particular case. Its advantages, however, soon began to be perceived, especially in low falls, and exam ples of its application speedily became numerous. This was favored by the theoretical notion, that a wheel of large diameter is, in all cases, the most economical; and, as already observed, this arrangement gives free scope to the millwright to adopt any diameter of wheel he may think fit. The system has now become general, and constitutes one of the main characteristic features of the modern bucketed wheel. It has, besides, removed the distinction between overshot and breast wheels, which was formerly significant. The term overshot is, indeed, not now applicable to any of our larger modern examples, except by a forced interpretation of the term, and instead we ought, in strictness, to employ the term high-breast, as better expressing the actual conditions. We have still, indeed, some wheels of a minor class scattered over the country, and employed chiefly for agricultural purposes, which belong to the primitive order; but they are only retained in situations where the power is superabundant, and where it is, therefore, not necessary to look narrowly into the economy of its employment.

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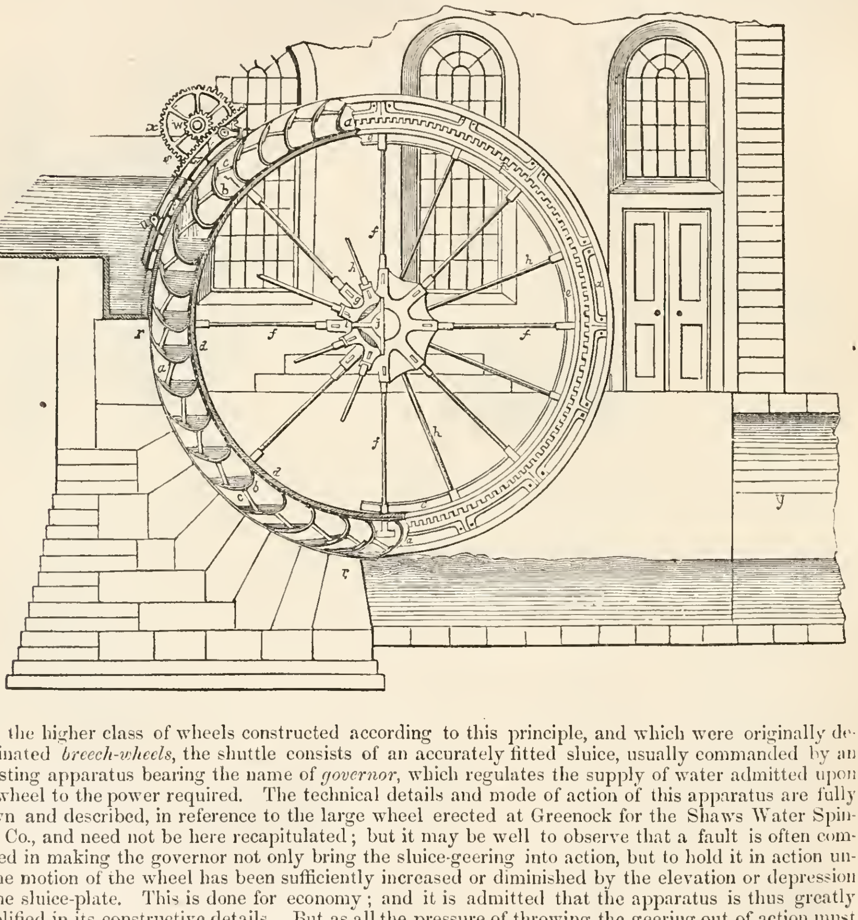

In the higher class of wheels constructed according to this principle, and which were originally denominated *breech-wheels*, the shuttle consists of an accurately fitted sluice, usually commanded by an adjusting apparatus bearing the name of *governor*, which regulates the supply of water admitted upon the wheel to the power required. The technical details and mode of action of this apparatus are fully shown and described, in reference to the large wheel erected at Greenock for the Shaws Water Spinning Co., and need not be here recapitulated; but it may be well to observe that a fault is often committed in making the governor not only bring the sluice-geering into action, but to hold it in action until the motion of the wheel has been sufficiently increased or diminished by the elevation or depression of the sluice-plate. This is done for economy; and it is admitted that the apparatus is thus greatly simplified in its constructive details. But as all the pressure of throwing the geering out of action must be overcome by the centrifugal force of the pendulum balls, these must, therefore, of necessity be of great weight, and consequently less susceptible of being affected by slight variations of motion, on account of their greater inertia. But the far greater evil consists in the geering being kept in action until the movement has been so far altered that the balls have acquired sufficient power to overcome the friction due to the pressure of the geering, and disengage itself; and which cannot possibly happen until the speed has been increased or diminished beyond the point required. To correct this, the governor immediately falls into action to produce the contrary effect, which again is overdone, and must again be corrected. From this cause, the movement of the wheel is never steady, but continually oscillates between two extremes, and the governing apparatus, though, in the first instance, less expensive, is speedily worn out, being constantly in action, and is never satisfactory. The principle to be kept in view is, to allow the pendulum balls to adjust themselves with perfect freedom to the velocity of the wheel, by giving them no other duty to perform; and, by a cam, obeying the motion of the balls, and shifting its position in obedience to theirs, to throw the geering into action in the manner done in the example above referred to.

When the height of the fall is considerably less than the diameter of the wheel, we then apply the term *breast* as expressing the relation. The wheel depicted in Figs. 3804 and 3805 comes under this general denomination; and to denote that the water is received above the line passing horizontally through the axis, it takes the name of *high-breast*. These terms, however, are manifestly only relative, for if the wheel had been made of somewhat larger diameter, the water would have been thrown upon a lower point of the circumference, and changed the character of the wheel to that of *low-breast*. These terms, therefore, convey no other positive intimation respecting the size of the wheel than that its axis is below, above, or in the plane of the water level. It, however, usually suggests that the fall is low, and, consequently, that every precaution is taken to render it, as much as possible, available upon the wheel. For this purpose an *arc* is usually constructed of the same radius as that of the wheel, to con-

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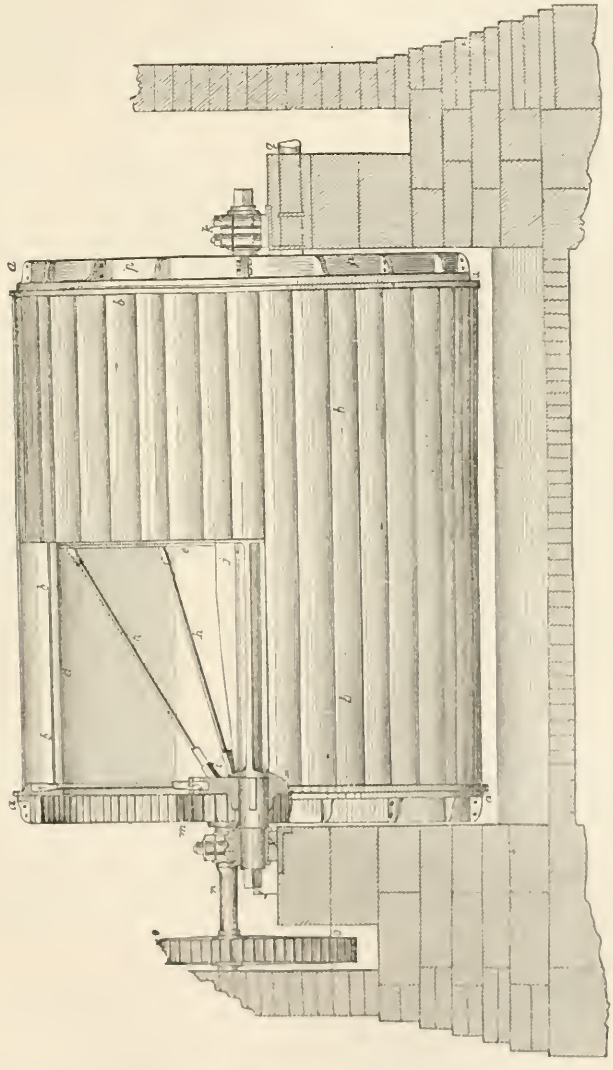

fine the water, and prevent it from being spilt from the buckets before it has arrived at the lowest point of the run. In the example referred to, this arc is built of hewn stone; but sometimes it is constructed of timber, and not unfrequently of cast iron plates. Sufficient clearance is of course necessary to allow of the wheel moving free of the arc, and to this extent there must always be a waste of water; but when the arc is properly constructed and wrought to the circle, this clearance need not exceed half an inch, which will be the measure of the plate of water which escapes without producing its effect upon the buckets immediately on their passing the plane of the axis. This arrangement is sometimes adopted with good effect in wheels belonging to the class called overshot, and it is applicable in all cases. But when the height of the fall is considerable, and the buckets properly constructed to retain and carry down the water, it is of less importance, as the small loss at the lower part of the revolution bears a diminished proportion to the whole effect realized. In the breast-wheel, the buckets are made more flat and radial than in wheels which receive the water near the summit, and are therefore not so well adapted to retain the water. The only reason assignable for this difference of form is, that it to some extent economizes the fall; for in every wheel the lip of the bucket must descend below the water-level before any water can enter it, and consequently there is a loss of fall incurred in filling equal to something more than the depth of the bucket; and the lower the fall is, this will evidently bear a greater ratio to the entire value of the water.

The power of all large wheels is taken off by a second shaft carrying a pinion, which geers with a large spur-wheel bolted upon the shrouding of the water-wheel. This spur-wheel is cast in parts or segments and bolted together, and is generally, though not invariably, an internal wheel. When there is considerable breadth between the shrouds, it is of importance to take the power at both sides, as shown in Figs. 3804 and 3805, and always from the loaded arc of the water-wheel. By this arrangement, all strain is taken off the arms and journals of the wheel, which otherwise would be excessive. The circumstances also accommodate themselves to this arrangement, in so far as the centre of pressure of the mass falls usually within the depth of the shrouding, and renders any calculation unnecessary.

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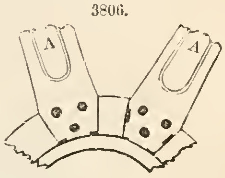

Wheels of a diameter up to 20 feet are frequently fitted with cast-iron arms, instead of being of the *spider* construction of that above referred to; and they have an advantage in being more rigid though more heavy, and therefore more severe on their journals. The common and best mode of fitting the cast-iron arms to the centres is shown by Fig. 3806. The arms A A are cast with projecting cheeks on their lower extremities, which are planed and fitted into the dressed recesses of the centre, and are secured generally by three, but sometimes by one bolt. The other extremities are cast with T ends, which are likewise planed and fitted into corresponding recesses in the shrouds, and fastened by two bolts, and sometimes by adjustable keys.

It is not uncommon to find the arms of spider-wheels secured with nuts instead of cotterals, as shown in the two examples given; but the latter mode is usually reckoned preferable, on account of the difficulty of maintaining the *truth* of the wheel in screwing up the nuts to the requisite degree of tightness; and the cotterals has the further advantage, that they are more secure, and less expensive. The constructive details of this mode of fitting have been already shown, and have been highly approved by some of the first builders both in Europe and in this country. The example to which these drawings refer is not only one of the very largest, but perhaps the most complete in its details, of any water-wheel yet constructed.

To determine the capacity of the wheel answering to a given supply of water, it is necessary to take into account the rapidity with which the buckets are filled and emptied; in other words, the angular velocity of the wheel. This velocity, it has been remarked, ought to be slightly less than that of the lamina of water falling into the wheel to prevent the back of the buckets, as they pass the receiving point, from striking against the descending stream, and thereby not only wasting a portion of the water by throwing it over the circumference of the wheel, but also diminishing the useful effect of that which passes into the buckets by the counteraction produced on the wheel.

The velocity of the stream may be generally determined in the following manner. Thus at the dam-sluice—if H be the depth to the centre of the sluice-opening, the velocity U of efflux will be expressed by

$$U = \sqrt{\frac{2\,g\,H}{1 + (\frac{1}{m} - 1)^2}}$$

m being a coefficient depending for its value upon the particular form of the sluice-gate, but which may be taken generally $= 0{\cdot}64$; and g the symbol of gravity $= 32{\cdot}2$. Consequently, if we substitute the numerical values of these symbols, we shall have the simple arithmetical rule

$$U = 7{\cdot}133\sqrt{H}$$

And if the lead or course be short, and h the total fall from its origin to the extremity where the water is delivered upon the wheel, the velocity u at that point will be found from the formula

$$u = \sqrt{U^2 + 2\,g\,h},$$

in which U and g have the same significations as above.

But if the lead be of considerable length, it will be necessary to take into account the retardation which the water experiences in its passage. This is found from a calculation of the surface which the water passes over in its transit, and knowing approximately the velocity with which it moves. If we call u (found as above) the ultimate velocity of the stream, and U that at its origin, calculated at the dam-sluice, then $\frac{1}{2}(u + U)$ will be nearly the mean velocity in the lead; and dividing the number of cubic feet of water to be delivered in a second by this mean velocity, the quotient will be the mean transverse area A of the current; and this divided by the mean width of the channel will give the depth of water. Now, the frictional retardation of a stream of water varying according to the amount of surface of the fluid in contact with the bed upon which it moves, is, therefore, inversely as the whole quantity of fluid—that is, for any given quantity of water, the resistance being as the surface of the bottom and sides of the channel directly, and as the whole quantity of water inversely, the diminution of velocity will be as $\frac{S\,L}{A}$ in which L is the length of the channel in feet, and S the surface (bottom and sides) over which the water glides. The retardation is expressed by

$$\sqrt{\left\{c\frac{\mathrm{S\,L}}{\mathrm{A}}\left(\frac{\mathrm{U}+w}{2}\right)^2\right\}}$$

in which c is a coefficient determined by experiment $=\cdot 007$. If, therefore, U be the velocity due to the pressure at the sluice, and h be the total fall upon the channel, the ultimate velocity will be expressed by

$$\mathrm{V}=\sqrt{\mathrm{U}^2+2\,g\,h-0{\cdot}007\frac{\mathrm{S\,L}}{\mathrm{A}}\left(\frac{\mathrm{U}+u}{2}\right)^2}$$

It is scarcely necessary to remark that this is only an approximation, which, however, may be considered sufficiently correct for all practical purposes; and if greater exactness be desired, the value of V thus found may be substituted for u and the equation resolved anew for a nearer value of V.

As the value of h can be modified at pleasure in making the channel, it is of moment that these calculations be considered previous to determining the position of the shuttle. If the channel be already existing, and it is wished to determine the quantity of water flowing in it, this may be done with sufficient correctness, by finding the surface velocity, and multiplying it by the mean cross-sectional area of stream: four-fifths of the quantity thus found will be very nearly the actual quantity flowing in the channel.

This rule, although often employed, and without material error when the quantity of water flowing is considerable and the velocity not great, is not to be relied upon when more than a rough approximation is desired. In some cases it is of importance to determine exactly the quantity of water supplied, as when a rental is paid for the power, when testing the efficiency of a wheel, or determining the power necessary to impel certain kinds of machinery; in these, and analogous cases, we must have recourse to more accurate formulæ. When the surface of the stream can be correctly ascertained over a portion of the channel, of which the cross-section is nearly uniform, the following rule, which is founded on that of M. de Prony, may be employed with considerable confidence. Let U denote the mean velocity of the stream, (which is sought to be determined,) and V the surface velocity measured by a float in the middle of the stream, both reckoned in feet per second, then

$$\mathrm{U}=\frac{\mathrm{V}+6{\cdot}50}{\mathrm{V}+8{\cdot}92}\times\mathrm{V}.$$

As an example—let the surface velocity be 5 feet in a second, then will $\mathrm{V}+6{\cdot}5=11{\cdot}5$ and $\mathrm{V}+8{\cdot}92=13{\cdot}92$, and

$$\frac{\mathrm{V}+6{\cdot}5}{\mathrm{V}+8{\cdot}9}=\frac{11{\cdot}5}{13{\cdot}9}=\cdot 824\text{; therefore, }\frac{\mathrm{V}+6{\cdot}50}{\mathrm{V}+8{\cdot}92}\times\mathrm{V}=\cdot 824\times 5=4{\cdot}12\text{ feet,}$$

that is, the surface velocity of the stream being 5 feet per second, the mean velocity U is 4·12 feet. And this velocity being multiplied by the sectional area of the stream, the result will be the volume of water flowing in a second; and therefore,

$$\mathrm{Q}=60\,\mathrm{S}\times\mathrm{U},$$

will be the quantity furnished in 60 seconds or 1 minute.

The maintaining power in a moving volume of water is obviously proportional to the quantity of descent in a given space; when, therefore, the motion is uniform, and is neither retarded nor accelerated by the force of gravitation, it is manifest that the whole weight of the water is employed in overcoming the frictional resistance offered by the bottom and the sides of the channel; and if the inclination vary, the relative weight, or the force which urges the particles along the inclined plane, will vary as the height of the plane when the length is given, or as the fall in a given distance. The retarding force, which is equal to the relative weight, must therefore also vary as the fall, and the velocity, which is as the square root of the impeding influence, must be as the square root of the fall; and supposing the hydraulic mean depth—that is, the depth which a current of water would take if spread out upon a horizontal surface equal to the bottom and sides of its channel—to be increased or diminished, the inclination remaining the same, the frictional resistance would be diminished or increased in the same ratio; and, therefore, in order to preserve its equality with the relative weight, it must be proportionally increased or diminished by increasing the square of the velocity in the ratio of the hydraulic mean depth, or the velocity in the ratio of its square root. We may, therefore, expect that the velocities will be conjointly as the square root of the hydraulic mean depth and of the fall in a given distance, or as a mean proportional between these two lines. From this reasoning, Eytelwein and some other writers on hydraulics, have deduced rules for determining the mean velocity of large bodies of water. Let δ denote the measure of declivity, and d the mean hydraulic depth of the current, then $100\sqrt{\frac{\delta}{d}}$ will express the resulting velocity in feet per second—showing that, if the rate of descent were only one in 100×100, the stream would acquire a velocity represented simply by the square root of the hydraulic mean depth. If f denote the fall in feet each mile, the formula for the velocity will take the form

$$\frac{100}{\sqrt{5280}}\sqrt{\delta f}=\frac{11}{8}\sqrt{\delta f}.$$

Hence, the velocity reckoned in miles an hour is expressed by

$$\frac{11}{8}\cdot\frac{15}{22}\sqrt{\delta f}=\frac{15}{16}\sqrt{\delta f}.$$

The square root of the product of the hydraulic depth into the fall each mile in feet being diminished by 1·16th, will hence represent the mean velocity of a river in miles each hour.

This rule, which is that deduced by Sir John Leslie for the velocity of water in rivers, may be compared with the result of Eytelwein's formula for the same purpose, as rendered by Dr. T. Young Taking two English miles as a given length, he finds a mean proportional between the hydraulic mean depth and the fall in that space, and inquiring what relation this bears to the velocity in a particular case, finds that, in general, the mean proportional sought is $\frac{11}{10}$ths of the velocity in a second.

In order to test the accuracy of this rule, Dr. Young takes an example which could not have been known to Eytelwein. Mr. Watt observed, as Prof. Robison informs us in the article River, of the Encyclopædia Britannica, that in a canal 18 feet wide above, and 7 below, and 4 feet deep, having a fall of 4 inches in a mile, the velocity was 17 inches in a second at the surface, 14 in the middle, and 10 at the bottom; so that the mean velocity will be 14 inches or somewhat less in a second. Now, to find the hydraulic mean depth, we must divide the area of the section, $2\,(18 + 7) = 50$, by the breadth of the bottom and length of the sloping sides added together, whence we have $\frac{50}{20{\cdot}6} \times 12 = 29{\cdot}13$ inches; and the fall in two miles being 8 inches, we have $\sqrt{(8 \times 29{\cdot}13)} = 15{\cdot}26$ for the mean proportional of which $\frac{10}{11}$ is 13·87, the mean velocity in inches each second.

To test Sir John Leslie's rule by the same example, we have $f = \frac{1}{3}$ ft. and $\delta = \frac{29{\cdot}13}{12} = 2{\cdot}4275$ ft.;

$$\text{therefore, } \delta f = {\cdot}8092 \text{ nearly, and } \sqrt{\delta f} = {\cdot}8996. \quad \text{Hence, } \frac{11}{8}\sqrt{\delta f} = \frac{11}{8} \times {\cdot}8996 = 1{\cdot}236 \text{ feet;}$$

that is, 14·83 inches, a result in excess of that found by Eytelwein's rule of $14{\cdot}83 - 13{\cdot}87 = 0{\cdot}96$ inch.

By M. de Prony's rule we have, $V = \frac{17}{12} = 1{\cdot}4167$ feet, and

$$\frac{V + 6{\cdot}50}{V + 8{\cdot}92} = {\cdot}77$$

which, multiplied by 17, the surface velocity gives 13·1 inches as the mean velocity. And, taking the common rule of deducting a fifth from the surface velocity for the mean velocity of the current, we have $17 - \frac{17}{5} = 13{\cdot}6$ inches, which does not differ greatly from M. Eytelwein's rule, in which we have most confidence, from our own experience, when the volume of water is very great. For smaller quantities of water, such as we find in leads cut to supply bucketed wheels, the modification which we have given of De Prony's rule is much more convenient, and we have found it, in general, very correct.

It is frequently difficult, and sometimes impossible, to apply any of these rules to determine the volume of water furnished; and it is often of importance, as when considerable accuracy is desired, to resort to more than one mode of measurement. In all ordinary experiments of this kind, there is a certain degree of uncertainty arising from inaccuracy of measurement; it is therefore of importance to have the means of checking the result of one rule by that obtained by a different process. The following method, which is not only simple and generally applicable, but likewise admitting of considerable

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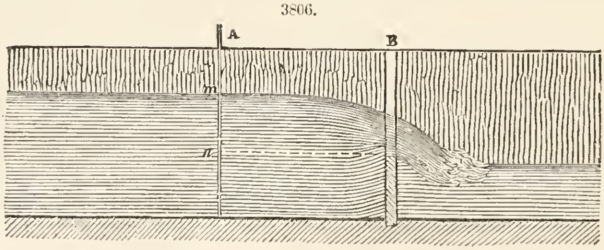

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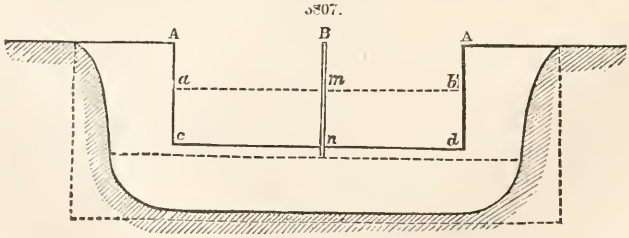


accuracy, will therefore be useful. This consists in erecting a *notch* in some convenient part of the watercourse where the velocity is not great. The notch is easily formed in leads of moderate size by a board A A, Fig. 3806, stretched across the channel, and having a rectangular part A *c d* A cut or notched out in the manner shown in Fig. 3807, and through which the whole of the water will be made to pass. The notch-board being fixed, a rod B must be fixed vertically in the channel a few yards behind, and having a mark n upon it at exactly the level of the edge $c\,d$ of the notch. The water being then permitted to descend in the lead, let its depth $n\,m$ upon the rod B be carefully noted in inches, then taking from the second or third column of the annexed table the quantity corresponding to one inch of width at the depth noted, multiply that quantity by the whole width in inches, and the result will be the whole quantity flowing through the notch in cubic feet per minute.

Thus, if the depth from m to n on the rod B be 16 inches, and the width of the notch $a\,b$ be 7 feet = 84 inches, then corresponding to 16 inches is 25·8 cubic feet in the second column, and which multiplied by 84 gives 2167·2 cubic feet as the whole quantity passing through the notch in a minute.

The quantity corresponding to 16 in the third column is 27·413 cubic feet, which multiplied by 84 gives 2202·7 cubic feet as the supply per minute, which is $35\frac{1}{2}$ cubic feet in excess of the result obtained by employing the second column. This discrepancy arises from the third column being calculated for weirs which discharge more water in a given time than notches, on account of their offering less impediment to the motion of the fluid. A weir is a wall built generally of solid masonry across the channel, with a parallel plank fixed horizontally on edge along the top of the building. The plank is termed the waste-board, and the water flows over it along the whole breadth of the channel, and thus suffers no lateral obstruction as it does in meeting the notch-board, in which the passage is usually contracted. But if the notch be made equal in width to the width of the channel, then this column ought to be employed, since under these circumstances the conditions are strictly analogous, and the notch may be called a weir.

Depth of the upper edge of the waste-board below the surface, in inches.	Cubic feet of water discharged in a minute by every inch of the notch, according to Du Buat's formula.	Cubic feet of water discharged in a minute by every inch of the waste-board of a weir, from experiments made by Mr. Smeaton.
1	0·403	0·428
2	1·140	1·211
3	2·095	2·226
4	3·225	3·427
5	4·507	4·789
6	5·925	6·295
7	7·466	7·933
8	9·122	9·692
9	10·884	11·564
10	12·748	13·535
11	14·707	15·632
12	16·758	17·805
13	18·895	20·076
14	21·117	22·437
15	23·419	24·883
16	25·800	27·413
17	28·258	30·024
18	30·786	32·710

When the preceding table cannot be conveniently applied, the value of Q, the quantity of water discharged in a minute, will be found very nearly from the expression,

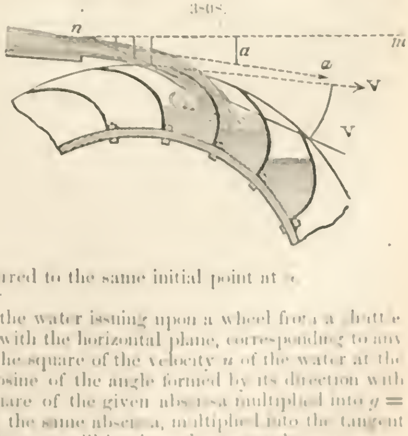
$$Q = 200\,H\,L\,\sqrt{H},$$

in which H is the height $m\,n$ of the surface level of the water above the sole of the notch, and L the width, all in feet. Thus taking the example given above, we have $H = \frac{4}{3}$ ft., and $L = 7$ ft., therefore,

$$Q = 200 \times \frac{4}{3} \times 7\sqrt{\frac{4}{3}} = 2155\text{·}3 \text{ cubic feet.}$$

To find the mean curve described by the lamina of fluid discharged upon the circumference of the wheel, when the water is carried over its summit, it is necessary, in the first place, to determine the velocity of the fluid vein at that point. Its rate of descent from the horizontal line $m\,n$, in Fig. 3808, may then be assigned by the following method:

3808.



Let u designate the velocity of the water at the extremity of the course, and a the angle, which the direction board of the spout forms with the horizontal line $m\,n$, and which expresses the deflection of the line denoting the velocity u from the plane of the horizon; then the curve described by the sheet of water will be expressed by the equation

$$y = \frac{g\,x^2}{2\,u^2 \cos^2 a} + x \tan a,$$

x being the abscissæ measured upon the horizontal plane, taken at half the depth of the fluid vein, where the mean velocity is u; and y the vertical ordinates referred to the same initial point at c.

This equation may be expressed verbally thus:

To find the ordinates of the mean curve described by the water issuing upon a wheel from a chute of which the direction board is inclined at a small angle with the horizontal plane, corresponding to any given horizontal abscissæ of the curve, multiply double the square of the velocity u of the water at the extremity of the direction-board by the square of the cosine of the angle formed by its direction with the horizontal plane, and by this product divide the square of the given abscissa multiplied into g = 32·2. To the quotient which results, add the product of the same abscissa, multiplied into the tangent of the angle a of the velocity u with the plane $m\,n$. The sum will be the ordinate sought =

In giving any values to x equal to 3 inches, 6 inches, 9 inches, &c., we obtain the corresponding values of y, and a curve being traced through them, will give the path of the middle film of water.

When the direction-board is horizontal, we have

$$a = 0, \cos a = 1, \tan a = 0,$$

and, therefore,

$$y = \frac{g\,x^2}{2\,u^2} = \frac{g}{2\,u^2}\,x^2,$$

which is the following verbal rule: divide 32·2 by double of the square of the velocity of the water at the extremity of the course, and multiply the quotient by the square of the given abscissa x. The product will be the ordinate y, corresponding to the value assigned to x.

If the water falls over a waste-board, as in breech and breast wheels, the mean velocity of the sheet will be obtained by taking 4-5ths of that due to the whole height H of the level of the water above the edge of the board.

$$\text{Thus, } u = \frac{4}{5}\sqrt{2\,g\,\text{H}} = 6{\cdot}4\sqrt{\text{H}}$$

This velocity will project it only slightly in a horizontal direction; and, if much accuracy is required, it is easy to determine for any such case the parabola described by the stream.

To exemplify the rule, as applied to the overshot-wheel, we must, in the first place, determine the point of the circumference where the mean jet encounters the wheel, draw a tangent to the parabolic curve described by the fluid in the direction of its final velocity V; and, having done this, we calculate the height due to the velocity u, adding the distance of the point of contact below the origin of the curve. The velocity due to the sum of these heights is that with which the water falls into the buckets.

Thus let it be required to find the final velocity of the water falling upon a wheel of $11\frac{1}{2}$ feet diameter, of which the axis is 10 inches before the vertical line, falling from the extremity of the direction-board, which has an inclination of 1 in 12? If we suppose that the extremity of the direction-board is ·8 inch above the wheel, and that the mean velocity of the lamina of water is 4 inches, and its velocity 9·84 feet in a second, then,

$$\tan a = \tfrac{1}{12} = 0{\cdot}083, \cos a = 0{\cdot}995, u = 9{\cdot}84 \text{ ft.}$$

$$y = \frac{32{\cdot}2\,x^2}{2\,(9{\cdot}84 \times 0{\cdot}995)^2} + 0{\cdot}083\,x = 0{\cdot}168\,x^2 + 0{\cdot}083\,x.$$

Taking, therefore, any values of x at pleasure, we find the value of y by a simple arithmetical process. Thus, let $x = 3$ in., we have $0{\cdot}168\,x^2 = 0{\cdot}168 \times 9 = 1{\cdot}512$ and $0{\cdot}083\,x = 0{\cdot}747$; hence $y = 1{\cdot}512 + 0{\cdot}747 = 2{\cdot}259$ inches.

The intersection of the curve thus determined with the circumference of the wheel is about $2\frac{3}{4}$ inches below the middle film of the vein at the extremity of the direction-board; that is, from the origin of the curve, and the height due to the velocity, 9·84 feet, a second being 1·52 feet, the total height due to the required velocity is 1 foot 9 inches, and, consequently, the velocity with which the water will strike the bottom of the buckets will be $\sqrt{64{\cdot}4 \times 1{\cdot}75} = 10{\cdot}6$ feet in a second.

The lead or channel by which the water is supplied to the wheel ought obviously to be so constructed that it shall consume as little as possible of the available fall. As a first condition, it ought therefore to be as nearly straight as the local circumstances will admit; for at every bend which it makes, a portion of the impulse of the water will be absorbed by the concave side of the channel, and therefore a greater declivity will be necessary to bring forward a given quantity of water in the unit of time. Moreover, the centrifugal force created at the sinuosities has the effect of raising the surface and augmenting the abrasion of the banks at those points; and if by any accident a breach be produced, the sweep of the current must necessarily tend to enlarge the concavity with an accelerated progression. The inclination ought likewise to be as nearly as possible uniform—more correctly, it ought to be so regulated that the transverse sectional area of the stream shall remain constant throughout its whole length. If the course be constructed of masonry, it is obvious, from the remarks made respecting the effects of the hydraulic mean depth on the velocity of the current, that it will be of advantage to build the side-walls vertically; and in order that the resistance may be the least possible, the depth of the stream should be equal to half the width. This rule may be followed when the quantity of water is small; but in leads of large area, the width at bottom is usually from four to six times the depth. When the depth is considerable, the walls are moreover built with a certain amount of *batter*. Mr. Eytelwein, indeed, recommends that the breadth at the bottom be $\frac{2}{3}$ds of the depth, and at the surface $3\frac{1}{3}$. The area of such a section is twice the square of the depth, and the hydraulic mean depth $\frac{2}{3}$ds of the actual depth.

The slope here recommended is 4 to 3, forming an angle to the plane of the horizon with the waterway of 37°; whereas, in this country, the ratio commonly adopted for canals is 3 to 2, making an angle of 34°, which is far more than sufficient for any watercourse intended merely for the purpose under consideration. The best angle to insure durability will, however, very much depend upon local circumstances, and the material of which the banks are constructed or composed.

Having fixed upon the dimensions of the lead and the intended depth of the current, if we call A the area of its transverse section, and q the volume of water to be brought forward in a second, the mean velocity U, which the water must have, will be expressed by $\text{U} = \frac{q}{\text{A}}$. And calling S the perimetrical surface, (bottom and sides,) and I the inclination or fall in 100 feet, which the channel ought to have to give the velocity U required, we shall have

$$\text{I} = \frac{\text{S}}{\text{A}}\,\text{U}\,(\cdot 00012\,\text{U} + \cdot 00444).$$

That is, to find the fall in 100 feet of length of the channel, multiply ·00942 by the given velocity U; add to the product ·00444; multiply the sum again by the velocity, and the product by the perimetrical surface, and divide the last product by the transverse sectional area of the channel.

Thus, if the quantity of water to be brought forward be 40 cubic feet every second, in a channel of 18 feet width, the depth of the water not to extend $2\frac{1}{2}$ feet, we shall have,

A the area of the section $= 10 \times 2{\cdot}5$ ft. $= 25$ sq. ft.

U the mean velocity $= \frac{40}{25} = 1{\cdot}6$ feet in a second.

S the perimetrical surface $= 10 + (2 \times 2\frac{1}{2}) = 15$ feet; therefore $I = \frac{15}{25} \times 1{\cdot}6\,(0{\cdot}00942 \times 1{\cdot}6 + {\cdot}00414) = {\cdot}0585$ feet, the fall in 100 feet of length of the channel.

This rule, at least the latter part of it, referring to the inclination, may be dispensed with when the channel is short. In cases where the whole run does not exceed a length of two or three hundred feet, the bottom may be made quite level, as the depth of the water in the channel will give sufficient fall for the velocity required, provided the area of section be made of ordinary magnitude.

Equal care is usually necessary in the construction of the tail-race as in that of the lead-run; for it is of quite as much importance that the water leave the wheel-pit freely, as that it be brought forward with as little loss of fall as possible. The same rule will apply in both cases; but without some judgment in the engineer to apply it, with allowance for sinuosities, it is better to err on the side of excess in the case of the fail-race, than to encounter the risk of flooding the wheel in backwater.

The quantity of water to be used being ascertained by the preceding methods, the capacity of the wheel may be readily determined. If q denote the volume of water flowing in a second of time, d the distance between two buckets reckoned upon the exterior circumference of the wheel, and v the velocity of those points of the circumference, it is evident that in one second there will pass under the apron of the shuttle a number of buckets equal to $\frac{v}{d}$, and consequently that each will receive a volume of water equal to q divided by $\frac{v}{d}$; that is, $= q\frac{d}{v}$. But it is manifestly necessary that the bucket be capable of containing not only this quantity, but even a quantity about three times as great, otherwise a portion of the water will be spilt from the buckets too soon, and without producing its effect upon the wheel. If l represent the width of the bucket, that is, the width of the wheel within the shrouds, and s the area of its transverse section—more correctly, the area of the section of the mass of fluid which it contains at the moment it passes the jet—$s\,l$ will represent its capacity, and in relation to the section of the bucket itself we shall have

$$s\,l = 3\,q\frac{d}{v} = 180\,\frac{q}{M\,N} = 3\,\frac{Q}{M\,N},$$

M being the number of buckets in the wheel, and N the number of revolutions which the wheel makes in a minute. And since

$$d = \frac{\pi D}{M} \text{ and } v = \frac{\pi D N}{60}, \text{ therefore } l = \frac{3\,Q}{M\,N\,S}$$

which is the width of the wheel when Q is the volume of water to be employed upon it in a minute, and when it is expected to realize the maximum mechanical effect of the water.

We proceed to establish the values of these symbols from considerations involved in the *modus operandi* of the wheel; but for practical purposes, we may remark that, with slight variation, s may be taken $= \frac{1}{4}$ square foot; $l = 4{\cdot}5\,\frac{Q}{N\,D}$ and $M = 2{\cdot}88$ D.

We have already seen that the whole dynamical force of the stream of water employed in impelling a wheel of any form is expressed by W H; but as the whole height H can in no case be rendered effective, we have found it necessary to affect this product by a coefficient m, which is always a proper fraction, expressing the ratio of the force expended to that realized by the particular mover. To ascertain the theoretical value of m, which often, however, differs considerably from the actual value, let us take, in the first place, the over-shot-wheel, as the simplest case which the problem presents. Referring to Fig. 3774, let the horizontal lines M A and F B represent the higher and lower water levels; the vertical distance A B will then indicate the entire height H of the fall. If we divide this height into three parts—A c the part comprised between the higher surface of the water and the point where the stream strikes the wheel; c D equal to the height of the arc of the wheel, which may be considered as filled with water; and B D the distance between the point at which the water may be considered to be wholly discharged and the bottom of the fall—this division will enable us to particularize and estimate the losses which take place between the several partial limits, and therefore between the extreme limits A and B.

Within the limit c and D we have the whole effect of the expenditure realized upon the wheel, since the whole volume of fluid acts constantly, and with its whole weight in the vertical direction, it must realize upon this part of the wheel an effect corresponding to the height through which it descends, and yield a result which, in conformity with the notation adopted, will be expressed by W × c D. The height A c is that due to the velocity with which the water falls into the buckets, and with which it would strike the start boards, if it did not experience any diminution between the shuttle and the point of impulse. But this condition does not hold true; for at the point where the fluid encounters the wheel, the height due to the velocity is not A c, (which, for brevity, we shall put $= h$,) but to a height $h - \mu\,h$. The value of the coefficient μ will depend upon various conditions. In the first place, there arises a loss equivalent to a loss of velocity from the contraction of the fluid vein (*vena contracta*) which the fluid ex periences in its passage through the orifice of the shuttle; secondly, from the resistance offered by the surfaces over which it passes; thirdly, from the dispersion of the filaments of the fluid by striking against the oblique plates of the buckets; and fourthly, from the oblique direction with which the mean volume of fluid arrives at the bottom of the buckets. This obliquity may, in general, be taken at 30°, causing a diminution in the value of h of 0·14, and consequently a corresponding diminution of the force of the impulse. All these causes combined are found according to local circumstances, such as a good or bad arrangement of the shuttle and direction-plate or apron, to be equivalent to form two tenths to three-tenths of the whole value of h. Let A a be the portion of the height A c, representing the value of $\mu\, h$, the remaining part $a\, c$ will then represent the height $h - \mu\, h$, due to the actual velocity V of the jet, and consequently equal to ·0155 V^2.

From what has been before explained regarding the impulsive action of a current of water, this height will be subject to two other reductions: the one $h' = \cdot 0155\, v^2$ is that due to the velocity v of the wheel in feet per second, and therefore increases with that velocity; the other $h'' = \cdot 0155\, (V - v)^2$ is the height due to the velocity lost by the shock, and which, on the contrary, decreases as the velocity v increases. The sum of these losses will be the least possible, or $\cdot 0155\, \{v^2 + (V - v)^2\}$ will be a *minimum* when $v = \frac{1}{2}$ V. They will be respectively equal, that is, each will be $\frac{1}{4} \times \cdot 0155\, V^2 = \frac{1}{4}\, h\, (1 - \mu)$; and the two together, that is, $a\, b + b\, d$, will be equal to $\frac{1}{2}\, h\, (1 - \mu)$. In this case of *minimum* loss, the remaining part $d\, c$, which is all of the fall A c that can be regarded as effective, will therefore be equal also to $\frac{1}{2}\, h\, (1 - \mu) = \frac{1}{2}\, a\, c$, and consequently less than $\frac{1}{2}\, h = \frac{1}{2}$ A c, that is, than half the head reserved between the surface level of the water and the point at which it is received upon the wheel.

Although the sum of the two losses h' and h'' cannot thus be less than $\frac{1}{2}\, h\, (1 - \mu)$, we know that it can be, and is, indeed, almost always considerably greater, and increases as the difference between h' and h'' increases. It will obtain its *maximum*, if one of the two quantities, h'' for example, should become zero, giving rise to the condition $V = v$. In that case we have $h' = \cdot 0155\, V^2 = h\, (1 - \mu)$, that is, $a\, b = a\, c$, showing that no part of the fall A c remains effective. But in practice this condition can never arise, unless by miscalculation of the primary values of V and v. This last must always be less than the former, and consequently h'' must always have a real value; and in every case where h'' is greater than zero, it is manifest, from what has gone before, that a certain portion, however small, of the height A c must remain effective. Theoretically, this is shown to be less than $\frac{1}{2}\, h$; and under the very best arrangements it cannot, in practice, be expected to amount to $\frac{2}{5}\, h$, and in ordinary cases it ought not to be assumed greater than $\frac{1}{3}\, h$. As a general rule in practice, it may therefore be admitted, that in bucket-wheels, about two-thirds of the part of the fall comprised between the level of the water at the shuttle, and the point where the fluid encounters the wheel, is lost, as respects the effect produced. The actual value of this height h, which may be generally expressed by $W\, \{h\, (1 - \mu) - h' - h''\}$, will therefore be represented by

$$W\, (h - \tfrac{2}{3}\, h) = \tfrac{1}{3}\, W\, h,$$

a result which we shall subsequently find is closely analogous to that obtained experimentally as the effect of the best forms of impulsive wheels.

Since, then, a third only of the part of the fall above the wheel is available as power, whilst the whole of the part from that point downwards to the turn of the buckets, namely, c D, the height of the loaded arc, is entirely realized, it is manifestly of advantage to augment this latter part as much as possible, at the expense of the former. But this augmentation has a near limit, since there would be no economy, but the converse, in raising the point of reception so much, that the water, in arriving at the wheel, would have a less velocity than the buckets. In this case, it could not begin to act upon the wheel, except as a retarding influence, until, by an acceleration of its velocity, it established the necessary condition $V > v$.

The portion of the fall D B, from the bottom of the loaded arc downwards, is evidently lost, without answering any beneficial purpose. This loss arises from two causes—rather consists of two parts. The part e B is a measure of the loss resulting from the form of the buckets, and the small portion D e of that caused by the velocity of the wheel, or, more correctly, it is a measure of the loss occasioned by the centrifugal force produced in the fluid by the angular velocity communicated to it in its descent in the buckets. Leaving this effect out of view in the mean time, it is evident that, if not influenced by any central force, the surface of the water contained in the buckets would continue horizontal. In proportion as the buckets descend, in consequence of the revolution of the wheel, this surface gradually approaches the lip of the containing or front plate of the bucket; and the instant after it arrives at this position, marked $h\, i$, it begins to be discharged, and the bucket will be completely emptied when the face has attained the horizontal position marked $k\, l$. The arc F h, which measures the distance of the base of the wheel to the point where the water begins to be discharged, will therefore include the partially loaded arc $h\, k$ and the empty arc k F. This last is equal to the angle $u\, k\, l$, which the front plate of the bucket makes with the tangent to the circumference, an angle which is known from the rules employed in tracing the lines of the buckets, and which we may here designate by a. The arc F h = F k + $k\, h$, and this last $k\, h$ is equal to the angle $x\, h\, i$, which the front plate of the bucket makes with the surface of the water at the point where the fluid begins to be discharged, and which, for brevity, may be called z. We have therefore F $h = a + z$.

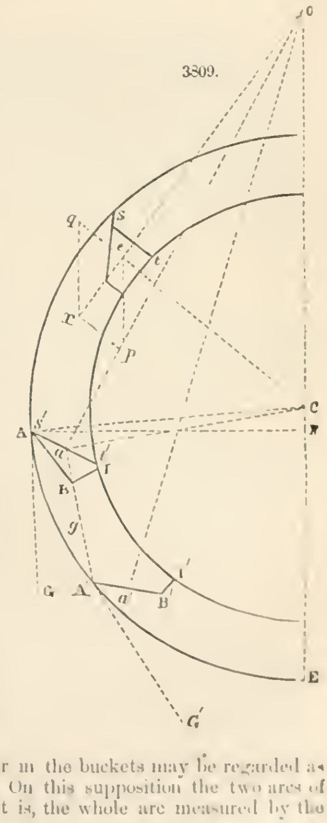
Whatever may be the magnitude of the two arcs of discharge, from these data we can always determine the rate of diminution of the quantity of water remaining in the buckets between the extreme points where it begins to overflow and where it leaves the bucket entirely empty, and therefore can determine the *mean arc of discharge*, and from this the mean quantity of effect due to the water carried below the commencement of the arc at h, in terms of the whole quantity which the buckets would be capable of carrying in their horizontal position in passing through the height c D. By determining the mean of this arc, we find the point at which, if the whole water were instantly discharged from each bucket as it passed, the effect upon the wheel would be the same as takes place when it is prolonged over the whole length of the arc $h\,k$. Generally, indeed, the mean is the arithmetical mean distance between h and k, and may be expressed by $a + \frac{1}{2} z$. If upon A B we take e at such a height that a horizontal line meeting the circumference of the wheel at a point equidistant from h and k, then will e B be the total loss of fall arising from the reversion of the buckets; and the wheel will yield the same result as if the entire water, instead of being gradually discharged between these points, were carried down to the point e, and then instantly thrown from the buckets. The arc below that point may therefore be regarded as entirely empty, and producing no effect; and to designate its relation, we have e B equal to the versed sine of that mean arc, of which the semi-diameter of the wheel is the radius; and therefore putting D to denote the diameter, we shall have

$$e\,\mathrm{B} = \tfrac{1}{2}\,\mathrm{D}\,\{1 - \cos(a + \tfrac{1}{2} z)\}.$$

It may be remarked that the angle z, which the surface of the fluid makes at the commencement of the discharge with the front plate of the bucket, will depend upon the volume of water in the buckets, as well as upon the form and dimensions of these, both of which are, of course, either known from the rules employed in the design of the wheel, or may be ascertained by direct measurement.

It remains to determine the loss of head resulting from the centrifugal force produced in the fluid filling the buckets, by the motion of the wheel. This loss is sometimes considerable, although not commonly reckoned among the influences to which wheels of this class are liable. M. Poncelet was the first, we believe, to direct attention to it, and has established a theorem for its determination, which may be said to complete the theory of the *modus operandi* of bucketed wheels.

It has been already stated that if a body move in a circle at a distance x from the centre, its centrifugal force will be expressed by $\frac{w}{g}\,\omega^2 x = \frac{w}{g} \cdot \frac{v^2}{x}$, when $\frac{v}{x}$ is put for ω, the angular velocity with which the body revolves. Now, since every molecule of fluid contained in the buckets of a wheel in motion is subjected to the action of the two forces—that of gravity and the centrifugal action—we may confine our attention to one such molecule e of which the mass $\frac{w}{g}$ may, for brevity of expression, be called m.



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If $e\,i\,p$ in the annexed diagram, Fig. 3809, represent the force $m\,g$ of gravity acting vertically, and $e\,q$, measured in the direction of the radius C e, represent the centrifugal force $m\,\omega^2 x$, the diagonal $e\,r$ of the parallelogram will be the resultant of the two forces, and may be regarded as representing the measure and direction of a new force replacing the two actual forces $e\,p$ and $e\,q$, and producing upon the molecule the same intensity of action. If we prolong $e\,r$ until it meets the vertical line E O passing through the centre C in O, this point will be such that $\mathrm{C\,O} = \frac{g}{\omega^2}$, and, therefore, is independent of the position of the molecules, and the same for all—all the resultants of the forces converging to that point, which is therefore the centre of action whence all the forces are directed. The surface of the fluid being always perpendicular to the direction of the force which acts upon the molecules, that of the fluid contained in all the buckets will be so to the lines passing to the point O from any point of the wheel, and, consequently, the section $s\,t$ of any given surface will be an arc of a circle having O for its centre.

In the revolution of the wheel, the extremity s of this arc approaches gradually the lip of the front plate of the bucket, and will arrive at it whenever the bucket shall have come into the position A B I. Immediately after it will begin to be discharged, and the discharge will continue until the bucket has descended to the position A′ B′ I′, where the limiting arc of the fluid surface will have passed under the bucket plate A′ B′.

In wheels moving at ordinary velocities the surface of the water in the buckets may be regarded as planes perpendicular to lines drawn to them from the centre O. On this supposition the two arcs of discharge, A E and A′ E, may be thus determined. The first, that is, the whole arc measured by the angle A C E, is equal to

$$\mathrm{G\,A\,F} = \mathrm{G\,A\,B} + \mathrm{B\,A}\,t' + t'\,\mathrm{A\,F} = a + z + y$$

in designating the angle $t'\,\mathrm{A\,F} = a\,\mathrm{O\,C}$ by y, the point a being equidistant between s' and t'. Taking $a\,g$ perpendicular to a C, and calling b the angle which the first of these lines makes with the tangent A G, supposing both produced until they meet, and which will necessarily be equal to the angle A C a; and

$$\angle\,\mathrm{O}\,a\,\mathrm{C} = \angle\,g\,a\,t' = \angle\,\mathrm{G\,A}\,t' - b.$$

Moreover, the triangle O a C gives

$$\sin a\,\mathrm{O\,C} : a\,\mathrm{C} :: \sin \mathrm{O}\,a\,\mathrm{C} : \mathrm{O\,C},$$

that is,

$$\sin y : \rho :: \sin(a + Z - b) : \frac{g\,r^2}{v^2}$$

in which r is the dynamical radius of the wheel, and ρ the same radius, diminished by half the depth of the buckets. From this analogy we obtain

$$\sin y = \frac{\rho v^2 \sin (a + z - b)}{g r^2}.$$

The angle b being generally very small, will very slightly influence the value of y, and may, therefore, be neglected in determining the angle of discharge without sensible error; but by way of compensation, we may substitute for ρ the dynamical radius r, making

$$\sin y = \frac{v^2}{g r} . \sin (a + z).$$

To find the measure of the arc A′ E: if we take y' to denote the angle a' O E we shall have A′ E $= \angle (a + y')$. And from the same species of reasoning employed for y we find

$$\sin y' = \frac{v^2}{g r} . \sin a.$$

From these values we might establish a general expression for the mean arc of discharge; but, as already remarked, this does not differ sensibly from the arithmetical mean, and may therefore be represented by $a + \frac{1}{2} z + \frac{1}{2} y + \frac{1}{2} y'$. And reverting to Fig. 3808, its versed sine will be represented by D B, which is the whole loss of head resulting from the form of the buckets and the centrifugal force conjoinedly, and may thus be calculated previous to the construction of the wheel. If we designate this loss by h''', we shall have

$$h''' = \tfrac{1}{2} D \{1 - \cos (a + \tfrac{1}{2} z + \tfrac{1}{2} y + \tfrac{1}{2} y')\}$$

As an example of the arithmetical process of determining this loss of head from *a priori* data, let the diameter of the wheel be 37½ feet, the number of buckets 92, the width $l = 3{\cdot}55$ feet = 3 feet 6½ inches and the depth 12·8 inches. The breadth A B of the first plate of the buckets is 1·522 feet, and a line joining A I = 1·683 feet. The angle G A B which A B makes with the tangent A G to the circumference is $31° 37' = a$; B A I = 9° 8′; and A I B = 53° 10′; the surface of the triangle B A I B is therefore = ·20344 square feet $= s'$. The dynamical radius r of the wheel is 17·935 feet, and the distance d between the buckets measured on the circle described by that radius is 1·225 feet; the velocity v at the same circle = 8·2 feet in a second. The quantity of water furnished in the same unit of time is 5·3 cubic feet $= q$. The section s of water contained in a bucket before it begins to discharge will therefore be

$$s = \frac{q d}{l v} = \frac{5{\cdot}3 \times 1{\cdot}225}{3{\cdot}55 \times 8{\cdot}2} = 0{\cdot}22299 \text{ sq. ft.}$$

But this section being greater than $\cdot 20344 = s'$, shows that the water surface meets the sole at some point t' higher than I. Now the angle z, that is, the angle which the surface of the water makes with the face-plate of the bucket, will be equal to the sum of the angles B A I and I A t'.

To find this last we may take, without sensible error,*

$$\tan \text{I A } t' = \frac{2 (s - s')}{\text{A I}^2 - 2 (s - s') \tan \text{A B I}} = \frac{\cdot 0391}{2{\cdot}8325 - \cdot 006286} = \tan 0° 47' 34'';$$

therefore, $z = \text{A B I} + \text{I A } t' = 9° 8' + 0° 47' 34'' = 9° 56'$ nearly.

To find y and y' we have, for the first,

$$\sin y = \frac{v^2}{g r} \sin (a + z) = \frac{(8{\cdot}2)^2}{32{\cdot}2 \times 17{\cdot}935} \times \sin (31° 37' + 9° 56') = \sin 4° 26' \text{ very nearly.}$$

$$\sin y' = \frac{v^2}{g r} . \sin a = \frac{(8{\cdot}2)^2}{32{\cdot}2 \times 17{\cdot}935} \times \sin 31° 37' = \sin 3° 30' \text{ very nearly.}$$

For the whole ineffective arc of discharge we have, therefore,

$$a + \tfrac{1}{2} z + \tfrac{1}{2} y + \tfrac{1}{2} y' = 40° 33';$$

and from this we obtain as the total loss

$$h''' - \tfrac{1}{2} \times 37\tfrac{1}{2} (1 - \cos 40° 33') = 4{\cdot}502 \text{ feet}$$

If we decompose this into the losses incurred by the form of the buckets and the centrifugal force, we find for the former

$$c \text{B} = \tfrac{1}{2} \times 37\tfrac{1}{2} (1 - \cos 36° 35') = 3{\cdot}694 \text{ feet};$$

$$\text{and } \therefore c \text{D} = (4{\cdot}502 - 3{\cdot}694) \text{ feet} = 0{\cdot}808 \text{ feet.}$$

These parts are, therefore, very nearly as 100 to 22; consequently, retaining these numbers, the loss of fall below the loaded arc is shown to be increased by the centrifugal force communicated to the fluid from 100 to 122.

In conformity with the principle before indicated, we must, in order to arrive at a complete theoretical expression of the value of the fall, subtract these several losses, and multiply the remainder by the weight of water for the total effect, which will then be expressed by

$$W (H - \mu h - h' - h'' - h''').$$

But this expression being deduced entirely from theoretical considerations, we must, in order to com-

* When the point t' falls below I, that is, when s' is greater than s, the formula for z becomes

$$\tan z = \frac{2 s \cdot \text{A B}}{\text{A B}^2 + 2 s \cot (180° - \text{A B I})}.$$

pare it with the results of experience, applicable to every particular case, introduce our coefficient of reduction m, when we will have as the actual effect developed by the wheel

$$E = m\,W\,(H - \mu h - h' - h'' - h''').$$

From this it therefore appears that in every bucket-wheel the ultimate effect will be increased as the five quantities μ, h, h', h'', h''' are diminished. Now these have respect,

μ, to the construction of the shuttle and watercourse, which ought accordingly to be adapted with care to the particular case;

h, to the diameter of the wheel, which, therefore, ought to be as great as the other conditions will admit, (it being understood here that the wheel is constructed on the overshot principle;)

h' and h'', to the difference of velocity between the water and the wheel for a given value of h; a condition which will be satisfied the more nearly as the velocity of the wheel approaches half the velocity of the water at the moment it arrives at the bottom of the buckets;

h''', to the proper disposition and form of the buckets, and a small velocity of the wheel, by which the water will be carried to the lowest point possible of the fall before it is discharged.

The only trustworthy experiments on wheels of this class, which have been published, are those of Mr. Smeaton, made in 1759, upon a small model wheel of two feet diameter. Various details are, however, wanting to enable us to compare his results with the preceding formulæ—especially the form and dimensions of the buckets. The following table contains the summary of his results:

No.	Whole descent.	Water expended in a minute.	Turns at the maximum in a minute.	Weight raised at the maximum.	Power of the whole descent.	Power of the wheel.	Effect.	Ratio of the whole power and effect.	Ratio of power of the wheel and effect.	Mean Ratio.
	Inch.	lb.		lb.						
1	27	30	19	6½	810	720	556	10 : 6·9	10 : 7·7	Medium 10 : 8·1
2	27	56⅔	16¼	14½	1530	1360	1060	10 : 6·9	10 : 7·8	
3	27	56⅔	20¾	12½	1530	1360	1167	10 : 7·6	10 : 8·4	
4	27	63⅓	20½	13½	1710	1524	1245	10 : 7·3	10 : 8·2	
5	27	76⅔	21½	15½	2070	1840	1500	10 : 7·3	10 : 8·2	
6	28½	73⅓	18¾	17½	2090	1764	1476	10 : 7·	10 : 8·4	10:8·2
7	28½	96¾	20¼	20½	2755	2320	1868	10 : 6·8	10 : 8·	
8	30	90	20	19½	2700	2160	1755	10 : 6·5	10 : 8·1	10 : 8·2
9	30	96⅔	20¾	20½	2900	2320	1914	10 : 6·6	10 : 8·2	
10	30	113⅓	21	23½	3400	2720	2221	10 : 6·5	10 : 8·2	
11	33	56⅔	20¼	13½	1870	1360	1230	10 : 6·6	10 : 9·	10 : 8·5
12	33	106⅔	22¼	21½	3520	2560	2153	10 : 6·1	10 : 8·4	
13	33	146⅔	23	27½	4840	3520	2846	10 : 5·9	10 : 8·1	
14	35	65	19¾	16½	2275	1560	1466	10 : 6·5	10 : 9·4	10 : 8·5
15	35	120	21½	25½	4200	2880	2467	10 : 5·9	10 : 8·6	
16	35	163½	25	26½	5728	3924	2981	10 : 5·2	10 : 7·6	
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.

From this table we perceive the small effects produced by an increase of the head A $c = h$ above the wheel. On the general results, he observes, that "the power of the water computed from the height of the wheel only, appears to observe a more constant ratio" than that between the power of the water reckoned from the whole descent and the ultimate effect. Thus the ratios in column 9 differ from that of 10 : 7·6 to 10 : 5·2; whereas, taking the mean set down in column 11, "we find the extremes to differ no more than from the ratio of 10 : 8·1 to 10 : 8·5; and as the second term of the ratio gradually increases from 8·1 to 8·5, by an increase of head from 3 inches to 11 inches, the excess of 8·5 above 8·1 is to be imputed to the superior impulse of the water at the head of 11 inches above that of 3 inches; so that, if we reduce 8·1 to 8, on account of the impulse of the 3-inch head, we shall have the ratio of the power, computed upon the height of the wheel only, to the effect at a maximum as 10 : 8, or as 5 to 4 nearly; and from the equality of the ratio between the power and effect, subsisting when the constructions are similar, we must infer that the effects, as well as the powers, are as the quantities of water and the perpendicular heights multiplied together respectively."

These inferences are corroborative of the principles which we have attempted more formally to illustrate; but we must also quote his remarks "concerning the velocity of the circumference of the wheel, in order to produce the greatest effect," as they are still frequently appealed to in justification of an erroneous interpretation of a true doctrine. The doctrine is thus stated by the author:—"If a body is let fall freely from the surface of the head to the bottom of the descent, it will take a certain time in falling; and in this case the whole action of gravity is spent in giving the body a certain velocity. But if this body in falling is made to act upon some other body, so as to produce a mechanical effect, the falling body will be retarded; because a part of the action of gravity is then spent in producing the effect, and the remainder only giving motion to the falling body: and therefore *the slower a body de* *scends, the greater will be the portion of the action of gravity applicable to the producing a mechanical effect;* and in consequence the greater that effect may be.

"If a stream of water falls into the bucket of an overshot-wheel, it is there retained until the wheel by moving round discharges it: of consequence the slower the wheel moves, the more water each bucket will receive; so that what is lost in speed, is gained by the pressure of a greater quantity of water acting in the buckets at once; and, if considered only in this light, the mechanical power of an overshot-wheel to produce effects will be equal whether it moves quick or slow: but if we attend to what has been just now observed of the falling body, it will appear that so much of the action of gravity, as is employed in giving the wheel and water therein a greater velocity, must be subtracted from its pressure upon the buckets, so that, though the product made by multiplying the number of cubic inches of water acting in the wheel at once by its velocity will be the same in all cases; yet as each cubic inch, when the velocity is *greater* does not press so much upon the bucket as when it is *less*, the power of the water to produce effects will be greater in the less velocity than in the greater: and hence we are led to this general rule, *that* cæteris paribus, *the less the velocity of the wheel, the greater will be the effect thereof.*"

According to this view of the subject we ought to introduce into our formula a further reduction of H depending upon the velocity of revolution, and which would therefore be a function of v. But if the mode in which h'' has been obtained be observed, it will be found that the circumstance which Mr. Smeaton had in view is there included. It is admitted that the gravitation of the fluid in the buckets cannot at the same time be producing pressure and velocity; but we have laid it down as a condition, which Mr. Smeaton also insists upon, that the water must have a higher velocity than the circumference of the wheel at the moment of its passing into the buckets. This condition being fulfilled, it is then clear that as no additional velocity has been generated in the fluid, after it has entered the buckets, no part of its power is thereby consumed below that level, and that all its effect will be realized upon the wheel. In other words, the effect of the volume of water on the loaded arc will be expressed by $W \times c\,D$.

This may be exhibited somewhat more formally, and as a preliminary step let it be required to prove that the weight of fluid carried in the loaded arc of the wheel, from the level of c to the lower level D, is equal to the effort which would be exercised by the weight of a prism of water G H placed at the extremity of the dynamical radius O P, the height of the prism being equal to c D, and the area of its base equal to the cross-section of the fluid arc, if the water in the buckets were uniformly distributed, and formed a continuous arc. To show that this is true statically, it will be sufficient to prove that the moments of pressure are in the two cases equal. For this purpose let it be supposed that the lengtl of the fluid arc is divided into an infinite number of small elementary arcs, such as $m\,n$ having a cross section σ. If then we designate by ϕ the specific gravity of the fluid, we shall have $\sigma \,.\, m\,n \,.\, \phi$ as the weight of the small arc $m\,n$. And since it acts vertically, the distance between the direction of its pressure and the centre of rotation will be the horizontal line $r\,s$. Thus then we have as the moment of its pressure $\sigma \,.\, m\,n \,.\, \phi \,.\, r\,s$. But the triangles $m\,n\,t$ and $r\,O\,s$ are similar; hence $m\,n \,.\, r\,s = O\,r \,.\, p\,q$, and therefore,

$$\sigma \,.\, m\,n \,.\, \phi \,.\, r\,s = \sigma \,.\, \phi \,.\, O\,r \,.\, p\,q.$$

Now the sum of all the partial moments will be the moment of the entire arc, and will be found by multiplying the common factor $\sigma \,.\, \phi \,.\, O\,r$ by the sum of all the small heights $p\,q$ of the elementary arcs; this sum is evidently $f\,g = c\,D$: the entire moment will therefore be $\sigma \,.\, \phi \,.\, O\,r \,.\, c\,D$. But that of the prism G H is manifestly $= \sigma \,.\, \phi\; G\,H \,.\, O\,P$; and since $G\,H = c\,D$ and $O\,r = O\,P$, the two moments are equal.

If we now bring into view the dynamical conditions imposed by the motion of the wheel, and keep in view that no motion is *communicated* to the water within the limits of the arc, we have as data a pressure applied at P in the direction of movement $\sigma \,.\, \phi \,.\, c\,D$, and a velocity at that point of v feet per second: the force impressed will therefore be expressed by $\sigma \,.\, \phi \,.\, c\,D \,.\, v$. And if q be the volume of water flowing in a second, with a continuous section σ, and velocity v communicated independently of the motion of the wheel, and acquired before it reached it, we have $q = \sigma \,.\, v$; and w being the weight of the volume q, we have besides $w = \phi \,.\, q$. Taking the values of σ and ϕ in these two equalities, and substituting them in the expression above of the force impressed, it becomes

$$\frac{q}{v} \,.\, \frac{w}{q} \,.\, c\,D \,.\, v = w \,.\, c\,D,$$

which is the condition we undertook to demonstrate, and upon which, it will be observed, the velocity of the wheel has no influence.

The best data which we possess for determining the value of the coefficient m in our formula of the actual efficiency of the wheel is a table of experiments furnished by M. D'Aubuisson containing all the conditions. The mean of these cases gives $m = \cdot 8997$, and the highest value is ·917, and the lowest ·874. We may, therefore, without serious error put $m = \cdot 9$. The other terms may also be simplified for the purposes of ready application. Thus the three terms μh, h', h'', taken together, we have already shown, do not differ widely from $\frac{2}{3}h$; and, except in extreme cases, h''' will not vary more than between $\frac{1}{7}$ and $\frac{1}{5}$ of the diameter of the wheel. Let us assume the mean of these extremes, namely, $\frac{1}{6}$ D, and substitute these quantities with a value of $m = 0\cdot 9$ in our formula, it will then be reduced to the following:

$$E = 0\cdot 9\; W\,(H - \tfrac{2}{3}h - \tfrac{1}{6}D),$$

and by putting Q = the number of cubic feet of water furnished in a minute, and expressing the effect in units of horse-power, conformably to the principle before explained, we have

$$E = \cdot 0017\; Q\,(H - \tfrac{2}{3}h - \tfrac{1}{6}D).$$

As an example, let the quantity of water be 1000 cubic feet a minute, and the fall 25 feet; in this case the wheel would be made about 22 feet diameter; therefore $\frac{2}{3}h = 2$ feet and $\frac{1}{6}D = 3\frac{2}{3}$ feet. Hence, the value of the fall would be reduced to $25 - (2 + 3\frac{2}{3}) = 19\frac{1}{3}$ feet, and this multiplied by 1000 = 19333. Finally, $19333 \times \cdot 0017 = 32 \cdot 87$ horse-power.

This formula may also be employed to determine the volume of water which it would be necessary to employ, with a given head, to obtain any required amount of power—a problem which very frequently occurs in practice.

In this we have confined our attention to the case of the overshot-wheel, on account of its being the most obvious; but the same formula may, by a very slight modification, be applied to determine the effect of a breech-wheel. The modification referred to is simply the replacing of $\frac{1}{6}D$ by its assumed equivalent h''', by which we have

$$E = \cdot 0017\, Q\, (H - \tfrac{2}{3}h - h''').$$

We replace h''', because in wheels of this kind its value ought to be always less than in the overshot arrangements. The breech-wheel, as we have already seen, has usually a diameter somewhat greater than the height of the fall; and as h''' is proportional to the diameter, we have by this arrangement the advantage of making it as small as possible within the limits of practice. We can, indeed, increase the diameter at pleasure, and thereby proportionally increase the length of the loaded arc—the grand source of power in the bucketed wheel of whatever form.

Robertson Buchanan, in his Essay on Water-Wheels, has endeavored to fix the proportion of the radius of the wheel to the height of fall to yield a maximum effect, but seems to have left out of view the effect of the centrifugal force, and to have supposed the wheel to revolve in an arc—which is, indeed, the usual arrangement now adopted. The following is his mode of calculation:—Let c = that portion of the circumference which is to be loaded with water—that is, the portion of the half circumference below the point at which the water flows upon the wheel; and let x = the arc comprehended between that point and the horizontal plane passing through the axis of the wheel; also make b = the area of the stream supplying the buckets. Then the solid which represents the effective force, that is, the arc of water below the point of reception, will be $\frac{1}{2}b\left(\frac{c^2 - 2x^2}{c - x}\right)$, and this is to be the greatest possible, or $\frac{c^2 - 2x^2}{c - x}$ = a maximum. By the principle of maxima and minima, this takes place when $x = c(1 - \sqrt{\frac{1}{2}})$ or $x = 0 \cdot 2929\, c$. Accordingly, the arc $c - x$ must be a quadrant, and the arc $x = 37 \cdot 27^\circ$.

From this it appears that the wheel will produce its greatest effect when the diameter is so proportioned to the height of the fall that the water flows upon the circumference at a point $90^\circ - 37 \cdot 27^\circ = 52 \cdot 73^\circ$ (nearly $52\frac{3}{4}$ degrees) distant from the summit of the wheel.

If R, then, be radius of the wheel to the extreme edge of the bucket, and h the height of fall measured to the point where it may be delivered upon the wheel, and which may be called the effective height, then we shall have

$$R = \frac{h}{1 + \sin 37\frac{1}{4}} = \frac{h}{1 \cdot 605}.$$

Since $\sin 37\frac{1}{4}$ degrees $= \cdot 605$. We have also by reduction $R = \cdot 623\, h$.

The effective height of the fall is less than the entire height H by as much as is necessary to give the water the required velocity, which may be taken generally at 10 feet in a second, or $1\frac{1}{2}$ feet of fall.

The French mechanicians calculate a somewhat greater diameter for their wheels than that given by the foregoing rule. Instead of laying on the water at $52\frac{3}{4}$ degrees from the summit, as is commonly done in this country, they lay it on at a distance of 60°, that is, 30 degrees above the horizontal plane passing through the axis of the wheel. Accordingly $R = \frac{h}{1 \cdot 5} = \frac{2}{3}h$. They also allow, as above recommended, $1\frac{1}{2}$ feet of the fall to give the required velocity to the water.

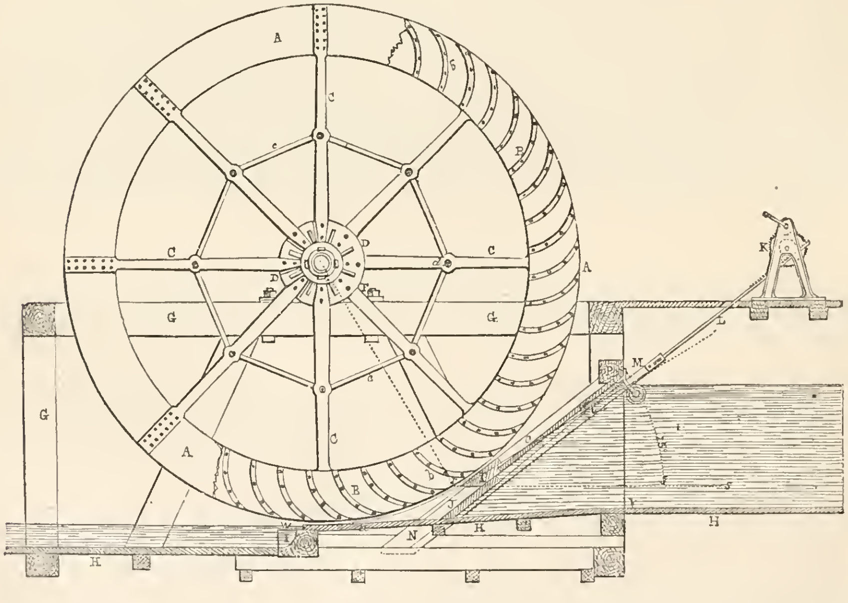
No line of demarcation has yet been determined to separate this species of wheel from the breast-wheel, except that this name is applied when the water is received upon the wheel at a greater distance from the summit than $52\frac{3}{4}$ degrees. But it has not been decided when this rule ought to be set aside, and the wheel become a breast wheel. A notion, not without foundation, prevails among millwrights that a wheel of large diameter is more advantageous than one of small diameter; in a wheel of large diameter the influence of the centrifugal force is less, and the mass in motion being greater, the movement is more uniform and may be proportionally slower, which, in the case of a low fall, is no inconsiderable advantage. There is, however, the disadvantage of additional friction upon the journals, and which, as these wheels are usually very broad, goes far to counterbalance the loss arising from centrifugal force.

As the question is therefore entirely one of practice, and incapable, we believe, of a theoretical solution, it may be stated as an opinion founded on a good example, that the diameter of the wheel, even for very large quantities of water, may be made to conform to the rule above given, down to 12 feet diameter. The example which we have in view is a double wheel of that size, using at least 3000 cubic feet of water per minute very satisfactorily. The same size of wheel might be used till the fall descends to about 6 feet, when a wheel on the undershot principle will be found less expensive and equally efficient. Under these circumstances the wheel will act partly by the impulse and partly by the gravity of the water—that is, partly as an overshot and partly as an undershot wheel; its effect may therefore be ascertained by computing the effect due to the difference of level between the surface of the water at the penstock and the point where it strikes the wheel, and adding the result to the effect, realizable from the height of a fall equal to the difference of level between the point where the water meets the circumference of the wheel and the level of the tail-water, and which may be calculated by the methods above indicated.

Undershot-wheels.—By undershot we understand here those varieties of wheels which move chiefly by the direct impulse of the fluid. In construction they differ little from the bucketed wheel, except that the buckets are replaced usually by radial floats upon which the impulse of the current is received. They are, also, usually confined in an arc, below the level of the water-line, to confine and economize the motive power; but, as this arrangement is also common to bucketed wheels, especially when the fall is low, it cannot be regarded as a peculiarity. In this form of wheel, especially if the volume of water be considerable, the spider construction is, however, only admissible when the power is taken off at the circumference by a pinion placed slightly above the point of impulse and on the same side. There is, then, only the small portion of the sole-frame put on strain by tension, between the two points. But, when the power is taken off at the axis, the construction ought to be of the more rigid kind, otherwise the continually changing direction of the strain, acting through a leverage equal to the radius of the wheel, will speedily prove fatal to the points of connection, if in any degree elastic.

The water is admitted upon the wheel by a sluice or shuttle in its immediate vicinity, as in the case of the bucket-wheel. What has been stated in reference to the loss of head experienced by the water passing through an opening in its course is therefore applicable in this case as before. It is also of moment, both on theoretical and practical grounds, that the sluice be placed as closely upon the wheel as other considerations will permit; and that the retaining cheeks of the aperture, inside of the sluice, be slightly contracted, answering to the natural contraction of the stream after passing through the orifice, in consequence of the resistance which it there encounters. The sides of the course or arc in which the wheel moves, must necessarily be parallel; but, immediately on passing the vertical plane passing through the axis of the wheel, the floor ought to deepen and the sides expand and leave the water as much space to diffuse itself over as possible. This arrangement is shown in Figs. 3810 and 3811, as far as it is applicable with a sluice-framing entirely constructed of wood; but, when the construction is of iron, the confinement of the water may be made much more complete.

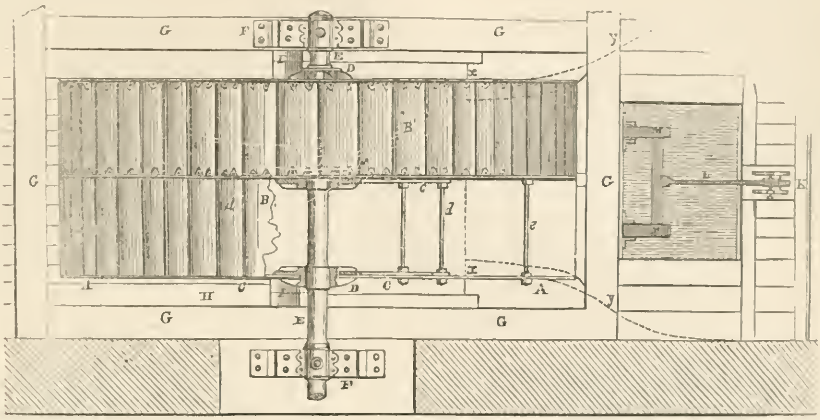
3810.



Supposing the floats to be placed radially, their breadth or depth in the direction of the radius ought obviously to be such, that in the rising of the water against the float which it first strikes, the portion which tends to pass over its superior edge shall not be thrown against the back of the succeeding float. Any action of this kind would manifestly be attended with a corresponding diminution of the effect of the wheel; and ought, therefore, to be avoided, as perhaps the most serious error which is liable to be committed in this form of wheel. This source of loss may, however, be, in general, entirely avoided, by giving to the floats a depth of about three times the thickness of the lamina of water acting upon them. The thickness of the lamina is usually from four to six inches, giving the range of depth of the floats from twelve to eighteen inches. The velocity with which the fluid precipitates itself upon the floats, ought also to be taken into account in providing for its expansive movement. The distance of the one float from the other, measured upon the exterior circumference of the wheel, may be generally taken equal to the depth. Their number will, of course, depend upon the diameter of the wheel, and this is almost arbitrary. We will, however, endeavor briefly to indicate the general principle which ought to be kept in view in fixing the diameter, without entering upon any strict investigation of the question.

As a consequence of the general theory already explained, it follows that the dynamical effect of the wheel is dependent upon the relation which the velocity of the floats bears to that of the water; but this relation is manifestly independent of the diameter. The velocity due to the current of water to be used is always an ascertainable quantity, and may therefore be regarded as known. Another determinate element of the calculation is the number of revolutions which it is desirable the wheel should make in a certain unit of time, as a minute, in order that the effect may be transmitted to the working points, with a rate of velocity the most advantageous for the particular purposes intended, and obtained

3811.



in the simplest manner possible, and with the least quantity of intermediate geering. It is also important that the wheel have a velocity and dimensions rendering it capable of fulfilling the purpose of a fly at the rate of motion which it is intended to maintain. If we put u to denote the velocity of the extremities of the floats, and N the number of turns desired in a minute, the diameter will be expressed by

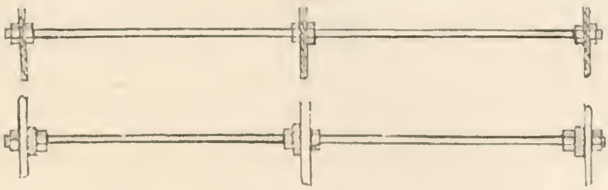
$$\frac{60\,u}{\pi\,N} = 19{\cdot}1\,\frac{u}{N}$$

And to obtain an effect approaching the maximum, we may assume $u = 2{\cdot}4\sqrt{H}$; and therefore the diameter expressed in terms of the velocity and height of fall will be

$$19{\cdot}1 \times \frac{2{\cdot}4\sqrt{H}}{N} = \frac{46}{N}\sqrt{H} \text{ very nearly.}$$

Thus, supposing the fall to be 6 feet, and the number of turns per minute required to be $10 = N$; then the diameter will be $\frac{46}{10} \times \sqrt{6} = 4{\cdot}6 \times 2{\cdot}45 = 11\frac{1}{4}$ feet nearly. This is nearly the minimum diameter of wheel which would under any circumstances be employed; 12 feet to 25 feet may indeed be taken as the usual range; but unless the volume of water be extraordinarily great—and then breadth is better than diameter—we cannot conceive of any advantage, other than may arise from some peculiarity in the nature of the machinery to be impelled, which may not be obtained with a diameter of 16 feet to 18 feet. It is, however, to be observed, that the smaller the diameter the greater is the nicety of adjustment required to make the water yield its effect upon the buckets; and possibly the errors which have been committed in this particular have led to the common opinion that a wheel of large diameter is always in practice the most effective.

3812.



Before the introduction of Poncelet's system of curved floats, various attempts were made to increase the efficiency of the under-shot-wheel, by placing the floats at some determinate angle with the circumference. And where the wheel moved in backwater, and especially in an uncontined channel, a certain beneficial effect was experienced. But in the ordinary cases of a confined course or arc, with proper provision for tail water clearance, these schemes do not seem to have been attended with any advantage. According to Bossut's experiments, indeed, the result appears to indicate that the radial float is the most efficient. Taking the effect obtained with the radial float as unity, the results which he obtained with the angular positions noted, are thus stated:

Angle of float, ...	0°	8°	12°	16°
Comparative effect, ...	1	0·949	0·956	0·998

Showing that at least no advantage is derived from *feathering the floats*, as it is denominated. In an indefinite volume of fluid, the case is, however, different; the inclination of the floats favors, not the action of the impelling fluid, but their disengagement. This is manifest when it is observed that as soon as the radial float passes into water, having a less velocity than its own, it begins to be retarded; and besides, in rising to the surface, it tends to lift with it a portion of the fluid, which, acting by its weight in the contrary direction to that of the wheel, also proportionally diminishes the useful effect.

This is sometimes obviated at great expense, in large wheels placed in situations where the fall is very small and liable to be flooded, by rendering them capable of being raised and lowered at pleasure, in conformity with the state of the river. The mechanism for this purpose is generally worked by manual labor; but sometimes also it is rendered self-acting, as in the case of some wheels worked by the tide in situations where the tidal oscillations are considerable. In these the floats are usually, though not always advantageously, inclined to the radius to assist the other arrangements.

Various other schemes for increasing the efficiency of impulsive wheels have been resorted to. One of these was to place a ledging on the ends of the floats to confine the action of the fluid; but with very little beneficial effect; and, it is obvious, that if any arrangement of this kind was likely to be of advantage, it could be most effectually secured by placing the floats within shrouds, as in the common bucket-wheel—a form of construction not uncommon. Another supposed improvement, still common in some parts of Europe, though never introduced into this country, and only applicable to very narrow wheels, is to form the floats of cylindrical arcs, with the axis of the cylinder in the direction of the radius of the wheel, and the concave face of the arc opposed to the motion of the water. This arrangement is stated to possess certain advantages, but we cannot conceive that they can possibly be so marked as to compensate the additional cost of construction; and we must still believe that the plain float with shrouding is both the simplest and most complete of all the deviations which have been attempted, excepting, indeed, M. Poncelet's application of the curved float, and even in this the advantage does not so much consist in the form of the float, as in the other beneficial adaptations with which it is associated.

To understand the action of the water upon the floats of a wheel of the kind under discussion, it is necessary to observe that the moment the sluice is raised, the fluid precipitates itself against the first float which obstructs its passage, and, in consequence, an accumulation takes place, which ultimately succeeds in putting the wheel in motion, and gradually accelerates its velocity until an equilibrium is established between the force of the current and the resistances to be overcome. In proportion as the velocity of the wheel increases, the pressure of the current becomes less, since this action is proportional to the relative velocities; and very soon the acceleration, which gradually diminishes, becomes imperceptible, and finally ceases; and the wheel, after a certain number of revolutions, in consequence of the velocity impressed upon it, and in consequence also of its inertia, continues to revolve as of itself, either with a motion perfectly uniform, or with a velocity oscillating between limits imposed by the varying nature of the resistances, and which may be reduced in effect to a mean continuous velocity always ascertainable.

Supposing the wheel to derive its effect entirely from the impulse of the current, and to obtain no advantage from confinement in an arc, by which a certain amount of the weight of the fluid is made to act in aid of the impulsive force, the dynamical effect, considered theoretically, of any given weight W of water upon a float receding before the stream with a velocity of v feet in a second, is expressed by

$$\frac{W}{g}(V - v)\,v.$$

But it may be questioned whether the same effect will be produced upon a suite of floats presenting themselves successively to the current, usually two and three at a time, and under various angles of inclination. On this point we derive our most important information from experience; but admitting, in the mean time, that the action of the impulse, although not equal, is of the same kind, and susceptible of an expression of the same form as that above, we shall ultimately succeed in comparing the results of experiment with those of calculation.

In the expression above, when the wheel is moved by a confined current, v is the only variable quantity. If $v = 0$, the effect is also cipher, for a machine which does not move yields no power. The power will also be cipher, when $V = v$, since, as before remarked, if the wheel move at the same rate as the current, it can receive no motive effect from the fluid. It is still more obvious that v cannot be greater than V. The limit is therefore between $v = 0$ and $v = V$, and between these extremes there will be a *maximum* of effect. If, then, we differentiate the variable part $(V - v)\,v$, and equate to zero in the usual manner, we have

$$V\,dv - v\,dv = 0;\ \text{whence}\ v = \tfrac{1}{2}V,$$

showing that the effect of the wheel is the greatest possible when it moves with half the velocity of the stream.

Now, the pressure of the water upon the floats being $\frac{W}{g}(V - v)$, this will also be a measure of the resistances (including all the passive resistances) overcome by the wheel, since the moments of pressure must obviously be equal in every case of equilibrium; hence, if in this expression we substitute for v its equivalent $\frac{1}{2}V$, we have, as the measure of the load when the dynamical effect is a maximum,

$$\frac{W \times V}{2\,g}$$

And the dynamical effect being equal to the load multiplied into the velocity of motion, viz., $v = \frac{1}{2}V$, we have, using this last as the measure of the velocity of the wheel,

$$\tfrac{1}{2} W \times \frac{V^2}{2g} \text{ equivalent to } \tfrac{1}{2} W H,$$

when H is put to denote the height of fall due to the velocity V, as before explained.

If, therefore, V be the whole velocity of the stream, and H the entire fall due to that velocity, this result shows that the greatest possible effect which can be realized from a wheel moved entirely by the impulse of the fluid, is only half of the mechanical power of the water expended; that is, considering both cases theoretically, is only equal to half the effect which a wheel acting entirely by the gravity of the fluid, ought to realize. But even this moiety is subject to reduction, and can be only distantly approached in practice.

We do not, unfortunately, possess many experiments upon which we can implicitly rely, with wheels of this kind. We have many of a mixed kind, in which the effects of impulse and gravity are combined, but few in which the impulsive action alone appears. Those of Mr. Smeaton, indeed, stand nearly alone in importance and accuracy; and, fortunately, they are complete in the necessary data. Although the model apparatus with which they were made was small, the well-known accuracy of the experimenter, and the purpose for which the investigation was undertaken, warrants the confidence which they have long commanded. The wheel was the same in diameter as his overshot model, viz., 2 feet, and was, indeed, adapted to the same apparatus. The power was measured directly by raising a weight vertically by a cord over a pulley; and perhaps the only objection which can be validly urged against the results, consists in his neglecting the additional friction thereby produced at the journals of the wheel. The data for this correction is, however, furnished, and may still be applied.

We subjoin the author's table of results, the columns of which are fully explained by the *headings* placed over them:

No.	Height of water in the cistern.	Turns of the wheel unloaded.	Virtual head deduced therefrom.	Turns at the maximum.	Load at the equilibrium.	Load at the maximum.	Water expended in a minute.	Power.	Effect.	Ratio of the power and effect.	Ratio of the velocity of the water and wheel.	Ratio of the load at the equilibrium, to the load at the maximum.	Experiments.
	In.		In.		lb. oz.	lb. oz.							
1	33	88	15·85	30·	13 10	10 9	275·	4358·	1411·	10:3·24	10:3·4	10:7·75	
2	30	86	15·0	30·	12 10	9 6	264·7	3970·	1266·	10:3·2	10:3·5	10:7·4	
3	27	82	13·7	28·	11 2	8 6	243·	3329·	1044·	10:3·15	10:3·4	10:7·5	
4	24	78	12·3	27·7	9 10	7 5	235·	2890·	901·4	10:3·12	10:3·55	10:7·53	At the 1st sole.
5	21	75	11·4	25·9	8 10	6 5	214·	2439·	735·7	10:3·02	10:3·45	10:7·32	
6	18	70	9·95	23·5	6 10	5 5	199·	1970·	561·8	10:2·85	10:3·36	10:8·02	
7	15	65	8·51	23·4	5 2	4 4	178·5	1524·	412·5	10:2·9	10:3·6	10:8·3	
8	12	60	7·29	22·	3 10	3 5	161·	1173·	328·	10:2·8	10:3·77	10:9·1	
9	9	52	5·47	19·	2 12	2 8	134·	733·	213·7	10:2·9	10:3·65	10:9·1	
10	6	42	3·55	16·	1 12	1 10	114·	404·7	117·	10:2·82	10:3·8	10:9·3	
11	24	84	14·2	30·75	13 10	10 14	342·	4890·	1505·	10:3·075	10:3·66	10:7·9	
12	21	81	13·5	29·	11 10	9 6	297·	4009·	1223·	10:3·01	10:3·62	10:8·05	
13	18	72	10·5	26·	9 10	8 7	285·	2993·	975·	10:3·25	10:3·6	10:8·7	At the 2d.
14	15	69	9·6	25·	7 10	6 11	277·	2659·	774·	10:2·92	10:3·62	10:9·	
15	12	63	8·0	25·	5 10	4 14	234·	1872·	549·	10:2·94	10:3·97	10:8·7	
16	9	56	6·37	23·	4 0	3 13	201·	1280·	390·	10:3·05	10:4·1	10:9·5	
17	6	46	4·25	21·	2 8	2 4	167·5	712·	212·	10:2·98	10:4·55	10:9·	
18	15	72	10·5	29·	11 10	9 6	357·	3748·	1210·	10:3·23	10:4·02	10:8·05	
19	12	66	8·75	26·75	8 10	7 6	330·	2887·	878·	10:3·05	10:4·05	10:8·1	The 3d.
20	9	58	6·8	24·5	5 8	5 0	255·	1734·	511·	10:3·01	10:4·22	10:9·1	
21	6	48	4·7	23·5	3 2	3 0	228·	1064·	317·	10:2·99	10:4·9	10:9·6	
22	12	68	9·3	27·	9 2	8 6	359·	3338·	1006·	10:3·02	10:3·97	10:9·17	
23	9	58	6·8	26·25	6 2	5 13	332·	2257·	686·	10:3·04	10:4·52	10:9·5	4th.
24	6	48	4·7	24·5	3 12	3 8	262·	1231·	385·	10:3·13	10:5·1	10:9·35	
25	9	60	7·29	27·3	6 12	6 6	355·	2588·	785·	10:3·03	10:4·55	10:9·45	5th.
26	6	50	5·03	24·6	4 6	4 1	307·	1544·	450·	10:2·92	10:4·9	10:9·3	
27	6	50	5·03	26·	4 15	4 9	360·	1811·	534	10:2·95	10:5·2	10:9·25	6th.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	

But it may be observed that several other columns of ratios might be deduced from the data therein furnished, and which would still further illustrate the action of this order of wheels. The last column has reference to the aperture at the sluice for the admission of the water to the wheel. The holes in the scale were placed diagonally, and to these a pin was fitted; so that when the pin was in the same hole, the opening for the water continued the same for all the experiments of that series.

From this table we find, on comparing the effect $p\,v$ produced at the maximum with the product $\frac{1}{2}$ W h, in which h is the virtual or effective head, that the coefficient of reduction m is very nearly 0·64; consequently, we shall have

$$\text{E or } p\,v = 0{\cdot}64 \times \tfrac{1}{2}\,\text{W}\,h = 0{\cdot}32\,\text{W}\,h.$$

The ratio of $p\,v$ to W h, we observe, varies from 0·28 to 0·32, giving a mean of 0·30. This led Mr. Smeaton to infer that one-third of the force produced on the floats by the current, may be realized in the larger wheels.

If we compare the effect realized with the entire power of the water expended, we find that the ratio increases from 0·16 in the first experiment, when the total head was 33 inches, to 0·25 in the last, when the entire head was reduced to 6 inches. From this it therefore appears, that the greatest effect which can be obtained from a given head of water, acting impulsively, is between a sixth and a fourth of the entire motive force expended; and in the case of large wheels, it is very doubtful whether even this last result can be obtained, although, as we have already seen, theory indicates as much as $\frac{1}{2}$ W H. or double.

The ratio of the velocity of the wheel to that of the current gradually augments from 0·34 to 0·52, giving a mean of 0·43. Mr. Smeaton, however, takes 0·40 as the mean; and it is worthy of remark that Bossut, in an analogous series of experiments, also adopted the same number. It, however, seems to us, from the nature of the case, that the proper velocity will approximate much more closely to the maximum limit, and will not deviate greatly from 0·50 of the mean velocity of the current, as indicated by theory. 0·45 will at least be, in general cases, a safe number to adopt in practice; that is, $v = 0{\cdot}45$ V.

Another result worthy of notice is the weight or "load at the equilibrium;" that is, the weight which is just sufficient to keep the wheel at rest against the force of the current. This, at an average, is little more than two-tenths greater than the load which the wheel was capable of carrying when yielding its maximum effect. According to theory it ought to be double, for, as already shown, the weight corresponding to $v = 0$ is $\dfrac{\text{W} \times \text{V}}{g}$, and that at the maximum is $\dfrac{\text{W} \times \text{V}}{2\,g}$.

The cases to which these observations apply are those in which the velocity of the wheel is adapted strictly to that of the current. But this is not always obtained, and accordingly the coefficient m being a function of v, fluctuates between extremes which it is impossible to comprehend in a general formula. However, when the velocity of the wheel does not fall below certain limits—from a third to two-thirds of that of the current—we may, without much chance of error, especially in excess, assume 0·60 as the coefficient, and accordingly we shall have as a general rule,

$$\text{E} = 0{\cdot}60\,\frac{\text{W}}{g}\,(\text{V} - v)\,v = \frac{1}{107}\,\text{W}\,(\text{V} - v)\,v = 1{\cdot}54\,\text{Q}\,(\text{V} - v)\,v.$$

The velocity V with which the water arrives upon the floats cannot always be easily assigned. It experiences certain losses between the sluice and the point of impulse, but it is not perhaps possible to give a general expression of their amount, even for an individual case, and much less for different forms and conditions of construction. Independent of any reducing influence, we have $\text{V} = \sqrt{2\,g\,h}$, in which h denotes the difference of level between the surface of the water in the lead and the centre of percussion of the floats, and which can readily be measured. But from Mr. Smeaton's observations on this point, it appears that the loss is sometimes as much as a fifth of this velocity; and he further remarked that the difference between the actual and calculated velocities diminished as the vertical opening of the sluice was augmented. In some instances, indeed, where the volume of water was very great, and the head small, he found that V hardly differed from $\sqrt{2\,g\,h}$. M. Poncelet also remarked the same circumstance—that the loss of velocity diminishes with the magnitude of the aperture through which the fluid issues. Even in the case of an opening of about $8\frac{1}{2}$ inches in height, and with a head of $4\frac{1}{2}$ feet, he had $\text{V} = 0{\cdot}99\,\sqrt{2\,g\,h}$. This, however, supposes the sluice to be constructed to the best advantage; and to make a slight allowance for untoward circumstances, we may take $\text{V} = 0{\cdot}95\,\sqrt{2\,g\,h} = 7{\cdot}6\,\sqrt{h}$. Substituting this value of V in the preceding result, we have

$$\text{E} = 1{\cdot}54\,\text{Q}\,(7{\cdot}6\,\sqrt{h} - v)\,v.$$

And, again, putting for v its equivalent $\frac{1}{2}\,\text{V} = 3{\cdot}8\,\sqrt{h}$, this expression is reduced to the following convenient form,

$$\text{E} = 22\tfrac{1}{4}\,\text{Q}\,h, \text{ or } \frac{1}{148}\,\text{Q}\,h,$$

when expressed in units of horse-power.

This is the case of the purely impulsive wheel; but in practice it is very rarely found that some slight amount of head cannot be reserved to act by its gravity. Under these circumstances an arc is formed concentrically with the wheel between the point at which the water strikes the wheel, and the lowest level terminating in the vertical plane passing through the axis. The clearance need not exceed ·4 inch, and may, if the arc be carefully constructed, be reduced to ·3 inch. To indicate the effect, let H, as before, be the whole height of fall; and let h be the portion employed in generating the required velocity. After that the water has struck the first float at the level $\text{H} - h$ it will afterwards descend by its weight through that height, producing an effect expressed by $\text{W}\,(\text{H} - h)$; and the effect of the impulse being as before $\dfrac{\text{W}}{g}(\text{W} - v)\,v$, we shall have as the sum of these partial actions,

$$W \left\{ (H - h) + \frac{1}{g} (V - v) v \right\}.$$

But we formerly found in discussing the impulsive action in the case of the overshot-wheel that

$$\frac{W}{g} (V - v) v = W (h - \mu h - h' - h''),$$

in which the three quantities μ, h', h'' have the significations then assigned. We may therefore make use of this expression as more definite. It is, however, in this case subject to two corrections which may be thus exhibited.

In the first place, when the whole volume of water has expended its impulsive effect upon the first float which it encounters, it immediately begins to descend by its pressure to the bottom of the arc; but let us observe what takes place in the spaces between the floats during the descent. The arc sustains a certain amount of the pressure of the fluid, and there is moreover a certain amount of clearance between it and the radial extremities of the floats. A portion of the fluid will therefore escape through this space without producing any effect, since its pressure is entirely exercised upon the superficies of the arc. This must, consequently, be subtracted from W in the expression W $(H - h)$. This loss cannot, indeed, be rigorously assigned, but may be pretty closely approximated by considering that the resistance experienced by this water against the face of the arc diminishes the velocity which gravity tends to give it, and that this diminution increases with its descent: also, that this velocity is further diminished by the continual entanglements to which the water is subjected by the varying conditions of the intervals between the floats, and which likewise become greater towards the bottom of the arc; and, finally, that the velocity is altered by the continual mingling of the descending laminæ, corresponding to the several spaces between the floats and the varying positions of the portions of fluid therein contained. We may therefore conceive, with all these retarding influences in action, that the velocity of the ineffectual portion will not differ greatly from that of the floats; accordingly, in this state of things if we denote by A the cross-section of the plate of water falling upon the wheel, and by a that corresponding to the intervals between the extremities of the floats and the arc, then will $W \frac{a}{A}$ be the portion of fluid lost as regards the effect of pressure; hence, by subtracting this from W, the expression of the effect given above, we shall have

$$W \left(1 - \frac{a}{A}\right) (H - h).$$

In the second place, the portion of the base of the wheel which dips in the water contained in the lower part of the course, loses there a part of its weight equal to the weight of water displaced. In consequence of this loss the equal distribution of the weight of the wheel about the axis of rotation no longer exists; and the wheel tends to turn in a direction contrary to that of the current. If we represent by p' the diminishing influence of this tendency, this will be a new resistance which the wheel has to overcome, and which ought, consequently, to be added to these other resistances of which the sum is p. We shall then have, taking m as the coefficient of reduction of the results of calculation to those of observation,

$$(p + p') v = m W \left\{ (H - h) \left(1 - \frac{a}{A}\right) + h + \mu h - h' - h'' \right\}.$$

In practice this formula may be considerably simplified. The quantities p' and $1 - \frac{a}{A}$, supposing the construction judiciously and carefully finished, will be very nearly proportional to the power of the wheel, that is, to W; they may, consequently, be comprised in the value of m. We have also before shown that the quantity $\mu h + h' + h''$ is always greater than $\frac{1}{3} h$, and differs little in ordinary cases from $\frac{2}{3} h$. Hence our formula may be reduced by these substitutions to the convenient form,

$$E = m W (H - \tfrac{2}{3} h).$$

In this the indefinite quantity is m, and, perhaps, the best authenticated experiments, by which its value may be assigned for the particular case assumed, are those of M. Morin, on a wheel constructed by Messrs. Aitken & Steel for the crystal works of Baccarat, in the Department of Meurthe, in France. The diameter of the wheel is 13 feet 3 inches; its width parallel to the axis 12 feet 9½ inches; the number of floats 32, of which the breadth in the direction of the radius is 1 foot 4 inches. The whole fall is 6 feet 9 inches, and the versed sine of the arc 6·04 feet. The water is thrown upon the wheel over the waste board of a sluice, of the same width as the wheel. The results varied with the thickness of the lamina of water admitted upon the wheel, as exhibited in the table on the following page. From this table then, it appears that $m = 0·772$; but as this is reputed to be a particularly well constructed wheel—considerably above the average—we may be generally safe in taking $m = 0·75$, by which our formula is reduced to

$$E = 0·75 W (H - \tfrac{2}{3} h).$$

From the same table it appears that the ratio of the effect to the whole power expended, is 0·717; this is a good result, and warrants us in taking, as the general expression of effect for a wheel of ordinary character under like circumstances, 0·65 W H.

The effect of curving the floats, as in M. Poncelet's wheel, is thus indicated: Supposing, in the first place, that the wheel is at rest, and that a film of fluid arrives horizontally with a velocity V upon the lower edge of the float, in continuing to advance it rises along the curve, and during its elevation the velocity which it possessed is gradually diminished, and becomes nothing when it has attained a height expressed by 0·0155 V^2. The velocity is not, however, lost; it is simply changed into gravity, in obedience to which the fluid immediately begins to descend upon the curved surface of the float, over which it ascended, and quits it with the same velocity V, which it possessed at the moment it arrived upon it. This velocity is acquired by falling from the height $0{\cdot}0155\ V^2$, and under the circumstances we have supposed to exist, its direction would be contrary to that first impressed upon the fluid. Let us now assume that the wheel turns with a velocity of v in a second at its periphery. When the filament of fluid, having the velocity V, shall have arrived at the float, it will then have a relative velocity

Velocity of the wheel in feet per second. v.	Thickness of lamina of water upon the waste-board of the sluice.	Ratio of effect to power expended W H $\frac{p\,v}{\text{W H}}$.	Ratio of effect to virtual head $H - \frac{3}{8}h$ $\frac{p\,v}{\text{W}\,(H-\frac{3}{8}h)}$.
	Feet.		
7·65	0·719	0·707	0·762
3·83	0·711	0·734	0·792
3·18	0·711	0·726	0·783
2·71	0·714	0·720	0·777
2·40	0·714	0·716	0·773
2·13	0·718	0·700	0·755
	Mean.	0·717	0·772

of $V - v$, and it will only be with this velocity that it will commence to ascend upon the curved surface of the float; it will therefore rise to a height of only $0{\cdot}0155\ (V - v)^2$, and after descending, will quit the lower edge of the float with the same velocity $V - v$. But this element will now have itself a velocity v in the contrary direction, for it partakes of the motion of the wheel; the absolute velocity with which it escapes will therefore be $V - (v + v)$. Consequently, if $v = \frac{1}{2}V$, the absolute velocity of escape will be $V - V = 0$, showing, that if the velocity of the wheel be half of that with which the water arrives, its absolute velocity in quitting the floats will be nothing. We have, therefore, the case of a motive current, which experiences neither shock nor loss of velocity at the moment of impulse upon the wheel, and which possesses none at the moment it quits the float; it has then expended all its movement upon the wheel, and communicated to it all its force. The two conditions, shown to be unattainable in the bucket and common impulsive wheels, is therefore theoretically attained with this arrangement, so that, if W be the weight of water, and h the height of fall due to the velocity V, we shall have as the expression of effect W h.

But although this may be nearly true for a simple film, it is not true for a volume or sheet of water of a certain thickness. Those molecules which strike the floats, making an angle more or less great with the element struck, lose both a portion of their velocity and force; and at the moment when the mass of particles quit the float upon which they have expended their action, their direction is not exactly opposite. Besides, as with all wheels which revolve in an arc, a part of the motive fluid escapes without yielding any useful effect. We may, therefore, conclude that the real effect is not W h, but m W h, in which m is some fraction less than 1.

A series of experiments was undertaken by M. Poncelet for the purpose of determining this fraction; that is, the ratio between the actual effect realized and the power expended. The annexed table contains the most important conclusions. The wheel, it may be observed, had a diameter of $11\frac{3}{4}$ feet; 30 floats of $12\frac{1}{2}$ inches depth in the direction of the radius, and 25 inches breadth between the shrouds. From these experiments and observations M. Poncelet concludes:

Rise of sluice in inches.	Ratios. $\frac{v}{V}$.	$\frac{p\,v}{\text{W}\,h}$.	$\frac{p\,v}{\text{W H}}$.
3·937	0·46	0·51	0·46
8·268	0·52	0·70	0·56
8·661	0·60	0·68	0·56
7·874	0·52	0·60	0·52
11·969	0·69	0·81	0·55
"	0·61	0·74	0·55
"	0·59	0·63	0·52

1. That the velocity of the wheel which gives the maximum of effect is 0·55 of the velocity of the current; but that it might be varied from 0·5 to 0·6 without any marked disadvantage.

2. That the dynamical effect is not under 0·75 W h for low falls with large volumes of water, and may be taken at 0·65 W h when the volume of water is small and the fall considerable.

3. That this same effect, compared with the entire force expended, namely, W H, may be taken at 0·60 in ordinary cases, and at 0·50 when the rise of the sluice is very small.

For those cases which ordinarily present themselves in practice, and supposing the wheels constructed with due care, and to be adjusted to velocities differing little from ·55 of the current, we may therefore take

$$E = 0{\cdot}75\ W\,h \quad\text{or}\quad E = 0{\cdot}60\ W\,H.$$

Comparing this result with that determined for impulsive wheels having radial floats, it appears that the effect is more than doubled. This conclusion, to which we arrive in both cases by experimental guidance, ought, of course, to decide which of the two forms of wheel ought to be employed in general cases. It is admitted that M. Poncelet's wheel involves a more precise acquaintance with the nature of the force employed than the common float-wheel; but nothing beyond the application of a few rules, which any millwright may readily comprehend and apply. These have in part been given in our description of Figs. 3810 to 3812. The extreme and interior circles of the shrouds being drawn such, that $o\,k = \frac{1}{4}$ the effective fall when not more than $4\frac{1}{2}$ feet, the circle $m\,n$ is described with a radius determined by the following considerations. From the point k at which the water is supposed to meet the exterior circumference of the wheel, draw the line $k\,p$ perpendicular to the direction of the fluid. It will form an angle of 24° to 28° with the radius. In that line take a point p equal to about a sixth of its length between the circles of the shrouding, within the inner circle, and through that point from the centre of the wheel describe the circle $m\,n$. Then will $p\,k$ or $p\,q$ be the radius of the curved float $k\,q$: and similarly all the radii of the other floats will terminate in that circle. Having determined the number of floats, and marked their extremities upon the external circle of the wheel, draw radii from these points to the axial centre, and upon the circle $m\,n$ set off the corresponding distances from these radii equal to $l\,p$, and the points thus found will be the centres of curvature of the floats. The distance between the floats will be about half that recommended when placed radially, and ought to be formed of sheet-iron both for convenience of making and subsequent economy of action.

The mode of constructing the arc at the base of the wheel has been explained in describing the figures referred to; it is further only necessary to observe that every care ought to be employed to absorb as little as possible of the velocity of the water previous to the moment of impulse, and to provide for its escape when it has expended its force upon the wheel.

It is also to be understood that this species of wheel, or, more correctly, the mode of supplying the water, will not be economical for falls of more than $4\frac{1}{2}$ feet; when the fall exceeds this limit, advantage ought to be taken of its weight as well as of its impulsive force. We conceive, however, that the form of wheel is itself well adapted to this double purpose; but the water, instead of issuing from the under edge of the sluice-plate, ought to be directed over it, as over a waste-board; and the height of the arc ought, at the same time, to be proportionally increased.

Wheels which move in an indefinite current of water, as a river, are usually of a heavier construction than those we have been considering; but differ only in that respect, and in the inclination of their floats, from the common impulsive wheel. It is usually found of advantage to make them of a diameter of 15 to 20 feet, with 12 to 16 floats, of which the best inclination appears from experiment to be 30°. Their best velocity—that at which the effect is a maximum—is a third of that of the current, and, under these conditions, it will be found that they yield an effect of about $\cdot 006\ W\ V^2$ of the water received upon the area of the floats—that is, about $\frac{2}{7}\ W\ h$ if $h = 0{\cdot}0155\ V^2$. This result may seem, at first sight, surprising, when it is remembered that the effect of the undershot-wheel working in a confined rectilineal course, does not yield more than $\frac{1}{3}\ W\ h$; but it is to be observed that in this last we include the whole volume of water acting; whereas, in the other, we take into account only the quantity received upon the floats, without reference to the large amount which escapes without producing any effect whatever, and which we cannot attempt to estimate.

This species of wheel is of very rare occurrence; yet there are numerous situations where it might be employed with good effect.

Horizontal Water Wheels. In horizontal water wheels, the water produces its effect by *impact*, by *pressure*, or by *reaction*, or by an union of these forces, but never directly by its weight. Impact wheels have plane or hollow pallets or floats on which the water acts more or less perpendicularly. The pressure wheels have curved buckets along which the water flows, and the reaction wheels have as their type a close pipe from which the water discharges more or less tangentially. Pressure wheels and reaction wheels are generally very similar to each other in construction; the essential difference in them being that in the former the tubes or conduits between two adjacent buckets are not filled by the water flowing through them, while in reaction wheels the section is quite filled.

Impact Wheels. To this class belong that variety of horizontal wheels usually called *tub wheels*. They consist of inclined pallets or floats on the inner or outer periphery of a drum, and the water is laid on by a short incline at such an angle that it strikes the float at right angles. The inclination of the floats is from 60 to 70° to the horizon. This wheel is extremely simple in its construction, and is found in all parts of the world. In the older saw mills it was almost invariably used for the running back of the carriage. The simplicity of its construction is its chief recommendation: it seldom exceeds in mechanical effect $33\frac{1}{3}$ per cent. of the water expended. The effect of impact wheels is increased by surrounding the buckets with a projecting border or frame, and by forming their surfaces like the bowls of spoons. If we give the buckets greater length, and form them to such a curve that the water leaves the wheel in nearly a horizontal direction, the water then not only impinges on the bucket, but exerts a pressure upon it, and the mechanical effect is proportionately increased. If the water be laid on without impact, the wheel becomes a pressure wheel solely. Among this class, though not strictly within the distinction made above between pressure and reaction wheels, may be included most of the wheels constructed on the principle of the smoke jack, the discharge being downwards; such wheels as are designated by the French as *roues en cuves*.

Reaction Wheels. As a solid body endowed with an accelerated motion, reacts in an opposite direction with a force equal to the moving force; so it is in the case of water when it issues from a vessel with an accelerated motion from the orifice. If a vessel filled with water be suspended by a cord, and a horizontal aperture be formed near the bottom, the vessel is forced backward, proportionately to the size of the aperture and the velocity of the issuing current. The simplest of all reaction wheels is what is usually termed Barker's Mill; a horizontal tube movable on an axis, is furnished with a cross tube extending at right angles across the bottom of the upright tube and connecting with it; this branch is closed at the ends, and orifices are formed near the extremities, one near each end of the tube, on opposite sides: if now the central tube be filled with water, the discharge through the orifice gives a rotary motion to the machine, and if the supply be maintained, a permanent motion results, available for practical purposes; by curving the arms, and properly proportioning the capacity of the tubes, the effect may be increased. Reaction wheels have from time to time been popular in this country from their cheapness, but till very recently they have not been introduced into the larger mills from the defects in their construction and rudeness of workmanship.

Among the first reaction wheels introduced here were those patented by Q. and A. Parker of Ohio, in 1829, which embodies many improvements which have since been claimed by foreign inventors.

The claims of the original patent of 1829 which expired 1850, were for the compound vertical percussion and reaction wheel, for saw-mills and other purposes, with two, four, six, or more wheels on one horizontal shaft. The concentric cylinder, with the manner of supporting them. The spouts which conduct the water into the wheels from the penstock, with their spiral terminations between the cylinders.

Second, the improvement in the reaction wheel, by making the buckets as thin at both ends as they can safely be made, and the rim no wider than sufficient to cover them. The inner concentric cylinder, the spout that directs the water into the wheel, and the spiral termination of the spout between cylinders.

Third. The rim and blocks; planks that form the apertures in the wheel, and the manner of forming the apertures. The conical covering on the blocks, with cylinder or box in which the shaft runs, and the hollow or box gate, in any form, either cylindrical, square, rectangular or irregular.

Another patent was issued to Messrs. Parker for improvements in water wheels, June 27, 1840, which expired June 27, 1854. The claim is, the placing of the said wheel, or wheels analogous thereto in their construction and mode of operation, within air or water-tight cases or boxes denominated drafts, substantially in the manner, and for the purpose set forth.

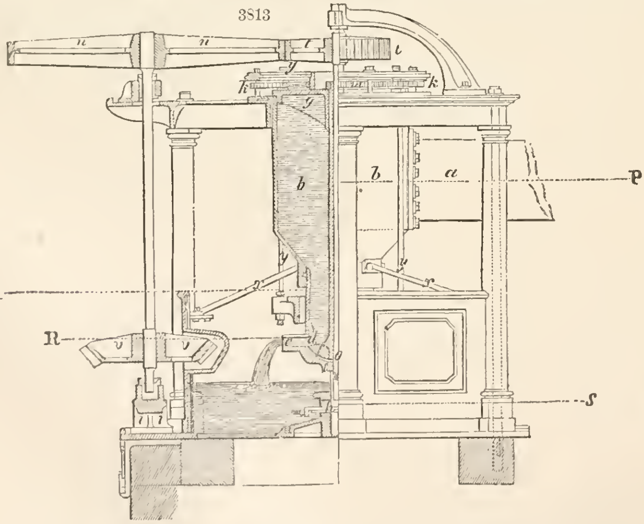
It will be observed that in the first patent, the wheels are placed vertically; this is a convenient form of application to saw-mills; the shaft of the wheel being used as the crank shaft, connected directly with the saw gate. For most other applications the horizontal wheel is more suitable, and is most economical in the use of water.

The varieties of reaction wheels at present in operation throughout the country are innumerable, differing in the form of floats, of guides, and of discharge. Among the most prominent are the Fourneyron and Jouval Turbine, and the Whitelaw reaction wheel.

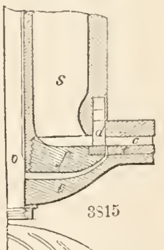
Fourneyron's Turbine. Fig. 3813 represents a general vertical section of the entire machine, showing its internal construction. Fig. 3814 is a half vertical section, on an enlarged scale, of the turbine and crown, showing the mode in which these are fixed to their respective centres, and exhibiting distinctly the manner in which the sluice-cylinder operates. Fig. 3815 is a quarter plan of the same parts as the above, with the sluice-cylinder and top plate of the turbine removed, in order to exhibit the form and relative disposition of the partition-plates of the turbine, and the direction-plates of the crown.

In 1834 M. Fourneyron received the prize of 6,000 francs offered by the Society for the Encouragement of the Arts at Paris, for the construction of the best horizontal wheel on the large scale. This was his first turbine erected at Pont, on the Oguon. In consequence of this decision the turbine excited great attention and discussion among the continental *savans;* and it must be remarked, that matters of practical utility are more subjects of interest among scientific men, especially in France, than elsewhere, where every thing of a technical character is considered to belong exclusively to the workshop.

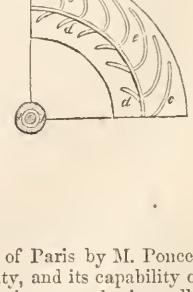
3813



3814



3815



In an elaborate report of this machine submitted to the Academy of Sciences of Paris by M. Poncelet, it is stated that the essential quality of the turbine consists in its high velocity, and its capability of working under water without much loss of effect. The expedient of bringing the water horizontally over all the interior circumference of the wheel, and of making it issue through the greater exterior circumference, allows also a large expenditure of power with a machine of very moderate diameter. Finally, it operates favorably under almost any fall, and at any velocity, without suffering any reduction of its effect from the hydrostatic pressure of the water, and which is stated to be a source of great inconvenience in wheels of this class.

The peculiar character of the machine is sufficiently explained in the description of the figures referred to, and which are supposed to represent one of the inventor's most successful applications of his principle; but, in order to bring the value and relation of the forces more closely into view, the action of the water may be here briefly indicated. Supposing the annular sluice to be so far let down as entirely to close the spaces *d*, which form the communication between the interior cistern *b* and the channels *c* of the revolving disk *e*, which is the *turbine*, properly so called, if the sluice between the reservoir and the supply-pipe *a* be opened, the water will precipitate itself into the cistern *b* and entirely fill it. The pressure on the interior of this cistern, as well as on the annular sluice at the orifices *d*, will be in proportion to the depth from the higher level of the water, and, therefore, for a unit of area of the surface acted upon, the pressure will be directly as the height H. If, then, the sluice be raised, the water rushes into the channels *c* with the velocity due to the head of pressure, and in the direction prescribed by the guide-curves, and impinging against the diaphragms of the channels *c* causes the disk *e* to revolve in a direction opposite to the direction of impulse, and finally escapes by the external extremities of the channels at the greater circumference of the turbine-disk.

The lower divisions of the sluice-ring, it may be remarked, are considerably increased in thickness, and rounded to avoid the contraction of the veins of fluid issuing into the channels *c*, and which would take place, if no provision were made for correcting the oblique motions impressed, when the water is projected through the apertures at the extremities of the guide-curves in a horizontal direction.

The construction of the machine depends upon the application of a few fundamental principles. Like all other hydraulic motors, its size ought to be proportioned to the effect which it is intended to produce—that is, in effect to the quantities W or Q and H. Thus the interior diameter D, one of the principal dimensions, is directly as the ratio of these two quantities; and as the turbine ought to be capable of expending the volume of water Q, arriving to it with the velocity V, the orifices must have an area, determined from the condition $Q = A\,V$, in which we denote by A the sum of the orifices of admission. On the water arriving in the same time upon all the whole interior circumference of the turbine, A will be equal to that surface, (after subtracting the area occupied by the thicknesses of the diaphragms), and, consequently, will be equal to $\pi D d$, in which d denotes the depth of the courses. The proportion fixed by M. Fourneyron, is $d = \frac{1}{7} D$; and, therefore, by making this substitution, we shall have

$$A = \tfrac{1}{7}\pi D^2 = 0{\cdot}45\, D^2.$$

$$\text{But } Q = A\,V \qquad = 0{\cdot}45\, D^2\, V.$$

$$\text{And } V = 6{\cdot}66\sqrt{H} \qquad \text{therefore } Q = 3\, D^2 \sqrt{H}$$

$$\text{From this we have the diameter } D = \sqrt{\frac{Q}{3\sqrt{H}}}.$$

This value of D ought, according to the views of the inventor, to be further affected by a coefficient, to allow for the entanglements which the fluid experiences in the cylinder and in entering the turbine, and for the effect of the obliquity with which the water is thrown by the diaphragms upon the moving circumference. This coefficient being introduced according to the practice of M. Fourneyron, we have

$$D = 1{\cdot}3\sqrt{\frac{Q}{\sqrt{H}}}.$$

It is here assumed that Q is the greatest volume of water which the machine is capable of discharging; but it is to be understood, that smaller quantities may be employed, and that the machine is capable of working with almost any less quantity without losing any remarkable amount of its proportional efficiency.

The diameter D may thus be taken as a function of the power of the machine, that is, of E, the dynamical effect in units of horse-power. Now, assuming the machine to realize 75 per cent. of the power which it expends, and that Q is the volume of water supplied in 1 minute, we have

$$E = \frac{Q\,H}{700}. \qquad \text{Hence, } Q = \frac{700\,E}{H}.$$

And, substituting this value of Q in the expression for D above given, it becomes

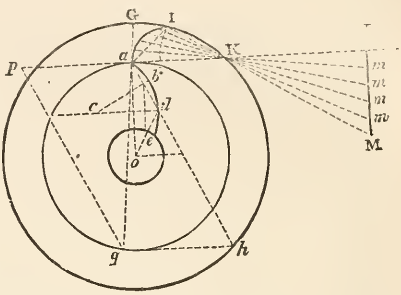
$$D = 1{\cdot}3\sqrt{\frac{700\,E}{H\sqrt{H}}} = 35\sqrt{\frac{E}{H\sqrt{H}}}.$$

The exterior diameter, in the practice of M. Fourneyron, varies from 1·2 D to 1·44 D. For turbines of large diameter, 6 feet and upwards, the first of these coefficients is taken, and for smaller diameters, the last.

The number of channels, of course, also varies as the diameter, but not proportionally. In the rules published by the inventor, 36 is given as a constant number with the same number of guide-curves on the interior disk; but in some of the machines of later construction these numbers are reduced. D'Aubuisson mentions turbines which he has examined having as few as 18 channels with from 16 to 9 guide-curves. Jariez gives the following rule for the number:—Divide the interior circumference by the height *d*, and the quotient number which results is the number of channels in the turbine. If this number be comprised between 18 and 24, its half represents the number of fixed guide-curves; if it be greater than 24, then a third of it will be the number of these fixed compartments. It is, however, easy to perceive that this rule must only be a distant approximation; but even an approximation is better than no rule where theory seems insufficient to determine the question. The number, according to Prof. Rühlman, depends principally upon the available quantity of water; they must be greater as more water is discharged in a given time. In any case, a large number of channels is an advantage, when they are formed of thin sheets, as thereby a greater number of filaments of water act directly upon their surfaces, and not indirectly through a mass of other water interposed.

We have above, following the rules laid down by M. Fourneyron, giving the depth of the channels as a seventh of the inside diameter of the turbine; but when the sluice is raised only a small part of this height, as it must be at times when the supply of water is scarce, the effect is not only absolutely less: it is relatively so on account of the water losing a portion of its force in diffusing itself over too much space. To avoid this, M. Fourneyron, in some of his last constructed machines, has divided the turbine, as before intimated, horizontally into two or three stages, by means of thin plates of sheet-iron placed in the channels.

3813.



The curvature of the water channels of the turbine and of the guide-curves in the fixed crown, may be determined by the following mode. Describe the interior circumference with radius $o\,a = D$, found as above directed; also the external or greatest circumference of the turbine with radius $o\,G = 1{\cdot}4\,D$. These circumferences being described, draw $a\,h$ making $\sin h\,a\,o = \frac{V}{2\,v}$. From the centre o draw $o\,d$, making with $a\,o$ an angle $d\,o\,a = d\,a\,o$; and from the point e, where $o\,d$ cuts the circle representing the tube or pipe through which the spindle of the turbine ascends, take $e\,b$ parallel to $o\,a$; from b draw $b\,e$ perpendicular to $a\,d$, and from d draw $d\,c$ perpendicular to $e\,b$; the point c where these two perpendiculars meet will be the centre of the fixed or guide-curve $e\,d\,b\,a$.

To find the curve of the vertical diaphragm a I of the turbine, draw $a\,p$ a tangent to the point a; and let $a\,p$ and $a\,h$ be proportional to the velocities v and V of the turbine and water: the diagonal $a\,q$ of the parallelogram constructed upon these two lines will be the direction of the first element of the curve. Prolong $a\,q$ to G, making a G perpendicular to a L, which is $p\,a$ prolonged indefinitely, cutting in K the exterior circumference of the turbine-disk. The point I at which the extremity of the curve terminates, is 2-5th of G K. The two extreme points being thus found, the curvature is determined as follows:—From the point K as a centre, and with a radius I K, describe the arc of a circle I i, and prolong indefinitely the right line I K. Measure the line $a\,i$, with any scale of equal parts, and divide the number expressing its length by 1 — cos M K L, and the quotient number of this division, taken in units of the same kind as $a\,i$, will express the length K M. From this point M draw M L perpendicular to K L; divide M L into any number of parts as m, m......as many as convenient, and the more the better; from each of these points draw a straight line passing through the point K, and with the length I M in the compasses mark off equal distances from the points m......on their prolongations beyond K, and the points thus marked off will be points in the curve a I, which may accordingly be traced through them.

*The attention of American engineers was directed to the improved reaction water-wheels in use in France and other countries in Europe, by several articles in the Journal of the Franklin Institute; and in the year 1843, there appeared in that journal, from the pen of Mr. Elwood Morris, an eminent engineer of Pennsylvania, a translation of a French work, entitled "Experiments on Water-Wheels having a Vertical Axis, called Turbines, by Arthur Morin, Captain of Artillery," etc. In the same journal, Mr. Morris also published an account of a series of experiments, by himself, on two turbines constructed from his own designs, and then operating in the neighborhood of Philadelphia. The experiments on one of these wheels, indicate a useful effect of seventy-five per cent. of the power expended, a result as good as that claimed for the practical effect of the best overshot-wheels.

BOYDEN'S TURBINE.* In the year 1844, Uriah A. Boyden, Esq., an eminent hydraulic engineer of Massachusetts, designed a turbine of about seventy-five horse-power, for the Picking House of the Appleton Company's cotton-mill, at Lowell, in Massachusetts, in which wheel, Mr. Boyden introduced several improvements of great value. The performance of the Appleton Company's turbine, was carefully ascertained by Mr. Boyden, and its effective power exclusive of that required to carry the wheel itself, a pair of bevel gears, and the horizontal shaft carrying the friction pulley of a Prony dynamometer, was found to be seventy-eight per cent. of the power expended. In the year 1846, Mr. Boyden superintended the construction of three turbines of about one hundred and ninety horse power each, for the same company. By the terms of the contract, Mr. Boyden's compensation depended upon the performance of the turbines, and it was stipulated that two of them should be tested. The mean maximum effective power of the two turbines tested, was eighty-eight per cent. of the power of the water expended.

The principal points in which one of them differs from the constructions of Fourneyron are as follows.

The wooden flume, conducting the water immediately to the turbine, is in the form of an inverted truncated cone, the water being introduced into the upper part of the cone, on one side of the axis of the cone (which coincides with the axis of the turbine) in such a manner, that the water, as it descends

* Lowell Hydraulic Experiments. J. B. Francis.

in the cone, has a gradually increasing velocity, and a spiral motion; the horizontal component of the spiral motion being in the direction of the motion of the wheel. This horizontal motion is derived from the necessary velocity with which the water enters the truncated cone; and the arrangement is such that, if perfectly proportioned, there would be no loss of power between the nearly still water in the principal penstock and the guides or leading curves near the wheel, except from the friction of the water against the walls of the passages.

The guides or leading curves are not perpendicular, but a little inclined backwards from the direction of the motion of the wheel, so that the water, descending with a spiral motion, meets only the edges of the guides. This leaning of the guides has also another valuable effect; when the regulating gate is raised only a small part of the height of the wheel, the guides do not completely fulfil their office of directing the water, the water entering the wheel more nearly in the direction of the radius, than when the gate is fully raised; by leaning the guides, it will be seen that the ends of the guides, near the wheel, are inclined, the bottom part standing further forward, and operating more efficiently in directing the water, when the gate is partially raised, than if the guides were perpendicular.

In Fourneyron's constructions, a garniture is attached to the regulating gate, and moves with it, for the purpose of diminishing the contraction; this, considered apart from the mechanical difficulties, is probably the best arrangement. In the Appleton Turbine, the garniture is attached to the guides, the gate (at least the lower part of it) being a simple thin cylinder. By this arrangement, the gate meets with much less obstruction to its motion than in the old arrangement, unless the parts are so loosely fitted as to be objectionable; and it is believed that the coefficient of effect, for a partial gate, is proportionally as good as under the old arrangement.

On the outside of the wheel is fitted an apparatus, named by Mr. Boyden the diffuser. The object of this extremely interesting invention, is to render useful a part of the power otherwise entirely lost, in consequence of the water leaving the wheel with considerable velocity. It consists, essentially, of two stationary rings or discs, placed concentrically with the wheel, having an interior diameter a very little larger than the exterior diameter of the wheel; and an exterior diameter equal to about twice that of the wheel; the height between the discs, at their exterior circumference, is a very little greater than that of the orifices in the exterior circumference of the wheel, and at the exterior circumference of the discs, the height between them is about twice as great as at the interior circumference; the form of the surfaces connecting the interior and exterior circumferences of the discs, is gently rounded, the first elements of the curves, near the interior circumferences, being nearly horizontal. There is, consequently, included between the two surfaces, an aperture gradually enlarging from the exterior circumference of the wheel, to the exterior surface of the diffuser. When the regulating gate is raised to its full height, the section, through which the water passes, will be increased by insensible degrees, in the proportion of one to four, and if the velocity is uniform in all parts of the diffuser at the same distance from the wheel, the velocity of the water will be diminished in the same proportion; or its velocity on leaving the diffuser, will be one-fourth of that at its entrance. By the doctrine of living forces, the power of the water in passing through the diffuser must, therefore, be diminished to one-sixteenth of the power at its entrance. It is essential to the proper action of the diffuser, that it should be entirely under water; and the power rendered useful by it, is expended in diminishing the pressure against the water issuing from the exterior orifices of the wheel; and the effect produced, is the same as if the available fall under which the turbine is acting, is increased a certain amount. The action of the diffuser depends upon similar principles to that of diverging conical tubes, which, when of certain proportions, it is well known, increase the discharge. Experiments on the same turbine, with and without a diffuser, show a gain in the coefficient of effect due to the latter, of about three per cent.

Suspending the wheel from the top of the vertical shaft, instead of running it on a step at the bottom. This had been previously attempted, but not with such success as to warrant its general adoption.

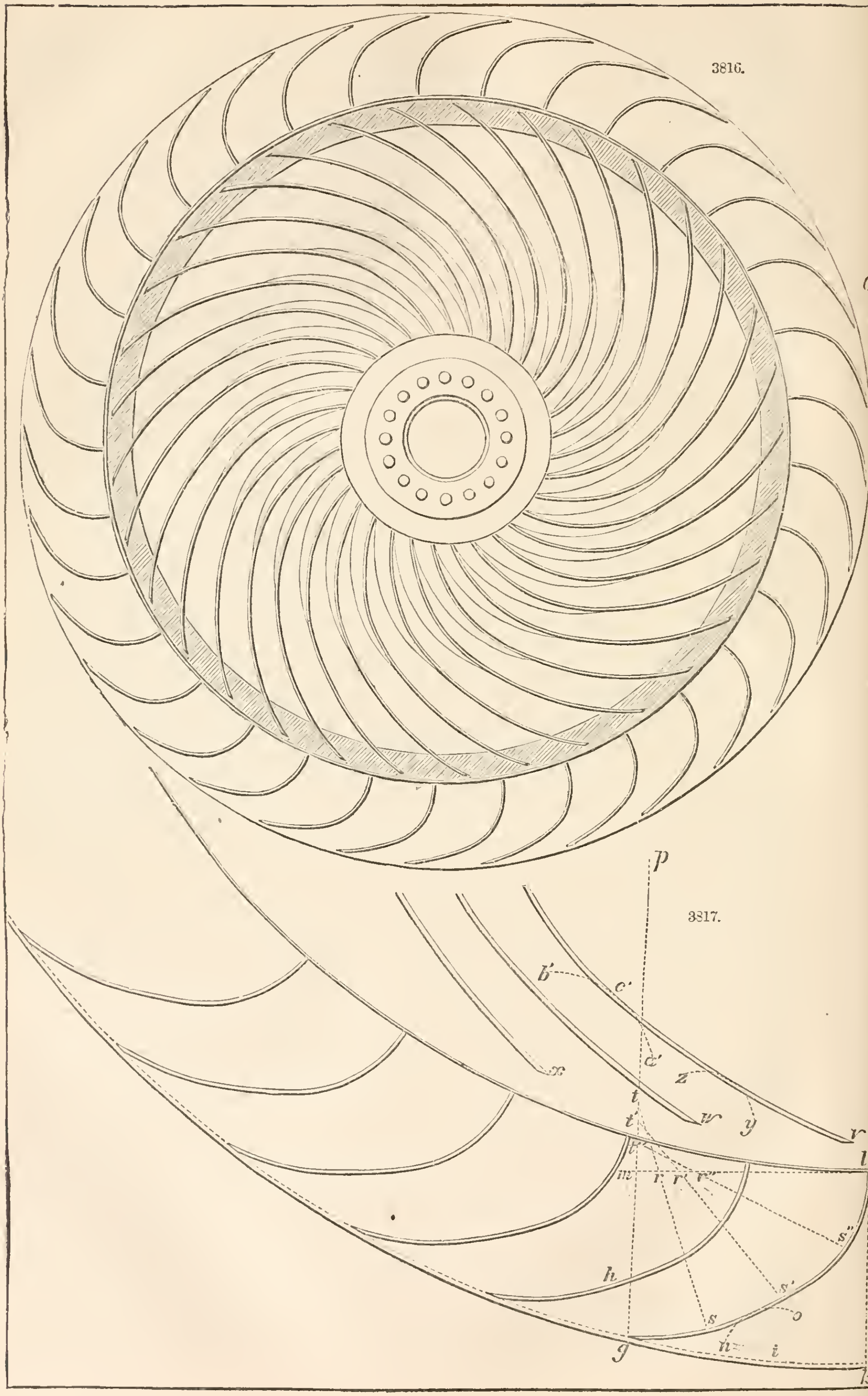
The manner adopted by Mr. Boyden is fully illustrated in the accompanying plates.

TURBINE WHEEL. Plate VIII. is a vertical section through the centre of a turbine wheel, and the axis of the supply pipe. Plate XI. is a plan of the turbine and wheelpit. Fig. 3816 is a plan of the whole wheel, the guides and garniture. This turbine was constructed for the Tremont Manufacturing Co. at Lowell, by Mr. James B Francis, and contains most of Mr. Boyden's improvements. Its expenditure of water, under 13 feet head and fall, is about 139 cubic feet per second, and its ratio of useful effect to the power expended, about 79 per cent.

B, the surface of the water in the wheelpit, represented at the lowest height at which the turbine is intended to operate. C, the masonry of the wheelpit. D, the floor of the wheelpit. To resist the great upward pressure which takes place when the wheelpit is kept dry by pumps, three cast-iron beams are placed across the pit, the ends extending about a foot under the walls on each side; on these are laid thick planks, which are firmly secured to the cast-iron beams by bolts. To protect the thick planking from being worn out by the constant action of the water, they are covered with a flooring of one inch boards. E, the wrought-iron supply pipe. This is constructed of plate iron three-eighths of an inch thick, riveted together. The supply pipe is furnished with the man hole and ventilating pipe G, and the leak box H, to catch the leakage of the head gate, whenever it is closed for repairs of the wheel.

The lower end of the supply pipe is formed by the cast-iron curbs I I I. The curbs are supported from the wheelpit floor by four columns, resting on the cast iron beam O; the beams N, rest immediately upon the columns, and the curb upon the beams, the latter projecting over the columns far enough for that purpose. The beams N also act as braces from the wheelpit wall to the curb, and are strongly bolted at each end.

K, the disc. This is of cast-iron, and is turned smooth on the upper surface, and also on its circumference. It is suspended from the upper curb I, by means of the disc pipes M M. The disc carries on its upper surface, thirty-three guides, (fig. 3816,) for the purpose of giving the water entering the wheel



3816.

3817.

proper directions. They are made of Russian plate iron, one-tenth of an inch in thickness, secured to the disc by tenons, riveted on the under side. The upper corners of the guides, near the wheel, are connected by the garniture L, which is intended to diminish the contraction of the streams entering the wheel, when the regulating gate is fully raised. The garniture is composed of thirty-three pieces of cast-iron, carefully fitted to fill the spaces between the guides; they are strongly riveted to the guides and to each other.

The upper flange of the disc pipe is furnished with adjusting screws, by which the weight is supported upon the upper curb. The escape of water between the upper curb and the upper flange of the disc pipe, is prevented by a band of leather on the outside, which is retained in its place by the wrought-iron ring P. The top of the disc pipe, just below the upper flange, has two wings, fitting into recesses in the top of the curb, to prevent the disc from rotating in the opposite direction to the wheel.

R, R, the regulating gate. Represented Plate XI. as fully raised. The gate is of cast-iron; the upper part of the cylinder is stiffened by a rib, to which are attached three brackets S S. To these brackets are attached wrought-iron rods, by which the gate is raised or lowered. To one of the rods is attached the rack V. The other two rods are attached by means of links, to the levers T T. The other ends of these levers carry geered arch heads, into which, and into the rack V, work three pinions, W, of equal pitch and size, fastened to the same shaft, so arranged that by the revolution of the pinion shaft, the gate is moved up or down, equally on all sides. The shaft on which the pinions are fastened, is driven by the worm wheel X; this is driven by the worm *a*, either by the governor Y, or the hand wheel Z. The shaft on which the worm *a* is fastened, is furnished with movable couplings, which, when the speed gate is at any intermediate points between its highest and lowest positions, are retained in place by spiral springs; in either of the extreme positions, the couplings are separated by means of a lever moved by pins in the rack V; by this means, both the regulator and hand wheel are prevented from moving the gate in one direction, when the gate has attained either extreme position. If, however, the regulator or hand wheel should be moved in the opposite direction, the couplings would catch, and the gate would be moved. The weight of the gate is counterbalanced by weights attached to the levers T T, and by the intervention of a lever to the rack V.

b b, the wheel consists of a central plate of cast-iron, and two crowns *c c*, of the same material to which the buckets are attached. The buckets are forty-four in number, made of Russian plate iron, $\frac{0}{64}$ of an inch in thickness, and are secured to the crowns by grooves cut in the crowns of the exact form of the buckets, and by tenons entered into the mortises in both crowns, and riveted on the opposite sides.

d d, the vertical shaft, of wrought-iron, runs upon a series of collars, resting upon corresponding projections in the suspension box *e'*. The part of the shaft on which the collars are placed, is made separate from the main shaft, and is pinned to it at *f*, by means of a socket in the top of the main shaft, which receives a corresponding part of the collar piece. The collars are made of cast steel; they are separately screwed on, and keyed to a wrought-iron spindle.

The suspension box is made in two parts, to admit of its being taken off and put on the shaft; it is lined with Babbit metal. It is found that bearings thus lined will carry from fifty to a hundred pounds to the square inch, with every appearance of durability.

f f', the upper and lower bearings, are of cast iron, lined with Babbit metal, adjustable horizontally by means of screws. The suspension box *e'*, rests upon the gimbal *g*. The gimbal itself is supported on the frame *h h* by adjusting screws, which give the means of raising and lowering the suspension box, and with it, the vertical shaft and wheel. The lower end of the shaft is fitted with a cast-steel pin *i*. This is retained in its place by the step, which is made in three parts, and lined with case-hardened wrought-iron.

The weight of the wheel, upright shaft, and bevel geer, is supported by means of the suspension box *e'* on the frame *k*, which rests upon the long beams *m*, reaching across the wheelpit, and supported at the ends by the masonry, and also at intermediate points by the braces *n n*.

Mr. Francis deduces the following rules for proportioning turbines:

The sum of the shortest distances between the buckets, should be equal to the diameter of the wheel.

The width of the crowns should be four times the shortest distance between the buckets.

The sum of the shortest distances between the curved guides, taken near the wheel, should be equal to the interior diameter of the wheel.

The number of buckets is, to a certain extent, arbitrary. As a guide in practice, to be controlled by particular circumstances, and limited to diameters of not less than two feet, the number of buckets should be three times the diameter in feet, plus thirty. The Tremont Turbine is $8\frac{1}{2}$ feet in diameter, and according to the proposed rule, should have fifty-five buckets instead of forty-four. The number of the guides is also to a certain extent arbitrary; the practice at Lowell has been, usually, to have from a half to three-fourths of the number of buckets.

As turbines are generally used, a velocity of the interior circumference of the wheel, of about fifty-six per cent. of that due to the fall acting upon the wheel, appears most suitable.

To lay out the curve of the buckets—

Referring to fig. 3817, the number of buckets N, having been determined by the preceding rules, set off the arc $g\,i = \frac{\pi D}{N}$. Let $w = g\,h$, the shortest distance between the buckets: t the thickness of the metal forming the buckets. Make the arc $g\,k = 5\,w$. Draw the radius $o\,k$, intersecting the interior circumference of the wheel at l; the point l will be the inner extremity of the bucket. Draw the directrix $l\,m$ tangent to the inner circumference of the wheel. Draw the arc $o\,n$, with the radius $w + t$, from i, as a centre; the other directrix $g\,p$, must be found by trial, the required conditions being, that when the line $m\,l$ is revolved round to the position $g\,t$, the point m being constantly on the directrix $g\,p$, and another point at the distance $m\,g = r\,s$, from the extremity of the line describing the bucket, being constantly on the directrix $m\,l$, the curve described shall just touch the arc $n\,o$. A convenient line for a first approximation, may be drawn by making the angle $O\,g\,p = 11°$. After determining the directrix according to the preceding method, if the angle $O\,g\,p$ should be greater than 12°, or less than 10°, the length of the arc $g\,k$ should be changed, to bring the angle within these limits.

The trace adopted for the corresponding guides is as follows:—The number n having been determined, divide the circle in which the extremities of the guides are found, into n equal parts, $v\,w$, $w\,x$, &c. Put ω' for the width between two adjoining guides, and t' for the thickness of the metal forming the guides. We have by rule $\omega' = \frac{d}{n}$. With w' as a centre, and the radius $\omega' + t'$, draw the arc $y\,z$; and with x as a centre, and the radius $2(\omega' + t')$, draw the arc $a'\,b'$. Through v draw the portion of a circle $v\,c'$ touching the arcs $y\,z$ and $a'\,b'$; this will be the curve for the essential part of the guide. The remainder of the guide $c'\,d'$, should be drawn tangent to the curve $c'\,v$, a convenient radius is one that would cause the curve $c'\,d'$, if continued, to pass through the centre O.

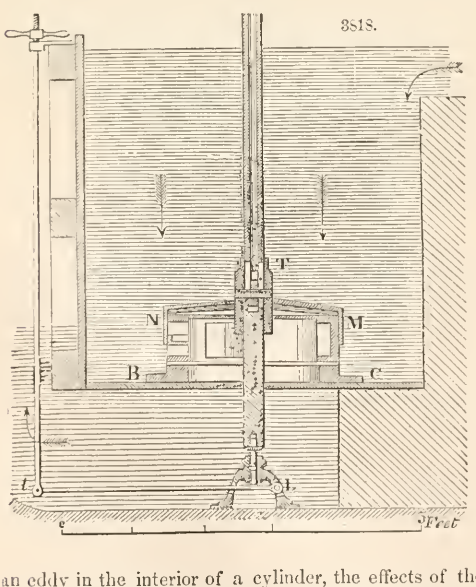
Passot's Turbine, *Figs.* 3818, 3819, 3820.

"Are composed of cylindrical vessels fixed to vertical arbors, and supplied at the circumference with orifices intended for the introduction or ejection of the water. The modification which M. Passot has introduced into the old reacting wheels, and which he claims as his invention, consists of having suppressed or got rid of the internal partitions, and reduced the old wheels to their only true essential elements—a motive cylinder to contain the motive fluid, with surfaces to receive its action, and corresponding orifices for discharge. The surfaces and the orifices are exactly included between two concentric circumferences; that is to say, that he carefully retrenches all other surface, or projection, capable of impressing the water with the angular movement of the wheel before having reached the parts destined to receive its action, as well as the orifices of discharge. "I form the new wheel," says M. Passot, "simply by placing either in the interior or exterior of a cylindrical drum, according as I want the pressure of the fluid to be exerted on the interior or exterior curved vanes in the arc of a circle, such as *a b c d*, Figs. 3819 and 3820; then I make orifices of discharge, by removing from these vanes and from the cylinder the part in form of a wedge, *a b d*, and the motion is effected by virtue of the pressure on the faces *c d*, *c′ d′*, *c″ d″*.

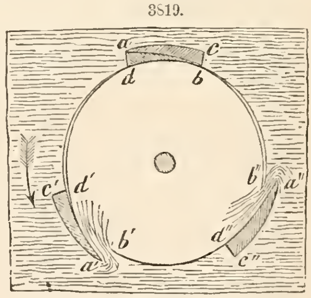
"While the machine is very simple, its properties are very remarkable. When the wheel turns without load or work, under a given difference of level or fall, its vanes take exactly the theoretical velocity due to the fall. It is no longer the same when in any manner the form of the new wheel is altered so as to approach those formerly known; all partitions, projections, and asperities which are either within or without two concentric circumferences, considerably diminish the theoretic velocity of rotation due to the fall, on account of the continual shock of these bodies in motion against the water in repose. Then it is not surprising if the useful effect of reacting wheels, when experimented upon, has never risen above 50 per cent.; that is to say, about the rate of breast-wheels of the usual varieties.

"The expenditure of water in Fig. 3820 with the internal action, is sensibly independent of the greater or less reaction of the wheel. In Fig. 3819, with external action, this cannot take place on account of the counter-pressure arising from the formation of an eddy in the interior; but this counter-pressure is, however, much less than might be supposed. I have demonstrated that when a fluid forms

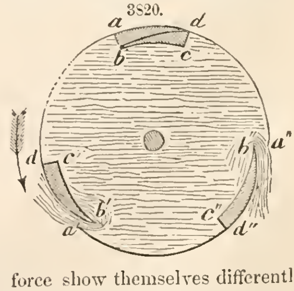
3818.



3819.



3820.



an eddy in the interior of a cylinder, the effects of the centrifugal force show themselves differently according to the different inclinations of the projections or orifices made on the circumference.

"In Fig. 3819 the orifices are disposed in the direction in which the centrifugal force can least influ ence the expenditure of water. Thus the coefficient of theoretical expenditure due to the work, during the experiments on the turbine which I constructed at Bourges, has been found very little different from that which agrees with the openings of ordinary sluices disposed so as to avoid contractions on three of the sides. The wheel which turned in work, with about half the velocity due to the fall, and the coefficient, was 0·70 to 0·79."

M. Poncelet, adopting an arrangement the reverse of that of M. Fourneyron, has proposed a system of turbines of the nature of the horizontal wheels used in the centre and south of France. The water enters by a spout placed on the outside, stretches the vanes, and is discharged by two openings made towards the centre. M. Cardelhac has constructed at Toulouse turbines on this plan; and Messrs. Mellet and Sarrus, of Lodeve, have exhibited one with the same arrangement. The principal part of their turbines consists in a case of particular form, provided with three openings, of which one is for the water to enter, and the two others to allow it to escape after its action on the wheel. In consequence of the spiral form of this casing, the water arrives on the wheel placed in the interior without any shock, and with a velocity due to half the height of the fall. Each of these veins or streams of water acts at the same distance from the axis, as if it were isolated and independent of the other. Its velocity is transformed into pressure by insensible degrees, and without any loss of power.

Whitelaw's reaction-wheel—Figs. 3814 to 3821.—The principle of this machine has been already explained, it therefore only remains in this place to indicate briefly the practical details and features of the construction. In this latter respect it is a much simpler machine than that above described; but still its efficiency depends in nearly an equal degree upon a correct appreciation of the principles involved in its *modus operandi*. The merely technical details have already been pretty fully pointed out in describing the figures enumerated above, but it may be necessary to indicate the rules employed in assimilating these to the conditions furnished by the particular circumstances of the individual case.

As in all other hydraulic machines, the data necessary to be assigned as the basis of any calculation of the size and angular velocity of the reaction-wheel, are the values of H and Q, that is, the height of fall under which it is intended to act, and the volume of water to be used. We have before seen that if the water in the arms of the machine experienced no increase of pressure from centrifugal force, the discharge assigned by theory is expressed by $S\sqrt{2gH}$; but in consequence of the centrifugal force produced by the rotation of the machine about its axis, this quantity will be increased to $S\sqrt{2gH + v^2\left(1 - \frac{r^2}{R^2}\right)}$. But we know from experiment that in consequence of frictional disturbance of the fluid in passing through the apparatus, the real quantity discharged is uniformly less than that assigned by theory, and that the reduction depends upon conditions which to some extent are within the control of the mechanician. On this subject we quote, with slight modification, from a paper read by Mr. W. M. Buchanan before the Philosophical Society of Glasgow (1846) on the theory of this species of machine. After stating the loss of head, observed in his experimental apparatus, by comparing the actual fall with the quantity of water actually discharged by a machine, of which the jet-orifices were accurately determined, the author assigns, as the sources of that reduction,

1. The pressure absorbed by the friction of the water in passing through the supply-pipe. This he regards as a known quantity, which is expressed in character and amount by

$$2f \cdot \frac{C}{A_{/}} L \cdot \frac{u^2}{2g},$$

in which C denotes the internal perimeter, $A_{/}$ the cross-sectional area, and L the length of the pipe; u, the velocity with which the water descends through it, and f an empirical coefficient $= \cdot 0035$. If, therefore, S denote the sum of the areas of the orifices, V the velocity of efflux, and D the diameter of the pipe, all in feet, this expression may be put under the form

$$8f \cdot \frac{L}{D} \cdot \frac{S^2}{A^2} \cdot \frac{V^2}{2g} = a\frac{V^2}{2g}.$$

2. The loss of head arising from the acceleration of the water in passing from the supply-pipe into the interior of the machine through the water-joint neck, formed by the mouth-piece and central opening, and which is commonly less in diameter than the supply-pipe, as shown in Fig. 3818. This he expresses by the formula

$$\frac{A_{//}^2}{A_{/}^2}\left(\frac{1}{m} - 1\right)^2 \frac{v^2}{2g} = \beta\frac{V^2}{2g},$$

in which $A_{//}$ is the area of the central opening, and v the velocity of the water passing through it: m a coefficient determined from experiment to be $= \cdot 9378$.

3. The small loss of head resulting from the resistance encountered by the water in traversing the arms of the machine, which he expresses by

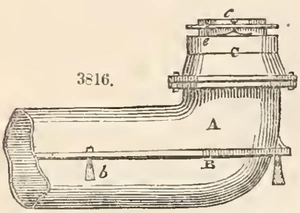
$$8f \cdot S^2 \frac{V^2}{2g}\int_0^L \frac{C_{/}}{A_{///}}\, dx = \gamma\frac{V^2}{2g},$$

in which $C_{/}$ and $A_{///}$ are respectively the transverse perimeter and area of the channels at a distance x from their origin.

4. The loss resulting from what is called the *contracted vein*. Although the volume of water discharged by any orifice under a given head pressure is invariably proportional to the area of that orifice and the square root of the head, the actual quantity is found to depend much upon the form of the orifice through which it issues. If the fluid be confined in a vessel of thin material, and the orifice be

simply a hole pierced in its side, the discharge in cubic feet per second will be nearly expressed by $\frac{5}{8} a \sqrt{2 g \mathrm{H}}$, the area of the orifice being a. If the jet from an orifice of this kind be closely observed, it will be perceived to converge through a short distance from its origin, forming, when the orifice is circular, a conoid, of which the area of the least section is $\frac{5}{8}$ths of the area of the orifice. If advantage

3816.



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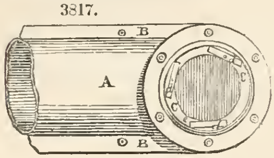

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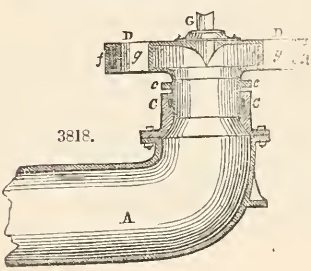

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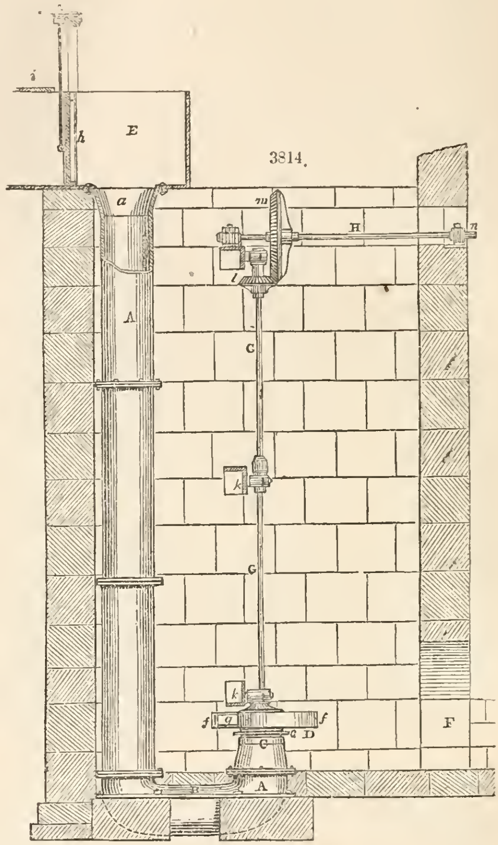

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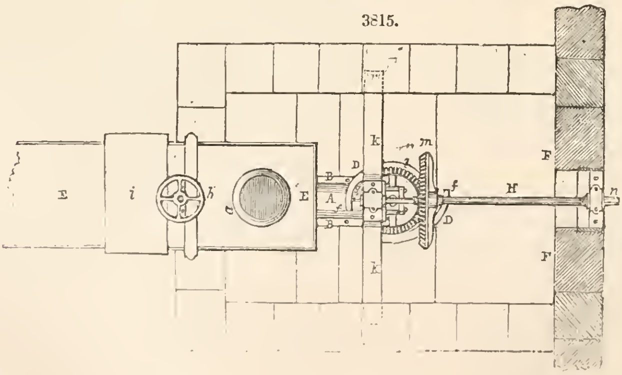
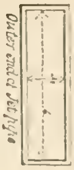


be taken of this circumstance to apply an ajutage to the orifice of the form assumed by the jet, the discharge will be found to approximate very closely to that assigned by the theoretical formula.

This difference of discharge in the two kinds of aperture is usually ascribed to the inclined directions which the molecules of the fluid assume previous to their exit, and which they tend to retain after passing the thin parietes of the simple orifice. For greater clearness, let us assume that the aperture is



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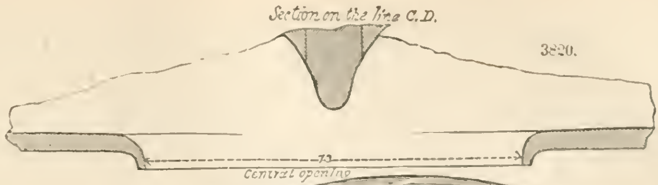

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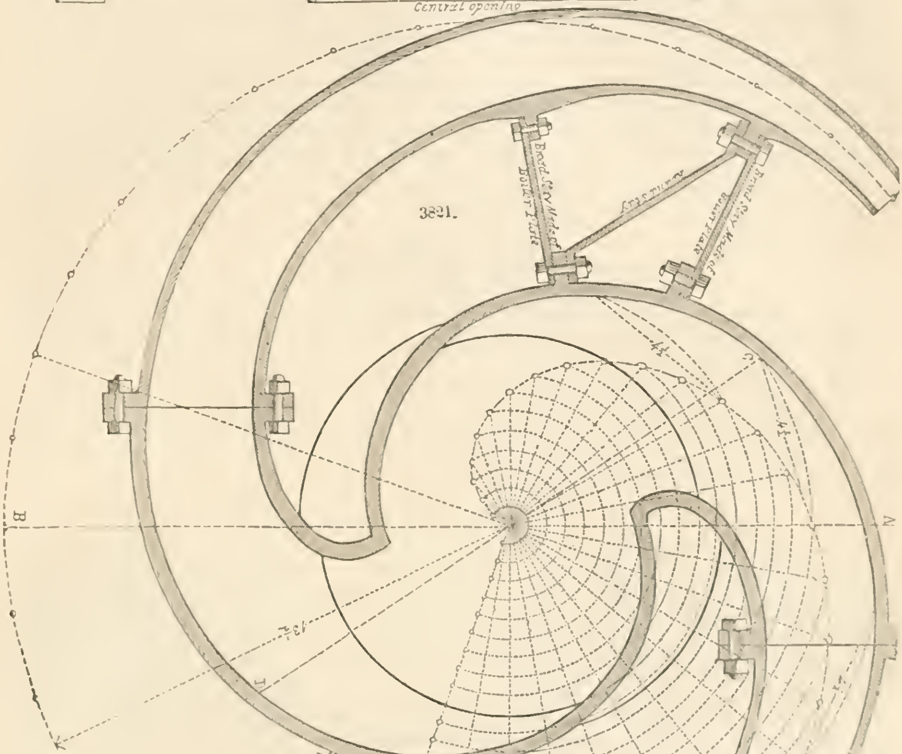
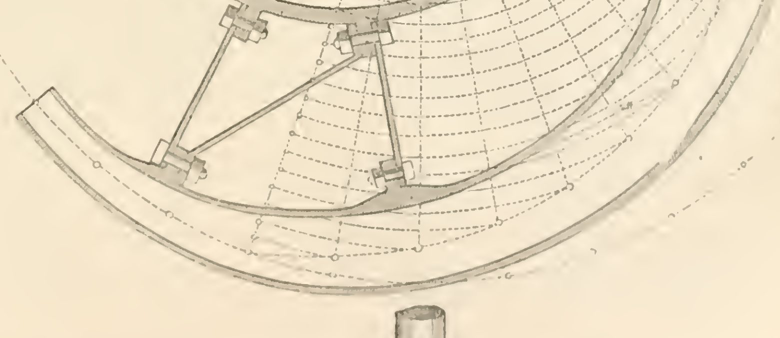


3821.


3822.

horizontal, circular, and of small area in comparison with the area of the containing vessel; under these conditions a large portion of the fluid will be put in motion, and will slowly approach the orifice during the efflux, in the form of an inverted cone, of which the orifice is the apex. The particles, as they come opposite to the orifice, are therefore impressed with motions converging to an axis; but these motions, in consequence of the mutual cohesion of the particles, must tend to a common velocity in that axis; and the length of the external conoid will express the time in which the oblique motions are converted into motions parallel to the axis of the jet. It is therefore only at the point of least section that the molecules of fluid have attained the effective velocity due to the head under which they issue; and it is therefore only in reference to that point that the hydraulic pressure of the jet is equal to a column of the fluid of double the *actual head*. By adopting an ajutage to the orifice of the shape indicated, the oblique motions of the particles are corrected in passing through it, and reduced to parallelism with the axis at the moment of efflux into the atmosphere. There still, however, remains to depreciate the discharge assigned by the formula $q = a\sqrt{2\,g\,H}$, the imperfections of wormanship in the construction, and the adhesion of the fluid to the perimeter of the ajutage, with possibly a slight atmospheric influence not yet defined. But assuming the ajutage to be made with all possible care, both as to form and finish, if we call the area of the orifice 1000, that of the contracted vein will be 975; and these numbers taken inversely will express the velocity of the jet at the two points measured by the discharge. The value of q for an orifice of this form will therefore be

$$q = \cdot 975\, a\sqrt{2\,g\,H},$$

showing a loss of head-pressure, as measured by the discharge, of

$$(1 - \cdot 975^2)\frac{U^2}{2\,g} = \cdot 049375\,H$$

when $U = \sqrt{2\,g\,H}$ the theoretical velocity due to the head H. And generally, if V be the actual velocity of efflux, and k the practical coefficient of discharge for any orifice, so that $U = \frac{V}{k}$, the head-pressure *not realized* in the measure of q, will be $\left(\frac{1}{k^2} - 1\right)\frac{V^2}{2\,g} = \delta\frac{V^2}{2\,g}$. And the pressure *not realized* in the measure of the reaction, will be expressed by

$$\text{Sin}\,\phi\left(\frac{1}{k^2} - 1\right)\frac{V^2}{2\,g} = \delta,\frac{V^2}{2\,g}$$

in which ϕ denotes the mean angle formed by the filaments of water of the jet with the axis.

But betwixt this the least contraction of the fluid vein, and that which takes place when the orifice is formed in a thin plate, we may evidently have a series of any number of terms expressing successive degrees of approximation of the ajutage to the theoretical form of least contraction. This is obvious, as regards the discharge from a fixed ajutage; and it is equally obvious, that if an ajutage be constructed to fulfil the conditions of least contraction when the vessel is at rest, it will no longer answer that condition when it moves in the line of the jet with any given velocity. If its motion be in the direction of the jet, its length will manifestly be virtually increased, and the contraction will approach to that of a jet issuing from a parallel pipe, the coefficient for which is ·8; and if the movement be in the contrary direction, the length of the ajutage will be in effect diminished, and the contraction will approach that from an orifice in a thin plate. This last is the actual case which falls to be considered in the reaction machine; the ajutages have a determinate velocity, in an opposite direction to that in which the fluid issues, and accordingly have their length virtually reduced. This must necessarily be provided against in the construction of the machine, and a length and form of the ajutages determined, which shall exactly correspond, at the given angular velocity of the machine, to the proper dimensions at which, if stationary, they would yield their maximum discharge. This is a problem which requires to be resolved for every machine.

It may, however, be stated as a general rule, that the contraction of the channels towards the orifices is half of that which would give the maximum discharge if the machine was at rest, and may therefore be taken at 7°.

If to these absorbing influences we add $\varepsilon\frac{V^2}{2\,g}$, comprehending the loss of atmospheric pressure due to the head H, and the effect of the cohesion of the water to the perimeter of the orifices, (not valued,) we shall have as the total calculated loss of head-pressure,

$$(\alpha + \beta + \gamma + \delta + \varepsilon)\frac{V^2}{2\,g},$$

and putting $\alpha + \beta + \gamma + \delta + \varepsilon = K$, we shall have as the velocity of efflux, taking the formula of p. 792,

$$\frac{1}{\sqrt{1+K}}\sqrt{2\,g\,H + v^2\left(1 - \frac{r^2}{R^2}\right)}.$$

In those machines constructed according to the proportions usually adopted by the makers, the quantity $\frac{1}{\sqrt{1+K}}$ does not differ sensibly in ordinary cases from 0·94; and it has been stated that $R = 2\cdot 5\,r$; if, therefore, we substitute these numbers in this formula, it is reduced to the following:

$$0\cdot 94\sqrt{2\,g\,H + \cdot 84\,v^2} = 7\cdot 5\sqrt{H + \frac{1}{77}v^2} = V$$

And multiplying this last expression by 60 times the area of the two orifices, (in feet,) we shall have, as the quantity of water discharged in a minute, $450\, S \sqrt{H + \frac{1}{77} v^2}$ cubic feet $= Q$.

We have already found as the measure of the effect of the machine $\frac{w}{g}(V - v)\, v$; if, therefore, in this expression we substitute the actual value of V found above, we shall have

$$E = \frac{w}{g}\left(7{\cdot}5 \sqrt{H + \frac{1}{77} v^2} - v\right) v.$$

But, in practice, the velocity v of the machine is taken equal to $8 \sqrt{H}$. If, therefore, we substitute this value in that found for E, and put for w its equivalent $62{\cdot}5\, q$, and for g its value 32·2, we shall have

$$E = 50\, q\, H \text{ very nearly.}$$

Or, taking the quantity of water expended in a minute, and expressing E in units of horse-power, we have

$$E = \frac{Q\, H}{660},$$

which is this rule: Multiply the quantity of water expended in a minute by the given height of fall, and divide the product by 660: the resulting quotient will express the effect in units of horse-power, (the horse-power being 33,000 lbs. raised through a height of 1 foot in a minute.)

This rule shows that the machine ought to yield, in practice, an effect of 79½ per cent. of the power expended, independently of the partial losses of head above enumerated, taking the fall from the middle of the depth of the machine to the surface of the water in the reservoir.

Height of fall. H.	Quantity of water expended in 1 minute. Q.	Weight on the arms of the friction brake. *p*.	Velocity in the circle of the brake. *v*.	Percentage of effect. $100 \frac{W H}{p v}$.	Diameter of model.
Feet.	Cubic feet.	Oz.	Feet.		
9·335	10·169	9	7910	75·212	7½ in. between centres of jets.
10·520	11·530	9¾	9510	76·664	
10·355	10·360	10¼	7820	74·933	
10·210	10·330	10	7820	74·433	
10·040	10·338	"	7900	76·333	
9·735	10·250	9¾	7820	76·630	
9·575	9·790	"	7330	76·460	
9·390	9·305	"	6690	74·868	
10·335	11·090	"	8960	76·440	
10·165	11·010	"	8840	77·236	
9·830	10·350	"	8030	77·173	
9·680	10·080	"	8420	77·887	
10·010	10·740	"	8580	78·040	
10·700	13·69	20½	5340	74·945	12 in. between centres of jets.
10·545	13·44	"	5240	76·015	
10·415	13·05	"	5040	76·237	
10·250	12·79	"	4900	76·845	
10·130	12·73	"	4870	77·644	
9·980	12·48	"	4630	76·425	
9·820	12·44	"	4500	75·745	
9·660	11·92	"	4280	76·420	
9·840	12·33	20¼	4600	77·000	
9·700	12·45	19¾	4750	77·910	
9·950	12·40	20½	4700	78·320	
10·270	12·68	21	4740	76·660	
10·160	12·47	22	4540	76·800	
	Lbs.				
8·05	562·32	14	3762·0	72·69	1·3 feet between centres of jets.
"	560·33	14½	3685·4	74·03	
"	558·75	15	3647·3	75·84	
"	553·61	15½	3488·5	76·01	
"	548·36	16	3380·4	76·56	
"	530·00	16½	3202·5	77·39	
"	514·25	17	2973·7	76·31	

The preceding table of experiments, upon three model machines, will show that this high percentage of effect is attainable. In the experiments with the first models, the fall was varible, and the proper velocity of the machine was, therefore, in no case strictly attained. The correct velocity was not attained in the third set of experiments, although the fall was constant, in consequence of the successive variations of load being too great. The maximum of effect is therefore not obtained in any of the results given, but some of the results approach it very closely.

The mode of performing the experiments was nearly the same throughout. The load was applied upon the equal arms of a friction brake of 1·59155 feet radius, (as nearly as could be measured,) so that its circle was exactly 10 feet. The revolutions of the machine were ascertained by a counter worked by a screw cut on its vertical spindle; and the water discharged was received into a cistern, of which the dimensions were accurately determined. The circle of the arms of the brake at the points where the weight was attached being 10 feet, the numbers in the column stating the velocity in that circle being divided by 10, the quotient will, of course, show the number of revolutions made by the machine in the unit of time, 1 minute.

The constructive rules, published by Mr. Whitelaw in the Artizan for Nov. 1845, are as follows, the height of fall and the quantity of water furnished in a minute being known:

A horse-power being taken at 33,000 lbs. raised one foot in a minute, this will be represented by 43,421 lbs. of water per minute, with a fall of one foot, supposing the machine to realize only 76 per cent. of the power expended; and the weight of a cubic foot of water being taken at 62,321 lbs., the equivalent of 43,421 lbs. will be 696·73 cubic feet. Taking Q and H as before, the quantity of water furnished in a minute and height through which it descends, we have as the value of E in units of horse-power,

$$E = \frac{Q\,H}{696{\cdot}73}.$$

From this the dimensions of the principal parts and the velocity of the machine are determined, as stated in the following expressions—it being understood that the machine has *two*, and only *two* jet orifices, and these so formed as not to cause the issuing jets to contract more than in the proportion of 97 to 100 after the fluid has left the orifices.

Width of each discharging orifice $= \sqrt{\dfrac{135\,E}{1000\,H\sqrt{H}}} = w_{,}$

Width of each arm of machine $= 4\,w_{,} = w_{,,}$

Diameter of the machine $= 50\,w_{,} = D_{,}$

Diameter of central opening $= 10\,w_{,} = D_{,,}$

Number of revolutions in a minute $\dfrac{149{\cdot}4338\sqrt{H}}{D_{,}}$

All these rules, except the last, may be departed from with impunity; but it is impossible to enumerate the circumstances and conditions under which modifications may be safely introduced, and where they would be prejudicial. These can only be appreciated by practice and a close investigation of the action of the machine. The rules are, however, safe within a wide range of fall—in fact, for all ordinary cases.

Comparison of the different species of wheels.—From what we have seen of the different conditions necessary to produce the maximum effect, it is evident that we ought not to be indifferent to the kind of wheel to be adopted in any particular case. The wheel ought especially to be adapted as far as possible, not only to the height of fall and quantity of water to be employed, but also to the kind of machinery which it is intended to propel. If the motion required be slow, and especially if it be besides irregular, a vertical wheel, of large diameter and considerable weight, will in general be the most satisfactory. On the contrary, where a high velocity is required, a horizontal wheel will be the most economical. The undershot-wheel is only commendable in cases where no other is applicable, on account of the lowness of the fall and large supply of water. It has the advantage, however, of being constructed at comparatively small cost, and if the run of the water be considerable, its velocity will be proportionally high in order that it may yield its maximum effect. Its great inconvenience is the smallness of that effect, which is in part remedied by employing the arrangement recommended by M. Poncelet now extensively adopted on the continent. This may be made to yield an effect of 50 to 60 per cent. of that of the water, when the head of water does not exceed 4½ feet. It also takes comparatively a high velocity, and it is to be kept in mind that the higher the velocity of any wheel of this species, the less will be its breadth, size of sluice, arc, and other parts influenced by the volume of water. It will, moreover, continue to work in backwater until the levels before and behind approach equality, and is therefore particularly fitted for level districts subject to inundations. It is, however, liable to this inconvenience, that its velocity cannot deviate sensibly from that at which it yields its maximum effect without losing greatly in power.

From falls from 4 to 7 feet, the breast-wheel with radial floats inclosed in an arc may be employed with advantage. If well constructed, and the arc be accurately fitted, to prevent waste of water, this species of wheel is capable of yielding from 60 to 70 per cent. of the power of the water expended. It may besides deviate very considerably from the correct velocity without losing much in effect; but it is to be observed that this velocity ought never to be very high. This species of wheel is therefore particularly applicable in cases where the ultimate velocity of the machinery impelled is low; but it lies under the disadvantage that, on account of the slowness of its motion, its breadth must be great, and all its constructive details conformably large and heavy. It is, besides, not well suited for situations subject to backwater, which very speedily brings it to rest. The bucket-wheel is applicable for higher falls and smaller supplies of water. It has all the advantages of the breast-wheel, with some of its defects. It may have a velocity varying from 3 feet a second to 7 feet; and adopting this higher speed, and allowing the buckets to be half filled with water, its expense will be greatly lessened

TABLE OF THE PROPORTIONS OF WATER-WHEELS CONSTRUCTED BY MR. WILLIAM FAIRBAIRN, OF MANCHESTER.

	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Diameter of Water-wheel	65 0	36 0	28 0	20 0	18 0	18 0	18 0	18 0	16 0	16 0	16 0	16 0	16 0	15 6	15 0
Breadth within the Buckets	6 0	16 7	13 0	17 0	21 0	20 0	18 0	12 0	21 0	20 0	18 0	16 0	14 9½	17 6	6 0
Depth of the Buckets	1 0	1 4	1 10	1 8	1 8	1 6	1 10	1 5	2 0	1 9	1 8	2 0	1 9	1 8	10
Revolutions of Wheel per minute	......	1·95	......	......	4·78	......	6·15	......	......	7·8	......	......	......	......	......
Speed of Periphery per second	......	3 7	......	3·82	4 6	......	5 8	......	......	6 5	5 6	......	6·3	5·51	......
Fall of Water	......	33 2	26 6	16 6	13 3	16 0	10 0	16 0	9 0	7 10	9 6	......	8 0	8 0	14 6
Cubic feet of Water taken per second	......	......	......	46	......	36	......	20	116	......	45	......	......	......	8
Diameter of Internal Driving Segment	63 3	33 8	......	18 0	16 1	......	14 0¾	......	14 0¾	15 4¼	14 0	14 0	14 0¾	......	......
Pitch of Teeth of do.	3¼	3	......	3¼	3	......	3	......	......	3	3	3	3	.. .	......
Breadth of Teeth	10	1 2	......	1 0	1 2	......	1 0	......	......	8	1 0	1 0	9	......	......
Estimated Horse-power	......	......	......	60	......	52	......	30	70	......	......	......	......	......	12
		Tons cwt. qr.			Tons cwt. qr.				Tons cwt. qr.						
Actual Weight of Cast-iron	......	32 7 0¾	Men's time in the workshops occupied by this wheel, 185 weeks, and for erecting at the mill, 65. Total 250 weeks.		26 14 3¾	Men's time in the workshops, 123 weeks, and in erecting at the mill, 46 weeks. Total, 169 weeks.			23 15 1⅓	Men's time in the workshops, 102 weeks, erecting at the mill, 36 weeks. Total, 138 weeks.			Reckoned as one man's time.		
Do. Wrought iron	......	15 8 3¾			11 17 3⅓				8 15 1¾						
Do. Brass	......	2 2¾			1 3¾				1 2						
Total Weight of Wheel and Cast-iron Cistern	......	47 18 3¼			38 14 2¾				32 12 1¼						

NOTE.—Mr. Fairbairn's maximum velocity of the periphery of the wheel is about 7 feet per second for a fall of 5 or 6 feet, and his minimum velocity from 2½ to 3 feet for a fall of 40 to 45 feet.

When the fall is high, 18 feet and upwards, it is not common to provide any arc to economize the water at the lower part of the revolution; and when the buckets are properly formed, an arc is not greatly wanted. But in general cases the buckets are formed without much attention seemingly to the functions which they are intended to perform, and, accordingly, a large waste of power is incurred which an arc would go far to prevent.

The inconvenience of the bucket-wheel is the low rate of its maximum speed where high working velocities are required. This occasions the multiplication of intermediate geering with all its concomitant evils. It is applicable, we have said, to high falls; but this has its limits. To obtain the full value of the water, the diameter must increase as the fall, and the dimensions and weight assume corresponding proportions. The construction, accordingly, becomes expensive in a high degree.

The preceding table of the proportions of wheels of this class, constructed by Mr. William Fairbairn, of Manchester, will be useful.

When the height of fall exceeds that for which it would be judicious to attempt to construct a bucket-wheel, it is then necessary to have recourse to one or other of the horizontal wheels described—namely, the turbine of M. Fourneyron, or the reaction-wheel of Mr. Whitelaw. The first of these may be made to yield an effect of about 50 per cent. of value of the water even on very low falls, and when immersed in tail-water; and about 70 per cent. on higher falls. The latter has also been made for situations in which it was intended to work occasionally in backwater, and with very considerable success; and, for high falls, we have seen that it is capable of yielding an effect at least equal to the bucket-wheel. It has advantage of the turbine in being less expensive, much more simple, and, we believe, is essentially more effective, on account of there being less loss of *vis viva* of the fluid in passing through the machine. Both have the advantage of being applicable to falls of any height, and of moving at velocities differing widely from that at which they yield their maximum, without much loss of effect. On low falls they have, what is generally reckoned, an advantage; they give immediately a comparatively high velocity which, in the case of cotton factories and the like, allows much heavy geering to be dispensed with. They have also a further very marked advantage in the little space which they occupy Several reaction-wheels, of 50 horse-power and upwards, might be referred to, placed in situations where, it may be said, they literally occupy no room, being situated in a small pit under the floors of the factories to which they furnish the motive power. In cases where the fall is very high—and both the turbine and reaction-wheel have been applied to falls which could not have been employed on wheels of the common kind—the high speed becomes an inconvenience, causing the use of intermediate geering for the purpose of reducing it. This can be remedied, to a certain extent, by increasing the diameter of the machine; but, when it is desired to take advantage of falls of 100 feet and upwards, perhaps some little inconvenience may be submitted to without reluctance.

There remains to be exhibited the turbine of Jonval, now being introduced in this country extensively.

Jonval's Turbine, as built by E. Geyelin, Hydraulic Engineer, Philadelphia.—The Jonval turbine was invented and patented in France a few years since, by a French gentleman whose name it bears.

The first turbine of this species, made by Messrs. André Koechlin & Co., was erected and put in operation in a large paper mill at Pont d'Aspach, in the vicinity of Mulhouse, upon which a committee of the Société Industrielle de Mulhouse experimented, and reported the following tables of the results. The experiments were made with the friction brake of Prony.

TABLE *of experiments with the Friction Brake, made on the Turbine of Pont d'Aspach, and reported by* Mr. AMEDÉ RIEDER, *Member of the Committee of the Industrial Society of Mulhouse.*

	Number of the Experiments.	Depth of the discharge of water, through an overflow of 3·200 m. wide.	Weight of water in kilogrammes expended per second.	Height of the fall in metres.	Theoretic power of the Motor. Kilog. lifted 1 metre high in one second.	Theoretic power of the Motor. Numb'r of horses of 75 kilog.	Weight on the friction brake in kilogrammes.	Number of revolutions of the Turbine.	Number of revolutions of the shaft when the brake was applied.	Velocity which the point of suspension of the resistance took in one second.	Effective power of the Motor. Kilog. lifted 1 metre high in one second.	Effective power of the Motor. Numb'r of horses of 75 kilog.	Percentage of the Motor.
				m.									
Small Turbine.	1	0·187	439	2·87	1·259	16·72	70·00	76·00	38·00	12·229	856	9·24	56
	2	0·190	447	2·87	1·282	17·10	65·00	96·00	48·00	15·448	1004	14·72	86
	3	0·195	463	2·90	1·351	18·03	57·00	124·00	62·00	19·94	1136	15·15	84
	4	0·195	463	2·82	1·305	17·47	47·00	134·00	67·00	21·56	1013	13·50	77
	5	0·195	463	2·71	1·254	16·73	37·00	164·00	82·00	26·39	976	13·02	77
	6	0·198	473	2·95	1·399	18·65	35·00	178·00	89·00	28·64	1002	13·36	72
Large Turbine.	1	0·239	639	2·78	1·776	23·68	89·80	84·00	42·00	13·51	1213	16·17	68
	2	0·243	654	2·78	1·818	24·24	67·25	124·00	62·00	19·94	1341	17·85	73
	3	0·243	654	2·78	1·818	24·24	65·00	128·00	64·00	20·59	1338	17·85	73
	4	0·230	641	2·78	1·782	23·76	67·25	128·00	64·00	20·59	1385	18·17	77
	5	0·225	581	2·78	1·618	21·57	52·00	134·00	67·00	21·56	1421	14·95	69
	6												
	7	0·245	669	2·78	1·859	24 78	60·00	142·00	71·00	22·85	1371	18·28	73
	8	0·245	669	2·78	1·859	24·78	57·25	144·00	72·00	23·15	1326	17·68	71
	9	0·248	678	2·78	1·884	25·13	50·00	164·00	82·00	26·39	1319	17·59	70

General Observations.—The metre is 3 feet 3 and 1-8 inches.

It will be observed here, that only a very strong change in the speed will alter the percentage of the wheel. The large wheel was in bad condition, as the guide-wheel rested on the turbine and created friction.

TABLE OF EXPERIMENTS, *made by* Mr. Theodore Bippert, *on the Turbines of* Messrs. Geigy, *of Steinen, Duchy of Baden. (These Turbines were improved in the curves of the wheels.)*

	Number of Experiments.	Depth of discharge on the overflow.	Theoretical velocity corresponding to the discharge of overflow.	Width of the overflow.	Quantity of water discharged per second.	Height of the fall.	Number of horse-power.	Circumference of the friction-brake.	Number of revolutions per minute.	Circumferential velocity of the brake per second.	Weight lifted by the brake.	Number of horse-power indicated by the brake.	Percentage of the Turbine.	General Remarks.
		H.	V.	L.	$M = V\,H\,G \times 0{\cdot}40$	F.	$\frac{M\,F}{750}$	M. $C = 16{\cdot}026$	N.	$V' = \frac{C \times P}{60}$	P.	$9 = \frac{V' \times P}{75}$	Q.	
		m.	m.	m.	litres.			m.			k.			
Small Turbine.	1	0·1780	1·870	4.09	514	1·64	11·90	16·026	73	19·49	36·5	9·50	0·80	The numbers 5 and 6, experiments on the large Turbine, show that the power can be reduced to one-fifth without greatly diminishing the percentage.
	2	0·1781	1·875	"	545	1·64	11·90	"	75	20·05	36·0	9·60	0·807	
	3	0·1782	1·875	"	546	1·64	12·08	"	80	21·36	35·0	9·97	0·825	
	4	0·1800	1·880	"	553	1·67	12·34	"	80	21·36	39·0	11·11	0·90	
		m.	m.	m.	litres.			m.						
Large Turbine.	1	0·180	1·880	4·09	553	1·64	12·10	16·026	83	22·17	35·	10.34	0·855	The coefficient of contraction used here is 0·40, given by Mr. Poncelet, on overflows discharging in the open air.
	2	0·180	1·880	"	553	1·66	12·25	"	96	22·97	35·	10·72	0·83	
	3	0·180	1·880	"	553	1·69	12·47	"	93	24·84	31·	10·26	0·82	
	4	0·180	1·880	"	553	1·69	12·47	"	85	25·38	30·	10·15	0·815	
	5	0·080	1·260	"	165	1·78	3·81	"	70	21·36	9·	2·56	0·67	
	6	0·075	1·215	"	119	1·785	3·55	"	84	19·75	9·5	2·49	0·70	

M. Amedé Rieder, in his report on Jonval's turbine, enumerates the following as its advantages:

1st. Its superior mechanical construction and simplicity.

2d. The great amount of power obtained from the quantity of water used.

3d. The regularity of its motion, and the facility of access to it.

4th. The great practical advantage of its being placed at the top of the fall.

Experiments have been made on a Jonval turbine at the powder-works of Messrs. E. J. Dupont, by Professor Cresson, and Messrs. Alfred Dupont, Alexis Dupont, S. V. Merrick, G. Harding, and E. Geyelin, members of the Franklin Institute. The following is the report, published in the Journal of the Institute, vol. xx., No. 3, 1850.

The Koechlin turbine.—The hydraulic motor known by this title has just been introduced in this vicinity by Mr. E. Geyelin, at the powder-works of the Messrs. Dupont, near Wilmington, Delaware, and at his request a trial was recently made by certain members of the Institute, to determine the practical coefficient of the wheel.

The turbine experimented upon is intended to produce 7 horse-power under a fall of 10 feet, and to drive the machinery of the new mixing mill at the lower works. It is $21\frac{1}{4}$ inches in diameter, $3\frac{1}{2}$ inches deep, and is to make 190 revolutions per minute, giving $63\frac{1}{3}$ revolutions of a horizontal shaft, to which it is geered 3 to 1. To this shaft was attached a Prony dynamometer, whose lever was 7·96 feet long, giving 50 feet circumference. At the time of the experiments, a wooden box, nearly water-tight, was placed in the tail-race, surrounding the lower part of the wheel. One side of it was cut away, forming a waste-board 3·83 feet wide, over which the water was discharged, and at the same time diminishing the usual head and fall about 9 inches.

Experiment No. 1.—The distance between the level of water in the penstock or forebay and that of the bottom of the waste-board was 10′ 1″, and the depth of water flowing over the waste-board $8\frac{1}{8}$″, leaving the actual head and fall $10'1'' - 8\frac{1}{8}'' = 9', 4\frac{7}{8} = 9{\cdot}34$ feet. By Morin's formula, (*Aide Memoire*, p. 37,) $Q = m\,L\,h\,\sqrt{2\,z\,h}$; Q being discharge per second, m the constant, which for ·74 depth = ·383, L = width of waste-board, = 3·83 feet, and h = depth of water upon it, = ·74. Then in this case $Q = {\cdot}383 \times 3{\cdot}83 \times {\cdot}74 \sqrt{64 \times {\cdot}74} = 7{\cdot}468$ cubic feet, and the theoretical power due to the water was $7{\cdot}468 \times 62{\cdot}5 \times 9{\cdot}34 \times 60 = 261{,}537$ lbs. raised 1 foot per minute = 7·92 horse-power.

It was found that at 63 revolutions per minute of the horizontal shaft, 63 pounds balanced the lever Hence the power developed by the wheel was $63 \times 63 \times 50 = 198{,}450$ lbs. = 6·014 horse-power.

Experiment No. 2.—The gates from the head-race were so far closed as to reduce the head 1 foot, and maintain it at that level during the experiment. The depth of water on waste-board was $8\frac{1}{8}$″, so that the head and fall was $9'1'' - 8\frac{1}{8}'' = 8'4\frac{7}{8}'' = 8{\cdot}41$ feet. Therefore, by the same formula, m being ·39 for this depth, $Q = {\cdot}39 \times 3{\cdot}83 \times {\cdot}677 \sqrt{64 \times {\cdot}677} = 6{\cdot}66$ cubic feet, and the theoretical power due to the water was $6{\cdot}66 \times 62{\cdot}5 \times 8{\cdot}41 \times 60 = 210{,}000$ lbs. raised 1 foot per minute = 6·36 horse-power.

It was found that 63 pounds balanced the lever at 49 revolutions per minute of the shaft. Hence the power developed by the wheel was $49 \times 63 \times 50 = 164{\cdot}350$ lbs. = 4·98 horse-power.

The coefficients are, then, for experiment No. 1, $\frac{6{\cdot}014}{7{\cdot}92} = {\cdot}760$ per ct.

" " " No. 2, $\frac{4{\cdot}98}{6{\cdot}66} = {\cdot}783$ "

And making allowance for leakage around the waste-board box, which was partially counterbalanced by the friction of the geering and horizontal shaft, the useful coefficient of the wheel may be taken at 75 per cent., and, as has been seen, remains the same when the wheel is working at 5 horse-power, which is but 70 per cent. of its full power.

For the information of those who are not familiar with this wheel, it may be stated that it is placed as near the top of the fall as possible, and revolves within a cast-iron pipe leading below the level of the tail-race. The "curved guides" are directly *over* the wheel, and may, therefore, be easily reached for cleaning or repair These curved guides are disposed radially around a hub, curving spirally around it as they descend, in such a manner that any horizontal linear element of a guide is in a radial line drawn from the axis. The buckets of the wheel are similarly curved, but in an opposite direction.

The following experiments were made on one of the 60-horse power turbines of Messrs. Jessup & Moore, with a dynamometer of Prony, and the quantity of water calculated by an overflow discharging in the open air.

Effective power $= \frac{R \times C \times W}{33000}$ R, number of revolutions per minute; C, circumference of the lever; W, the weight of the lever and balance.

$$R = 104. \quad C = 80 \text{ feet.} \quad W = 223{\cdot}50 \text{ lbs.}$$

$$\text{Effective power} = \frac{104 \times 80 \times 223{\cdot}50}{33000} = 56{\cdot}30 \text{ horse-power.}$$

Theoretical power of the water $= \frac{Q \times 62{\cdot}5 \times F}{33000}$. Q, number of cubic feet of water discharged through the wheel per minute. 62·5, weight in pounds of the cubic feet of water. F, fall of the water in feet and fraction.

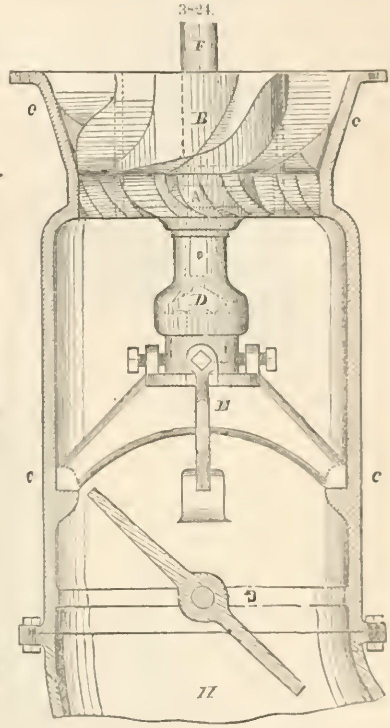
The quantity of water was measured by an overflow of 172·875 inches width. The depth of water discharging through it was $13\frac{11}{16}$ inches. This, with the coefficient of contraction, 0·45, adapted by Mr Poncelet for large overflows, gives 3794 cubic feet of water per minute. The total fall during the operation of the turbine was 8 feet $10\frac{3}{4}$ inches, = 8·89 feet.

Hence the theoretical power is $\frac{3794 \times 62{\cdot}5 \times 8{\cdot}89}{33000} = 63{\cdot}92$ horse-power.

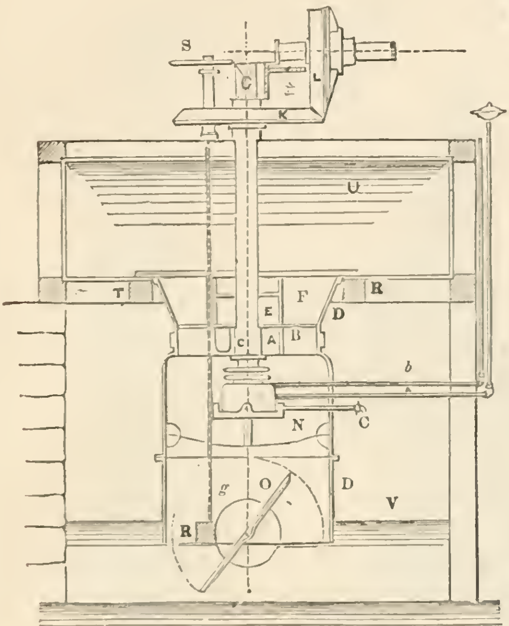
Effective power, 56·30 } 0·88 coefficient of the turbine.
Theoretical power, 63·92 }

General description of the Jonval Turbine.—Fig. 3823 represents a vertical section of a turbine. A represents the *movable wheel*, consisting of a cast-iron rim, having a given number of wrought-iron buckets, of the proper curve, mortised into and riveted to it, and occupying the space marked B; it is keyed to the *main or upright shaft* C, and revolves freely in the cylinder D, the outside of the buckets and the cylinder having a small space between them. The *stationary wheel* E consists of a cast-iron rim, hav-

3824.

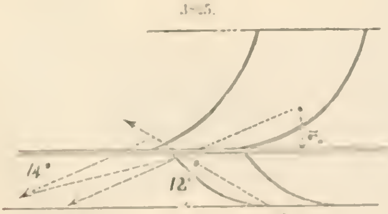


3823.

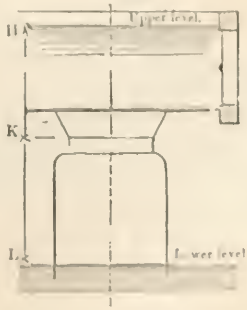


ing also a given number of wrought-iron guides mortised into and riveted to it, and occupying the space F. This wheel occupies the conical part of the cylinder, just above the movable wheel, with sufficient space between them to allow the movable wheel to revolve freely. The upper edges of the guides are level with the upper surface of the flanch of the cylinder. The upright shaft C has its lower bearing or step running in the oil-box H; the upper bearing C′, runs in a pedestal attached to the bridge G. This bridge, made of cast-iron, is supported on some of the cross timbers of the forebay, and supports also the pedestal for the journal of the line-shaft J.

3825.

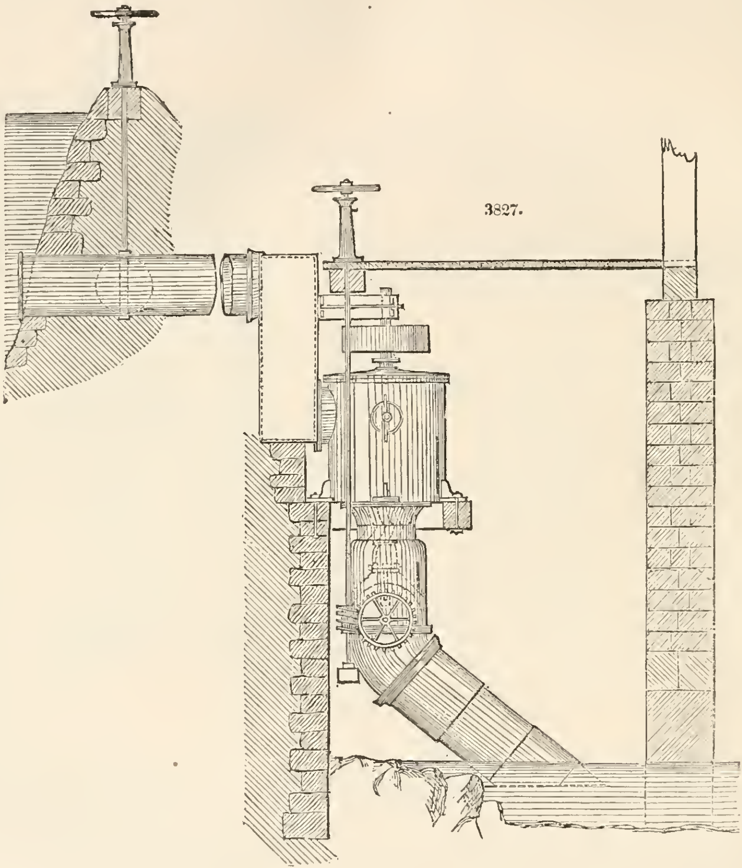


3826.



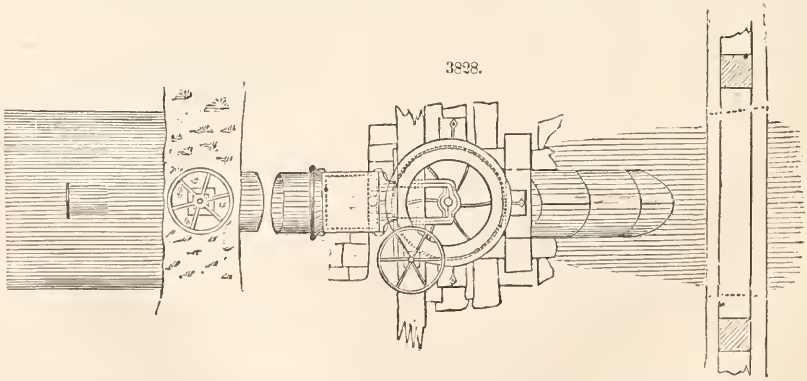
The oil box H, is supported by the cast iron bridge M, which rests on the lugs N N, on the inside of the cylinder. The gate O, resembling a throttle valve, is fastened to the shaft P, which works in stuffing-boxes cast in the cylinder. To one end of this shaft a worm wheel is attached, which, being moved by the endless-screw R, opens and shuts the gate.

The screw R is moved by the hand-wheel or governor S. The cylinder D D D, cast in one or more pieces, is supported by the timbers T T. U represents a section of the forebay and tail-race. The oil-box is filled with oil through the gas-tube *a*, which runs from the top of the forebay. The tube marked *b* is to allow the air to escape from the box when it is being filled; that marked *c* is for drawing off the oil when it is necessary to change it. Should the step wear any, the toe can be changed with great facility. The oil-box is held to its proper position in the bridge by set-screws *h h*. As it is represented in the different figures of this article, there are sometimes wooden steps where it is preferred.



3827.

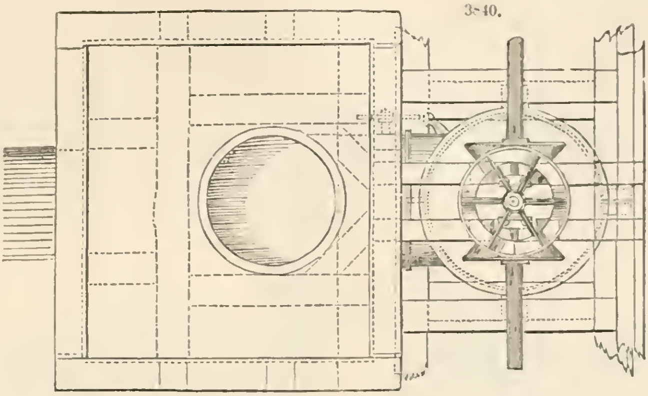
3828.



The operation of the wheel.—The operation of this wheel is very simple; the top of the cylinder is placed from 4 to 6 feet from the upper level of the water, or at a sufficient distance to prevent the water from becoming agitated; thus it will be seen that the movable wheel or turbine is suspended between the two levels of the fall. The water is made to come on the wheel and leave it so as to exert its utmost effect by the proper construction of the guides and buckets, which, together, form an annular section. The following is the action of the water discharging through the wheels.

The water, as it leaves the forebay, follows the guides of the stationary wheel, curved in a spiral form, and leaves them at an angle of 16° to the horizontal line and tangential to the circumference, and thus presses on the movable wheel, which, by the proper course of its buckets, retrogrades and lets the

3840.



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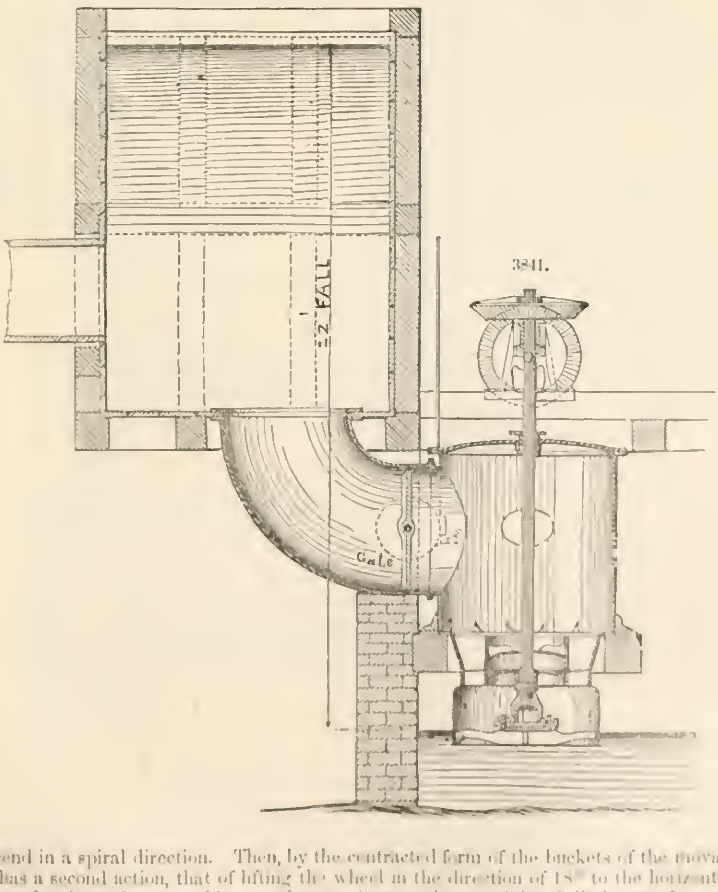
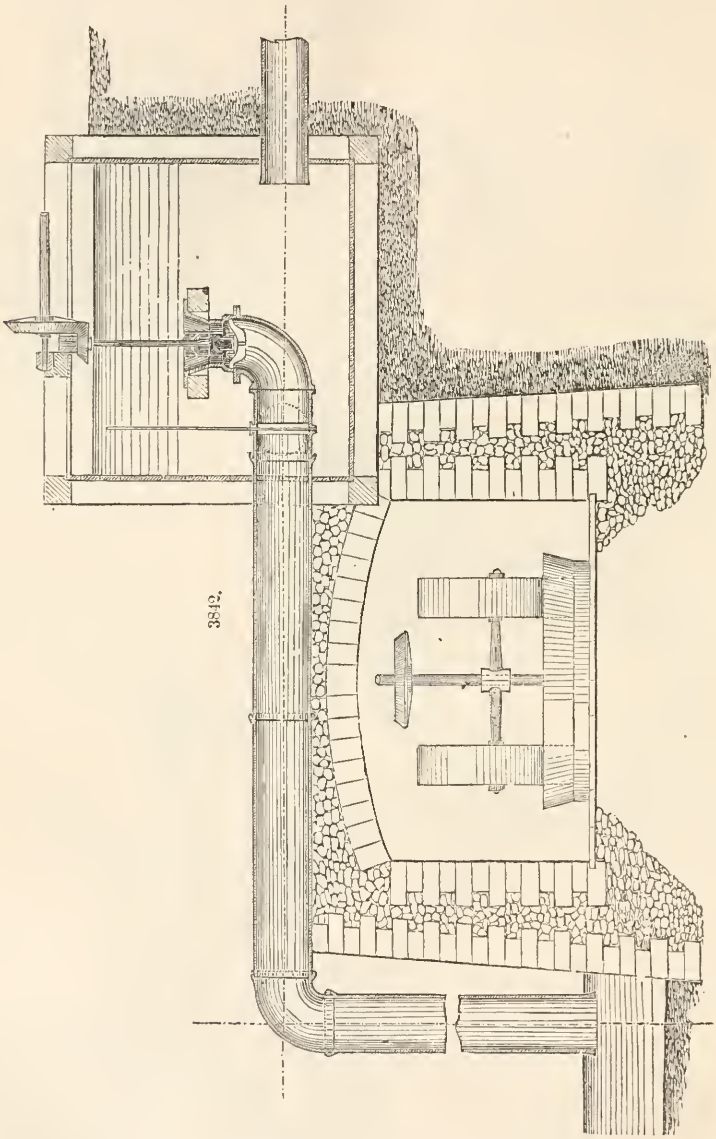


water descend in a spiral direction. Then, by the contracted form of the buckets of the movable wheel, the water has a second action, that of lifting the wheel in the direction of 18° to the horizontal line and tangential to the circumference; this second action is upon the principle of discharge of water through a conical pipe, and has the effect of throwing the pipe back.

These two forces are in the proportion of 10 to 1, and in constructing the parallelogram of forces in the respective directions, the diagonal or resultant will be at an angle of 14° to the horizontal line and tangential to the circumference.

The water discharged through this contracted space falls in a large air-tight cylinder, and descends, partially suspended by the tendency of *vacuum*, to the tail-race. The following is the effect of the column of water on the wheel.

As mentioned above, the column of action on these kind of turbines is divided into two distinct ones-1st, from the upper level of the fall to the upper part of the turbine; 2d, from the upper part of the turbine to the lower level of the fall.



3842.

The first part of the column operates by the same laws as in ordinary wheels, that is to say, the quantity of water multiplied by the velocity corresponding to the height of the fall. The second part of the column, that is to say, from the turbine to the lower part of the fall, would, in ordinary wheels which discharge in open air, be of no additional effect to the wheel, as the water would leave this point without velocity, and would only fall by its gravity; but by this peculiar arrangement of excluding the air from the whole column by means of an air-tight cylinder immersed in the lower level of the fall, the water passing through a contracted part of the air-tight cylinder discharges in a larger part, which also, below, has a larger discharge than admission from the wheel.

The water, consequently, cannot fill the whole space of the cylinder below the wheel, and the air would rush in to fill the vacant space, but this element being completely excluded, the tendency t form a vacuum keeps the column of water suspended to the proportion of the height to that of perfect vacuum; and the velocity which the water would, through its gravity, acquire at the lowest part of its fall, would be communicated to the upper part, where, instead of pressure, the water acts as suction.

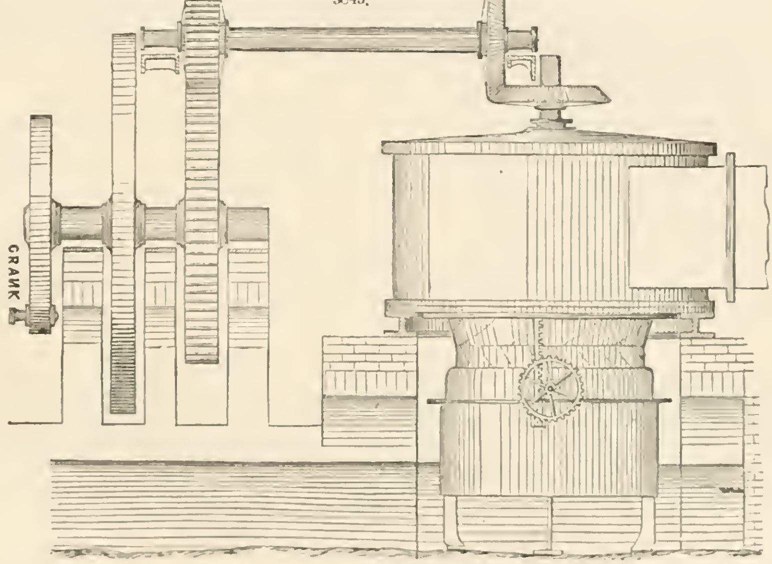
This principle is true as far as the tendency of vacuum can be rendered perfect, (that is to say, to the height of 32 feet) and thus produce by suction an equal in effect to the atmospheric pressure; above this the surplus of pressure would force air in the column from below, and so reduce the effect, which, in placing the wheel below 32 feet from the lower level, would be equal to pressure.

Reduction of power in the wheel.—The difference of quantity of water in dry and wet seasons, and also the difference of power used in certain kinds of mills, at different times, in the working operations, have shown that it is necessary for these iron wheels to be adaptable to these changes.

In consequence of their operating with much higher speed than wooden wheels, the difference of power affects its operation more sensibly if there is no means to regulate it.

Various forms of gates have been tried, but not found to give full satisfaction. In these wheels there have been employed a series of movable divisions, by which a part of the inner periphery of the wheel is inclosed, and the whole water to be absorbed is thrown to the external periphery. This arrangement has been most satisfactory in its operation, and a wheel used for 60 horse-power in wet seasons can operate at 40 horse-power in dry seasons, and does not vary in its percentage more than 5 to 6 per cent. in its effect by this change.

3843.



It will require only half an hour to insert these divisions, but for instant change of speed or power there is also the gate by which *one-fifth* of its power can be taken off without any considerable change in effect.

Advantages obtained by these wheels over other first-class wheels.—1st. In consequence of its suspension between the two levels of the fall, in case of backwater, the power only changes by its diminution of fall, but should the fall remain the same, the backwater would not have a bad effect.

2d. As expressed above, the velocity of turbines in general is greater than that of wooden wheels, and in all factories and mills where a high velocity is required, the amount of power absorbed in the geering is gained, and the use of greasing and chance of getting out of order is greatly lessened.

3d. As shown in Figs. 3827, 3828, and 3842, the water can leave the wheel at any angle, even to the horizontal line, and such presents very great advantages where there exist rocks below, or quicksand, or structures which could not be removed without much expense.

4th. By the position of the stationary wheel placed above the movable, where it is suspended in the conical part of the air-tight cylinder, and its only being kept down by the column of water above and its own weight, it cannot present the chance of breaking should some stick or stone come between its plates, as would be the case in Fourneyron's wheels, which are bolted to their respective places. A Jonval turbine will, by such obstruction, have the stationary wheel lifted out of its place. In other wheels, where the guides cannot give way, the division plates must be broken.

5th. In breast, pitchback, and overshot wheels, the water acts partly by its weight and partly by the velocity due to the head on the gates of discharge on the wheel, and on this account loses a head of water equal, first, to the half of the head on the gate; second, the depth of the buckets on the wheel itself. In turbine wheels this is not the case, as the full fall is utilized.

6th. In case of repair this wheel can be rendered instantly dry and accessible, while all other iron wheels, acting only by pressure, are submerged, and in order to reach the wheel the water has to be pumped out of the tail race.

The Jonval turbines are guarantied to give, 1st, 75 per cent. of its effect with a fall from 30 feet and above down to 12 feet. 2d, 70 per cent. of its effect with a fall from 12 feet to 6 feet. 3d, 60 per cent. of its theoretical effect from 6 feet to 4 feet.

These wheels are built by Mr. E. Geyelin, Philadelphia.

Figs. 3827 and 3828, elevation and plan of a 15 horse-power turbine, built by E. Geyelin for Mr. Le Carpentier, Philadelphia. Fig. 3824, section of the turbine-wheel of the same.

Figs. 3840 and 3841, plan and elevation of a turbine of 50 horse-power, 22 feet fall, in operation in the paper-mill of Messrs. Manning, Peckham, & Howland, of Troy, New York, built at the West Point Foundry, by E. Geyelin.

Fig. 3842, turbine built at the powder-works of the Messrs. Dupont, Wilmington, Delaware.

Fig. 3843, turbine built for the Fairmount Water-works of Philadelphia.

WEIGHTS AND MEASURES. The weights and measures of this country are identical with those of England. In both countries they repose, in fact, upon actually existing masses of metal (brass) which have been individually declared by law to be the units of the system. In scientific theory they are supposed to rest upon a permanent and universal law of nature—the gravitation of distilled water at a certain temperature, and under a certain atmospheric pressure. And in this aspect, the origination is with the grains, which must be such, that 252,458 of these units, in brass, will be in just equilibrium with a cubic inch of distilled water, when the mercury stands at 30 inches in a barometer, and in a thermometer of Fahrenheit at 62 degrees, both for the air and for the water. Unfortunately, the expounders of this theory in England used only the generic term brass, and failed to define the specific gravity of the metal to be employed; the consequence of this omission is to leave room for an error of $\frac{1}{100000}$ in every attempt to reproduce or compare the results. This is the minimum possible error: the maximum would be a fraction of the difference in specific gravity between the heaviest and lightest brass that can be cast.

Length.—1 yard = 3 feet = 36 inches = 432 lines = 5184 seconds = 62,208 thirds.

In the actual government standards at the custom-houses, the yard is divided decimally into tenths and hundredths.

In the measurement of cloths, muslins, linens, cottons, silk, and in general of what are termed dry goods, the yard only is used—subdivided into halves, quarters, eighths, sixteenths, and half-sixteenths. This lowest denomination = 1·125 inch.

Surveyors and engineers employ neither the yard nor the inch, but use the foot and its decimal divisions.

Architects and artificers reckon by the foot and subdivisions, as given above. Nevertheless, the most usual and most recent workmen's scales bear the foot divided into inches, and eighths and sixteenths of an inch.

Mariners measure by cable-lengths and fathoms:

1 cable-length = 120 fathoms = 240 yards = 720 feet.

The unit of length—the yard, upon whose subdivisions all the weights and capacity measures repose for verification—is, in fact, derived from ancient arbitrary standards of England. In theory, the inch—the 1-36th of the yard—is presumed to be contained 39·13929 times in the length of a pendulum that, in a vacuum, and at the level of mid-tide, under the latitude of London, vibrates seconds of mean time.

Itinerary.—1 statute mile = 2 half miles = 4 quarter miles = $7\frac{1}{3}$ cable-lengths = 8 furlongs = 80 chains = 320 perches or poles = 880 fathoms = 1760 yards = 5280 feet = 8000 links = 63,360 inches.

1 nautical league = 3 equatorial miles = 3·457875 statute miles.

Chains and links are denominations employed by land surveyors, thus:

1 chain = 4 poles = 66 feet = 100 links.

Agrarian and superficial.—1 square mile = 640 acres.

1 acre = 4 roods = 10 square chains = 160 square perches = 4840 square yards = 43,560 square feet

1 square yard = 9 square feet = 1296 square inches.

Architects and builders reckon 1 square = 100 square feet.

Liquid capacity.—1 gallon = 2 half gallons = 4 quarts = 8 pints = 16 gills.

The gill is not among existing standards of public authority, though it is used in commerce. There are other denominations higher than the gallon, such as barrels, hogsheads, pipes, etc., but these are only vessels, not measures, and are always gaged and sold by their actual capacity in gallons. The gallon, in fact, is almost exactly equivalent to a cylinder 7 inches in diameter and 6 inches high. In theory, it must contain just 231 cubic inches; and, filled with distilled water at the temperature of maximum density, (say 39°·8 Fah.,) weighs, according to the official report, at that temperature, and at 30 inches of the barometer, 8·339 commercial or avoirdupois pounds; or, more nearly, 58372·1754 grains. It is in the temperature only that this unit differs from the former wine-gallon of Great Britain.

The apothecaries use the same gallon, but divide it differently, as follows:

1 gallon = 8 pints = 128 fluid ounces = 1024 fluid drachms = 61,440 minims (or drops) = 231 cubic inches.

These are graduated measures: they also use sometimes the following approximate ones from vessels in domestic use:

1 tea-cup = 2 wine-glasses = 8 table-spoons = 32 tea-spoons = 4 fluid ounces.

Dry capacity.—1 bushel = 2 half bushels = 4 pecks = 8 gallons.

There are also in this, as in the former measure, higher denominations (barrels, sacks, etc.) known in commerce, whose capacity is intended to be constant. They are, however, always gaged by the bushel. This bushel is the old Winchester bushel of England. In fact, it is a cylinder 18·5 inches in diameter, and 8 inches deep. In theory, it must contain 2150·42 cubic inches, and holds, of distilled water at the temperature of maximum density, and at 30 inches of the barometer, 77·6274 commercial or avoirdupois pounds; or, more nearly, 543391·89 grains.

Solid.

1 cubic yard = 27 cubic feet = 46,656 cubic inches.
1 cubic foot = 12 reduced feet (plank measure) = 1728 cubic inches.
1 reduced foot (plank measure) = 1 square foot × 1 inch thick = 144 cubic inches.

In practice, all planks and scantlings less than an inch in thickness are reckoned at an inch.

1 perch of masonry = 1 perch ($16\frac{1}{2}$ feet) long × 1 foot high × $1\frac{1}{2}$ foot thick = 25 cubic feet.

In fact, the dimensions given for the perch do not result in 25 cubic feet, but this last number has been adopted for convenience.

1 cord of fire-wood = 8 feet long × 4 feet high × 4 feet deep = 128 cubic feet.

Weight.

1 mint or troy pound = 12 ounces = 240 pennyweights = 5760 grains.
1 apothecary pound = 12 ounces = 96 drachms = 288 scruples = 5760 grains.
1 commercial pound = 16 ounces = 256 drachms = 7000 grains.
1 long ton = 20 cwt. = 80 quarters = 2240 commercial pounds.
1 short ton = 20 hundred weight = 2000 commercial pounds.

In the actual government standards the ounce troy is divided, decimally, down to the $\frac{1}{10000}$ part.

TABLES OF UNITED STATES WEIGHTS AND MEASURES.

MEASURES OF LENGTH.

12	inches	= 1 foot.
3	feet	= 1 yard.
$5\frac{1}{2}$	yards	= 1 rod.
40	rods	= 1 furlong.
8	furlongs	= 1 mile.

Inches.	Feet.	Yards.	Rods.	Furl.
36 =	3.			
198 =	$16\frac{1}{2}$ =	$5\frac{1}{2}$.		
7920 =	660 =	220 =	40.	
63360 =	5280 =	1760 =	320 =	8.

Gunter's Chain.

7·92 inches....... = 1 link.
100 links......... = 4 rods, or 22 yards.

Ropes and Cables.

6 feet.............. = 1 fathom.
120 fathoms .... = 1 cable-length.

Geographical and Nautical Measure.

1 degree of a great circle of the earth............. = 69·77 statute miles.
1 mile.. = 2046·58 yards.

Log Lines.

1 knot.................................... = 51·1625 feet, or 51 feet $1\frac{3}{4}$ + inches.
1 fathom................................. = 5·11625 feet, or 5 feet $1\frac{1}{3}$ + inches.

Estimating a mile at $6139\frac{1}{3}$ feet, and using a 30″ glass. If a 28′ glass is used, and eight divisions, then

1 knot.................................... = 47 feet 9 + inches.
1 fathom................................. = 5 feet $11\frac{5}{8}$ inches.

The line should be about 150 fathoms long, having 10 fathoms between the chip and first knot for stray line.

Note.—Bowditch gives 6120 feet in a sea mile, which, if taken as the length, will make the divisions 51 feet and 5 1-10 feet.

Cloth.

1 nail...................... = $2\frac{1}{4}$ inches...................... = 1-16th of a yard.
1 quarter.................. = 4 nails.
5 quarters................ = 1 ell English.

Pendulums.

6 points.. = 1 line.
12 lines .... = 1 inch.

Shoemakers'.

No. 1 is $4\frac{1}{3}$ inches in length, and every succeeding number is $\frac{1}{3}$ of an inch.
There are 28 divisions, in two series of numbers, viz., from 1 to 13, and 1 to 15.

Circles.

60 seconds.................... = 1 minute.	″	
60 minutes.................... = 1 degree.	3600 =	60.
360 degrees .... = 1 circle.	1296000 =	21600.

1 day is.. ·002739 of a year.
1 minute is .... ·000694 of a day.

Miscellaneous.

1 palm........................ = 3 inches.	1 span...................... = 9 inches.
1 hand........................ = 4 inches.	1 metre...................... = 3·28174 feet.

The standard of measure is a brass rod, which, at the temperature of 32° Fahrenheit, is the standard yard.

1 yard is .... ·000568 of a mile.
1 inch is .... ·0000158 of a mile.

MEASURES OF SURFACE.

		Inches.
144 square inches	= 1 square foot.	
9 square feet	= 1 square yard.	1296.

Land.

		Yards.	Rods.	Roods.
30¼ square yards	= 1 square rod.			
40 square rods	= 1 square rood.	1210.		
4 square roods / 10 square chains	= 1 acre.	4840 =	160.	
640 acres	= 1 square mile.	3097600 =	102400 =	2560.

NOTE.—208·710321 feet, 69·5701 yards, or 220 by 198 feet square = 1 acre.

Paper.

		Sheets.
24 sheets	= 1 quire.	
20 quires	= 1 ream.	480.

Drawing Paper.

Cap	13 × 16 inches.		Columbier	33¾ × 23 inches	
Demy	19½ × 15½ "		Atlas	33 × 26 "	
Medium	22 × 18 "		Theorem	34 × 28 "	
Royal	24 × 19 "		Double Elephant	40 × 26 "	
Super-royal	27 × 19 "		Antiquarian	52 × 31 "	
Imperial	29 × 21¼ "		Emperor	40 × 60 "	
Elephant	27¾ × 22¼ "		Uncle Sam	48 × 120 "	

MEASURES OF CAPACITY.

Liquid.

		Gills.	Pints.
4 gills	= 1 pint.		
2 pints	= 1 quart.	8.	
4 quarts	= 1 gallon.	32 =	8.

Dry.

		Pints.	Qrts.	Galls.
2 pints	= 1 quart.			
4 quarts	= 1 gallon.	8.		
2 gallons	= 1 peck.	16 =	8.	
4 pecks	= 1 bushel.	64 =	32 =	8.

United States standard bushel.—The standard bushel is the Winchester, which contains 2150·42 cubic inches, or 77·627413 lbs. avoirdupois of distilled water at its maximum density.

Its dimensions are 18½ inches diameter inside, 19½ inches outside, and 8 inches deep; and when heaped, the cone must not be less than 6 inches high, equal 2747·70 cubic inches for a true cone.

		Inches.
1728 cubic inches	= 1 foot.	
27 cubic feet	= 1 yard.	46656

Miscellaneous.

1 chaldron = 36 bushels, or .... 57·25 cubic feet.
1 cord of wood .... 128 cubic feet.
1 perch of stone .... 24·75 cubic feet.

MEASURES OF WEIGHT.

Avoirdupois.

		Drachms.	Ounces.	Pounds.
16 drachms	= 1 ounce.			
16 ounces	= 1 pound.	256.		
112 pounds	= 1 cwt.	28672 =	1792.	
20 cwt	= 1 ton.	573440 =	35840 =	2240

1 lb. .... = 14 oz. 11 dwt. 16 gr. troy.

Troy.

		Grains.	Dwt.
24 grains	= 1 dwt.		
20 dwt	= 1 ounce.	480.	
12 ounces	= 1 pound.	5760 =	240.

Apothecaries'.

		Grains.	Scruples.	Drachms.
20 grains	= 1 scruple.			
3 scruples	= 1 drachm.	60.		
8 drachms	= 1 ounce.	480 =	24.	
12 ounces	= 1 pound.	5760 =	288 =	96.

Diamond.

16 parts	= 1 grain	= 0·8 troy grains.	
4 grains	= 1 carat	= 3·2 "	

7000 troy grains .... = 1 lb. avoirdupois.
175 troy pounds .... = 144 lbs. "
175 troy ounces .... = 192 oz. "
437½ troy grains .... = 1 oz. "
1 troy pound .... = ·8228 + lb. "

Miscellaneous.

1 cubic foot of anthracite coal from .... 50 to 55 lbs.
1 cubic foot of bituminous coal from .... 45 to 55 lbs.
1 cubic foot Cumberland coal .... = 53 lbs.
1 cubic foot charcoal .... = 18·5 " (hard wood).
1 cubic foot charcoal .... = 18 " (pine wood).
1 cord Virginia pine .... = 2700 "
1 cord Southern pine .... = 3300 "
1 stone .... = 14 "

Coals are usually purchased at the conventional rate of 28 bushels (5 pks.) to a ton = 43·56 cubic feet.

MEASURES OF VALUE.

1 eagle .... = 258 troy grains.
1 dollar .... = 412·5 "
1 cent .... = 168 "

The standard of gold and silver is 900 parts of pure metal, and 100 of alloy, in 1000 parts of coin.

MEASURES OF LENGTH.

BRITISH.—Yard is referred to a natural standard, which is the length of a pendulum vibrating seconds in vacuo in London, at the level of the sea; measured on a brass rod, at the temperature of 62° Fahrenheit, = 39·1393 inches.

FRENCH. *Old system.*— 1 Line...... = 12 points...... = 0·08884 United States inches.
1 Inch...... = 12 lines....... = 1·06604 " "
1 Foot...... = 12 inches...... = 12·7925 " "
1 Toise .... = 6 feet......... = 76·755 " "
1 League . = 2280 toises (common).
1 League . = 2000 toises (post).
1 Fathom . = 5 feet.

" *New system.*— 1 Millimetre .... = ·03938 " "
1 Centimetre .... = ·39380 " "
1 Decimetre .... = 3·93809 " "
1 *Metre* .... = 39·38091 " "
1 Decametre .... = 393·80917 " "
1 Hecatometre .... = 3938·09171 " "

AUSTRIAN .... 1 Foot .... = 12·448 " "
PRUSSIAN .... 1 Foot .... = 12·361 " "
SWEDISH .... 1 Foot .... = 11·690 " "
SPANISH .... 1 Foot .... = 11·034 " "
1 League (common) .... = 3·448 United States miles.

TABLE showing the relative length of *Foreign Measures* compared with those of the United States.

Places.	Measures.	Inches.	Places.	Measures.	Inches.
Amsterdam ...	Foot	11·14	Malta	Foot	11·17
Antwerp.......	"	11·24	Moscow.........	"	13·17
Bavaria.........	"	11·12	Naples	Palmo..........	10·38
Berlin	"	12·19	Prussia	Foot	12·36
Bremen...	"	11·38	Persia	Arish	38·27
Brussels	"	11·45	Rhineland......	Foot	12·35
China	" Mathematician's	13·12	Riga	"	10·79
"	" Builder's.......	12·71	Rome	"	11·60
"	" Tradesman's...	13·32	Russia	"	13·75
"	" Surveyor's	12·58	Sardinia	Palmo..........	9·78
Copenhagen ...	"	12·35	Sicily...........	"	9·54
Dresden	"	11·14	Spain	Foot	11·03
England	"	12·00	"	Toesas	66·72
Florence	Braccio..........	21·60	"	Palmo..........	8·34
France..........	Pied de Roi.........	12·79	Strasburgh	Foot	11·39
"	Metre	39·381	Sweden.........	"	11·69
Geneva	Foot	19·20	Turin	"	12·72
Genoa	Palmo..........	9·72	Venice	"	15·10
Hamburgh	Foot	11·29	Vienna	"	12·45
Hanover	"	11·45	Zurich	"	11·81
Leipsic	"	11·11	Utrecht.........	"	10·74
Lisbon..........	"	12·96	Warsaw	"	14.03
"	Palmo..........	8·64			

TABLE showing the relative length of *Foreign Road Measures* compared with those of the United States.

Places.	Measures.	Yards.	Places.	Measures.	Yards.
Arabia	Mile	2148	Hungary	Mile	9113
Bohemia	"	10137	Ireland	"	3038
China	Li	629	Netherlands	"	1093
Denmark	Mile	8244	Persia	Parasang	6086
England	" Statute	1760	Poland	Mile, long	8101
"	" Geographical	2025	Portugal	League	6760
Flanders	"	6869	Prussia	Mile	8468
France	League, marine	6075	Rome	"	2025
"	" common	4861	Russia	Verst	1167
"	" post	4264	Scotland	Mile	1984
Germany	Mile, long	10126	Spain	League, common	7416
Hamburgh	"	8244	Sweden	Mile	11700
Hanover	"	11559	Switzerland	"	9153
Holland	"	6395	Turkey	Berri	1826

Measures of Surface.

FRENCH. *Old system.*—1 Square Inch = 1·1364 United States inches.
1 Arpent (Paris) = 900 square toises.
1 Arpent (woodland) = 100 square royal perches.
" *New system.*—1 *Are* = 100 square metres.
1 Decare = 10 ares.
1 Hecatare = 100 ares.
1 Square Metre = 1550·85 square inches, or 10·7698 sq. ft
1 Are = 1076·98 square feet.

TABLE showing the relation of *Foreign Measures of Surface* compared with those of the United States

Places.	Measures.	Sq. yards.	Places.	Measures.	Sq. yards.
Amsterdam	Morgen	9722	Portugal	Geira	6970
Berlin	" great	6786	Prussia	Morgen	3053
"	" small	3054	Rome	Pezza	3158
Canary Isles	Fanegada	2422	Russia	Dessetina	13066·6
England	Acre	4840	Scotland	Acre	6150
Geneva	Arpent	6179	Spain	Fanegada	5500
Hamburgh	Morgen	11545	Sweden	Tunneland	5900
Hanover	"	3100	Switzerland	Faux	7855
Ireland	Acre	7840	Vienna	Joch	6889
Naples	Moggia	3998	Zurich	Common acre	3875·6

Measures of Capacity.

BRITISH. The *Imperial gallon* measures 277·274 cubic inches, containing 10 lbs. avoirdupois of distilled water, weighed in air, at the temperature of 62°, the barometer at 30 inches
For Grain. 8 bushels = 1 quarter.
1 quarter = 10·2694 cubic feet.
Coal, or heaped measure. 3 bushels = 1 sack.
12 sacks = 1 chaldron.
Imperial bushel = 2218·192 cubic inches.
**Heaped bushel*, 19½ inches diameter, cone 6 inches high = 2815·4872 cubic inches.
1 chaldron = 58·658 cubic feet, and weighs 3136 pounds.
1 chaldron (Newcastle) = 5936 pounds.

FRENCH. *New system.*—1 *Litre* = 1 cubic decimetre, or 61·074 U. S. cubic inches.
Old system.—1 Boisseau = 13 litres = 793·964 cubic inches, or 3·43 gallons.
1 Pinte = 0·931 litres, or 56·817 cubic inches.

SPANISH. 1 Wine Arroba = 4·2455 gallons.
1 Fanega (common measure) = 1·593 bushels.

* When heaped in the form of a true cone.

TABLE showing the relative *Capacity of Foreign Liquid Measures* compared with those of the United States.

Places.	Measures.	Cub. inch.	Places.	Measures.	Cub. inch.
Amsterdam ...	Anker	2331	Naples	Wine Barille	2544
" ...	Stoop	146	"	Oil Stajo	1133
Antwerp	"	194	Oporto	Almude	1555
Bordeaux	Barrique	14033	Rome	Wine Barille	2560
Bremen	Stubgens	194·5	"	Oil "	2240
Canaries	Arrobas	949	"	Boccali	80
Constantinople	Almud	319	Russia	Weddras	752
Copenhagen ...	Anker	2355	"	Kunkas	94
Florence	Oil Barille	1946	Scotland	Pint	103·5
"	Wine "	2427	Sicily	Oil Caffiri	662
France	Litre	61·07	Spain	Azumbres	22·5
Geneva	Setier	2760	"	Quartillos	30·5
Genoa	Wine Barille	4530	Sweden	Eimer	4794
"	Pinte	90·5	Trieste	Orne	4007
Hamburgh	Stubgen	221	Tripoli	Mattari	1376
Hanover	"	231	Tunis	Oil "	1157
Hungary	Eimer	4474	Venice	Secchio	628
Leghorn	Oil Barille	1942	Vienna	Eimer	3452
Lisbon	Almude	1040	"	Maas	86·33
Malta	Caffiri	1270			

TABLE showing the relative *Capacity of Foreign Dry Measures* compared with those of the United States.

Places.	Measures.	Cub. inch.	Places.	Measures.	Cub. inch.
Alexandria	Rebele	9587	Malta	Salme	16930
"	Kislos	10418	Marseilles	Charge	9411
Algiers	Tarrie	1219	Milan	Moggi	8444
Amsterdam ...	Mudde	6596	Naples	Tomoli	3122
" ...	Sack	4947	Oporto	Alquiere	1051
Antwerp	Viertel	4705	Persia	Artaba	4013
Azores	Alquiere	731	Poland	Zorzec	3120
Berlin	Scheffel	3180	Riga	Loop	3978
Bremen	"	4339	Rome	Rubbio	16904
Candia	Charge	9288	"	Quarti	4226
Constantinople	Kislos	2023	Rotterdam	Sach	6361
Copenhagen ...	Toende	8489	Russia	Chetwert	12448
Corsica	Stajo	6014	Sardinia	Starelli	2988
Florence	Stari	1449	Scotland	Firlot	2197
Geneva	Coupes	4739	Sicily	Salme gres	21014
Genoa	Mina	7382	"	" generale	16886
Greece	Medimni	2390	Smyrna	Kislos	2141
Hamburgh	Scheffel	6426	Spain	Catrize	41269
Hanover	Malter	6868	Sweden	Tunnar	8940
Leghorn	Stajo	1501	Trieste	Stari	4521
"	Sacco	4503	Tripoli	Caffiri	19780
Lisbon	Alquiere	817	Tunis	"	21855
"	Fanega	3268	Venice	Stajo	4945
Madeira	Alquiere	684	Vienna	Metzen	3753
Malaga	Fanega	3783			

Measures of Solidity.

FRENCH.	1 Cubic foot	=	2093·470 U. S. inches.
	Decistre	=	3·5375 cubic feet.
	Stere (a cubic metre)	=	35·375 "
	Decastere	=	353·75 "
	1 Stere	=	61074·664 "

Measures of Weight.

BRITISH ... 1 troy Grain = .003961 cubic inches of distilled water.
1 troy Pound = 22·815689 cubic inches of water.

FRENCH. *Old system.*—	1 Grain	=	0·8188 grains troy
	1 Gros	=	58·9548 "
	1 Once	=	1·0780 oz. avoirdupois.
	1 Livre	=	1·0780 lbs. "

Measures of Weight—Continued.

FRENCH. *New system.*—	Milligramme	=	·01543 troy grains.
	Centigramme	=	·15433 "
	Decigramme	=	1·54331 "
	Gramme	=	15·43315 "
	Decagramme	=	154·33159 "
	Hecatogramme	=	1543·3159 "
	1 Millier = 1000 Kilogrammes	=	1 ton sea weight.
	1 Kilogramme	=	2·204737 lbs. avoirdupois.
	1 Pound avoirdupois	=	0·4535685 kilogramme.
	1 Pound troy	=	0·3732223 "
SPANISH	1 "	=	1·0152 lbs. avoirdupois.
SWEDISH	1 "	=	0·9376 "
AUSTRIAN	1 "	=	1·2351 "
PRUSSIAN	1 "	=	1·0333 "

NOTE.—In the new French system, the values of the base of each measure, viz., Metre, Litre, Stere, Are, and Gramme, are decreased or increased by the following words prefixed to them. Thus,

Milli expresses the 1000th part.	Hecato expresses 100 times the value.
Centi " " 100th "	Chilio " 1000 "
Deci " " 10th "	Myrio " 10000 "
Deca " " 10 times the value.	

TABLE showing the relative value of *Foreign Weights* compared with those of the United States.

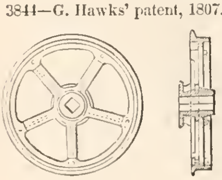
Places.	Weights.	Number equal to 100 avoirdupois pounds.	Places.	Weights.	Number equal to 100 avoirdupois pounds.
Aleppo	Rottoli	20·46	Hanover	Pound	93·20
"	Oke	35·80	Japan	Catty	76·92
Alexandria	Rottoli	107·	Leghorn	Pound	133·56
Algiers	"	84·	Leipsic	" (common)	97·14
Amsterdam	Pound	91·8	Lyons	" (silk)	98·81
Antwerp	"	96·75	Madeira	"	143·20
Barcelona	"	112·6	Mocha	Maund	33·33
Batavia	Catty	76·78	Morea	Pound	90·79
Bengal	Seer	53·57	Naples	Rottoli	50·91
Berlin	Pound	96·8	Rome	Pound	133·69
Bologna	"	125·3	Rotterdam	"	91·80
Bremen	"	90·93	Russia	"	110·86
Brunswick	"	97·14	Sicily	"	142·85
Cairo	Rottoli	105·	Smyrna	Oke	36·51
Candia	"	85·9	Sumatra	Catty	35·56
China	Catty	75·45	Sweden	Pound	106·67
Constantinople	Oke	35·55	"	"	120·68
Copenhagen	Pound	90·80	Tangiers	" (miner's)	94·27
Corsica	"	131·72	Tripoli	Rottoli	89·28
Cyprus	Rottoli	19·07	Tunis	"	90·09
Damascus	"	25·28	Venice	Pound (heavy)	94·74
Florence	Pound	133.56	"	" (light)	150·
Geneva	" (heavy)	82·35	Vienna	"	81·
Genoa	" "	92·86	Warsaw	"	112·25
Hamburgh	" "	93.63			

To convert English Imperial gallons into United States gallons, multiply by 1·20032. And to convert United States gallons into English Imperial gallons, multiply by ·83311.

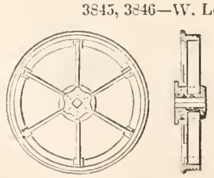
For an extended view of the various systems of weights and measures in use, see a work on this subject by Professor J. H. ALEXANDER, of Baltimore.

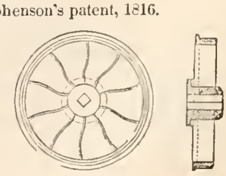
WHEELS. Under this head we give a few of the best forms of railroad-car wheels in use. See also APPENDIX.

3844—G. Hawks' patent, 1807.

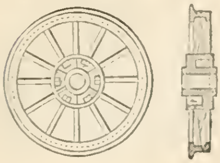


3845, 3846—W. Losh & G. Stephenson's patent, 1816.



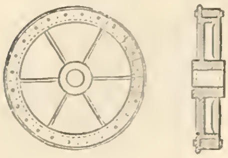


3847—T. Jones' patent, 1826.

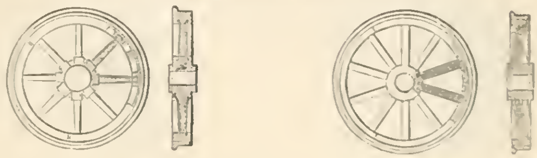


3848........3849..........3850..W. Losh's patent, 1830..3851.

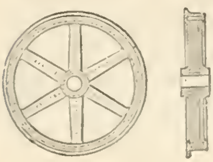
3852—W. Frost's model, 1830.



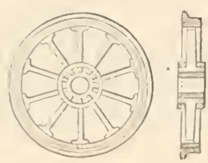
3853....G. Stephenson's patent, 1831....3854.



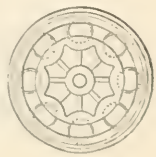
3855—G. Forrester's patent, 1831.



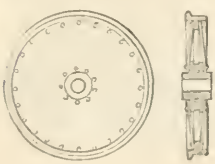
3856—R. Roberts' patent, 1832.



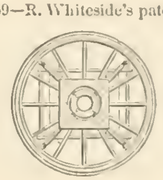
3857—Mechanics' Mag. 1832



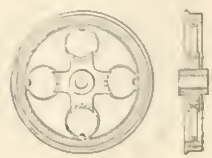
3858—B. Hicks' patent, 1834.



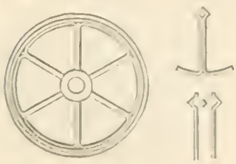
3859—R. Whiteside's patent, 1834.



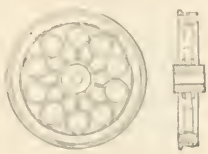
3860—W. B. Adams' patent, 1835.



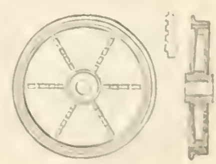
3861—I. Day's patent, 1835.



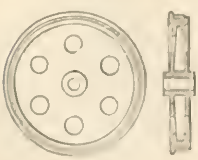
3862—R. R. Reinagle's patent, 1836.



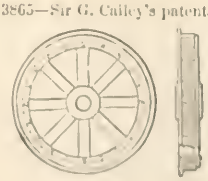
3863—H. Van Wart's patent, 1836.



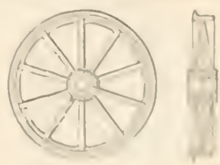
3864—A. Tiers' Mech. Mag. vol. xxv.



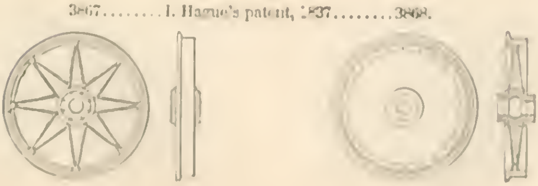
3865—Sir G. Cailey's patent, 1837.



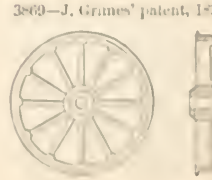
3866—G. Cottam's patent, 1837



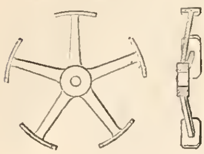
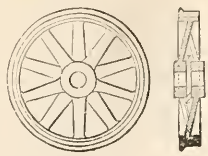
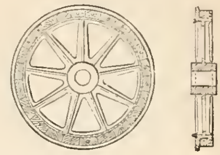
3867........I. Hague's patent, 1837........3868.



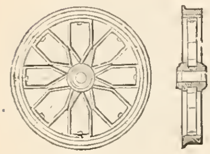
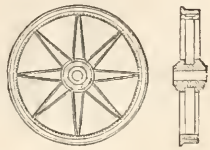
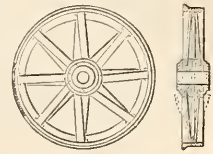
3869—J. Grimes' patent, 1838.



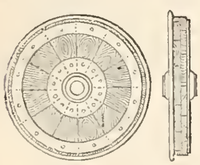
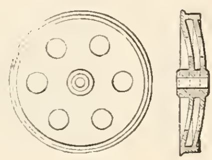
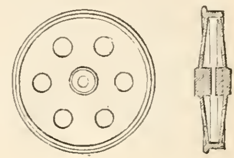
3870....J. F. Bourne & I. Bartley's patent, 1838.. .3871. 3872—I. Rivington, 1839.

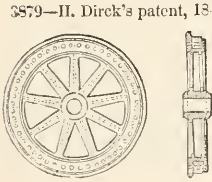
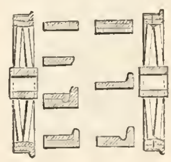
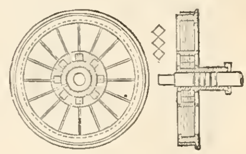
3873....I. G. Haddan & G. Hawkes............3874...... .....Patented in 1839..............3875.

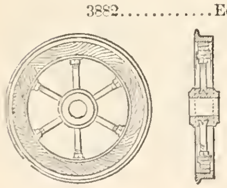
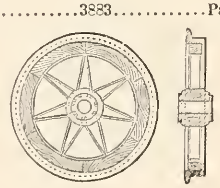
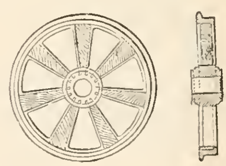
3876—T. Parkin's patent, 1839. 3877—Truscott & Co.'s Mag. vol. xxxi. 3878—Bonney & Co.'s Mag. vol. xxxi.

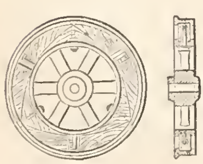
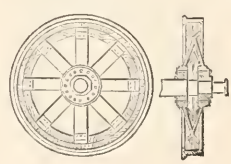
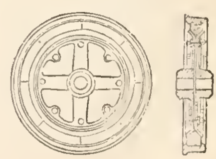
3879—H. Dirck's patent, 1840. 3880—D. Gooch's patent, 1840. 3881—J. Beattie's patent, 1840.

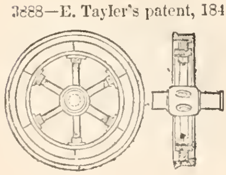
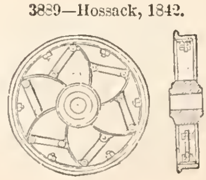
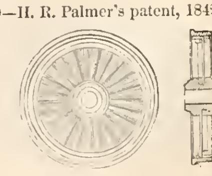
3882............Ed. Tavier.................3883............Patented in 1841............3884.

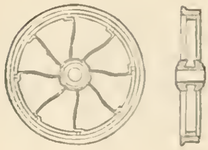
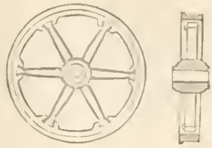
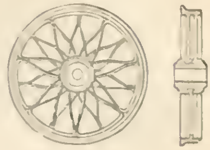
3885............I. O. Young................3886............Patented in 1841............3887.

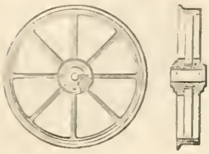
3888—E. Tayler's patent, 1841. 3889—Hossack, 1842. 3890—H. R. Palmer's patent, 1842.

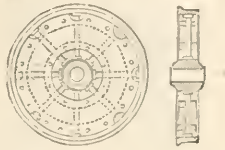
3891............W. Losh....................3892............Patented in 1842............3893.

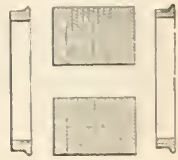
3894—T. Banks' patent, 1842



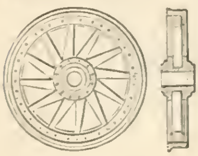
3895—F. Lipscombe's patent, 1843.



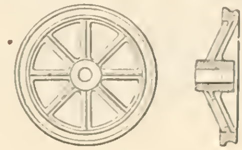
3896—I. Saunders' patent, 1843.



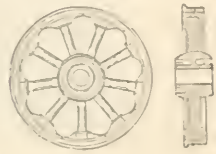
3897—G. Parlby's patent, 1843.



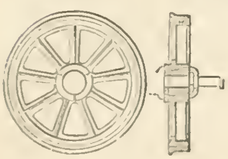
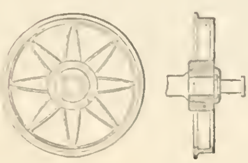
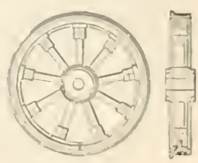
3898—C. H. Greenhow's patent, 1846.



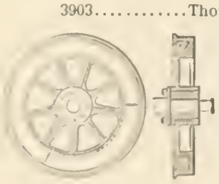
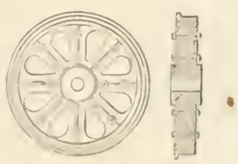
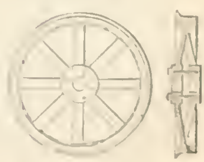
3899—H. Greaves' patent, 1846.



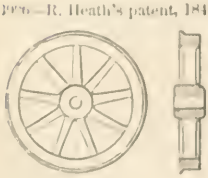
3900............Thomas Melling................3901.............Patented in 1846............3902.

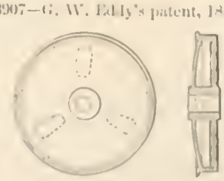
3903............Thomas Melling................3904.............Patented in 1846............3905.

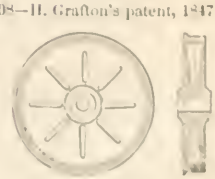
3906—R. Heath's patent, 1847.



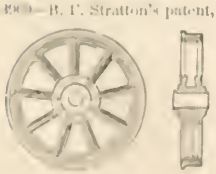
3907—G. W. Eddy's patent, 1846.



3908—H. Grafton's patent, 1847



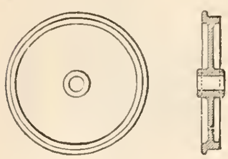
3909—B. F. Stratton's patent, 1847



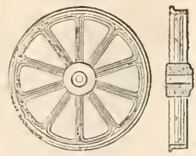
3910—P. [illegible], registered in 1847.

3911—P. Chaplin's patent, 1847

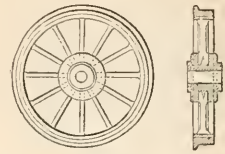
3912—W. E. Newton's patent, 1847.



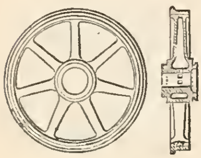
3913—G. Stephenson & Co.



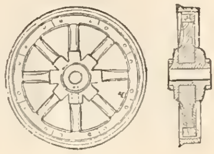
3914—Locomotive-engine wheel.



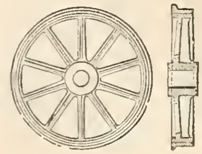
3915—I. G. Bodmer, 1842.



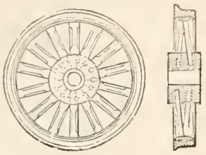
3916—The Pimlico wheel, 1843.



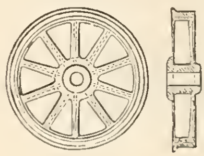
3917—R. Roberts, 1833.



3918—Bristol and Exeter Railway, 1840.

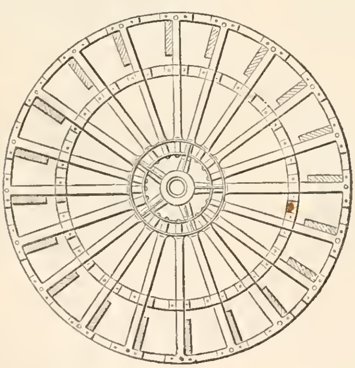


3919—Sharp, Brothers & Co., 1846.

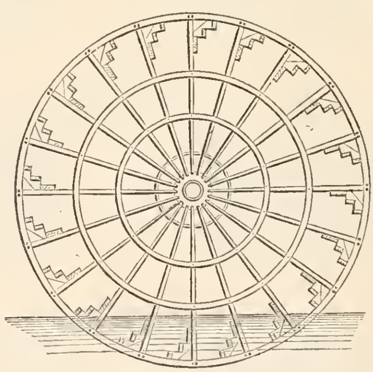


WHEELS, PADDLE, the wheels employed in the propulsion of steamboats. Common paddle-wheels mostly consist of iron framing, supporting paddle-boards or floats fixed at equal distances around the rim, and radiating from the centre; they are placed one upon each side of the vessel, and are secured to a strong shaft passing across it, which is turned round by the engines, each engine working a crank fixed upon it; and are placed at right angles to each other. Fig. 3920 represents the common paddle-wheel.

3920.



3923.

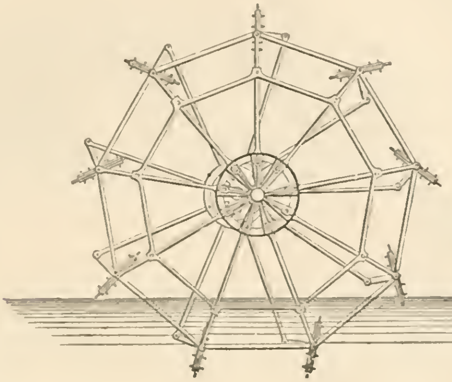


There is a supposed loss of power attending this description of wheel, on account of only one of the floats striking the water in a vertical position at the same time, the action of the others being oblique; some of them, in fact, backwater, or partially oppose the motion of the vessel. Attempts have been made to obviate these defects by constructing improved wheels, the paddles of which maintain a vertical position in their passage through the water, when in front of the wheel, by having feathering floats, and these are called *vertical paddle-wheels.* Figs. 3921 and 3922 represent a section and elevation of the vertical paddle-wheels of the "Medea." They have been found to answer well for sea-going packets, where the paddle-wheels are deeply immersed in the water; but they are more liable to derangement than the ordinary wheels; the floats may be made to leave the water at any required angle. Mr. P. W. Barlow, C. E., states the proportion of the power expended on Morgan's vertical wheels at 546, and of the former at 151 to 197.

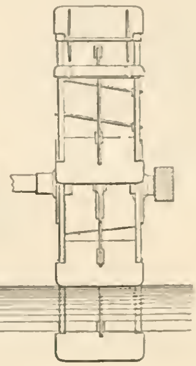
The Cycloidal paddle-wheel, Fig. 3923, (the paddle-wheel of the "Great Western,") forms, the most recent improvement, and is said to possess the advantages of each of the former, being effective and strong, yet simple, in point of construction. It was patented by Mr. Galloway in the year 1835, although first used by Mr. Field in 1833. The floats are divided into a number of parts, which are placed upon the wheel in the curve of a cycloid, so that they enter the water at the same spot, and follow one another so rapidly as to cause little resistance to the engine; in passing the centre, there is full scope to their action, and in coming out they allow the water to escape readily from them.

The draught of the vessel is necessarily greatest at the commencement of a voyage, particularly if it should be a long one, on account of the full quantity of coals for the whole voyage increasing the amount of tonnage, and other similar contingencies; the wheels are, therefore, immersed very deep in the water, which has the effect of increasing the resistance; but this loss of power diminishes as the

3921.



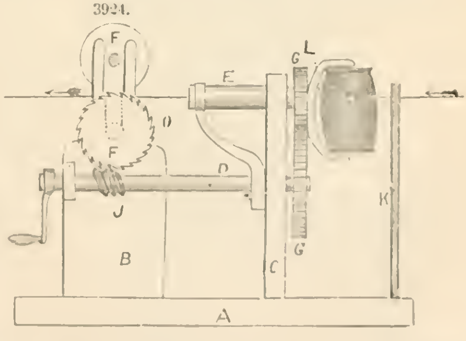
3922.



vessel proceeds. The adjusting of the floats of paddle-wheels to the requisite depth of immersion is called *reefing the floats*, and there is some difficulty connected with it; but this defect may be partly rectified with the cycloidal wheels, as the outer floats need not be fixed at starting, but fitted on as the voyage proceeds; and the larger the wheel, the less will the vessel be affected by this defect, as the diameter of the wheel increases in a greater proportion than the variation of immersion of the vessel; the latter is consequently proportionately less than other vessels, when each are laden.

WIRE COVERING MACHINE. Fig. 3924 is a simple machine for covering bonnet or telegraph wire, and which may be easily constructed. There are other kinds of machines which we have seen in operation that can cover five and six wires at once, but this one is certainly not surpassed for simplicity.

3924.

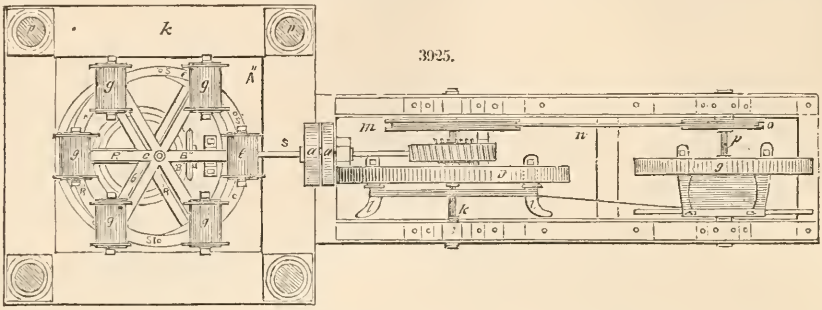


A A, sole of machine, made of wood, into which are mortised the two uprights B B, only one of which is shown—they are placed about three inches apart; C, upright frame for carrying shaft D and tube E; F F, two rollers for drawing through the wire as it is covered: the top roller is made of lead, so as to give pressure to the wire to take it through; E, tube or hollow spindle through which the wire passes; G G, spur-wheel and pinion for driving hollow spindle and bobbin A; I, brackets for carrying end of hollow spindle; J, endless-screw for working the pulley-wheel O, fixed on the outer end of the under-roller F; K, support for steadying the wire as it passes through the spindle E. H, bobbin containing the thread for covering the wire; L is a small eye fixed into the frame that carries the bobbin, through which the thread passes on to the wire. In using the machine the wire to be covered is held by the hands, and kept stretched as it is drawn through by the two rollers; another pair of rollers might be applied to keep the wire stretched, the same as the drawing-rollers.

WIRE ROPE MACHINERY. The machinery by which so intractable a material as iron wire, when compared with hemp, is spun into a rope, is most simple and complete, and has been patented in England by Mr. Smith. As the drums on which the wire is wound deliver it to the spinning portion of the machinery, the rope, beautifully and regularly finished, is seen flying away with inconceivable rapidity, and the harmony, smoothness, and freedom from jar or strain with which the whole works is truly admirable. The motion is entirely new for such a purpose, being without wheels, and is effected by a mechanical arrangement similar to an orrery, or the sun and planet motion; it effects great economy in working cost from the decreased friction, takes up much less space than the ordinary machines, and makes but little noise when in most rapid operation. The following is the specification and description:

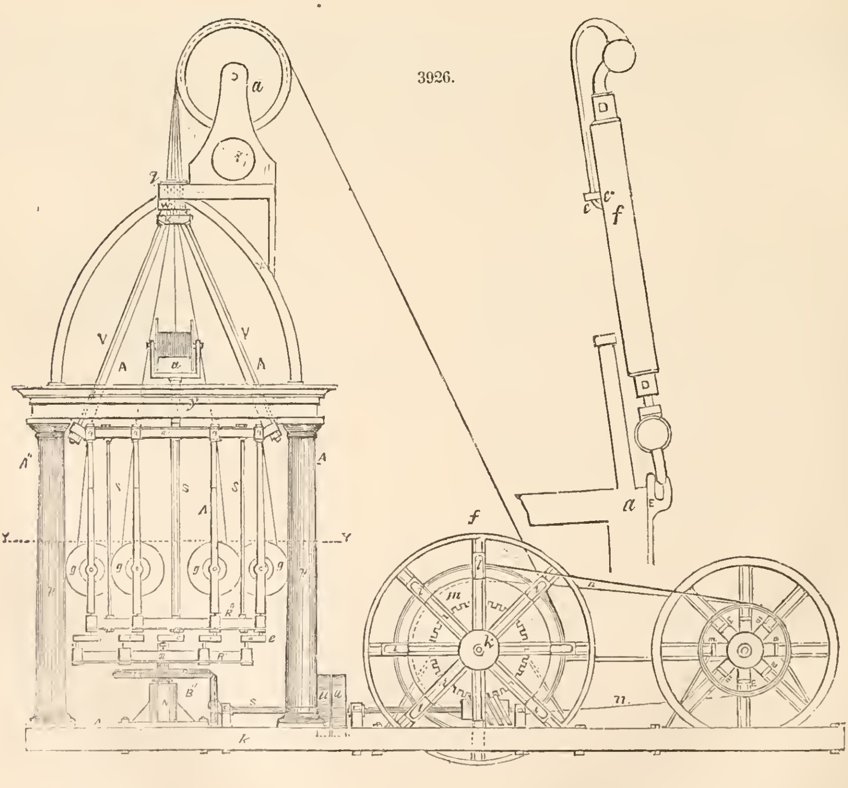
Firstly, my invention, in so far as it regards machinery for, or methods of manufacturing rope or cordage, has relation to the means employed to give motion to the reels or bobbins in laying the yarn or wire into strands, or in laying strands into rope or cordage, and consists in the improved arrangements for that purpose represented in Figs. 3925 and 3926, the former of which is a plan of the machinery on the line $y\,x$, and the latter a side elevation thereof. The bobbins or reels $g\,g$ (of any convenient number) are mounted in a circular frame A, which is upheld by screw-rods $v\,v$, with an outer framework A^2 consisting of a basement k, four pillars $p\,p$, an entablature y^1, spandrills $x^1\,x^1$, and conical apex w. The principal parts of the frame A are three six-armed rings R^1, R^2, R^3, which are connected vertically to-

3925.



gether in the manner to be presently explained, and two laying-plates $t\,t$ at top of all. The undermost ring R^1, is connected by a series of cranks C $e\,e$, with the second ring R^2, and R^2 with the third ring R^3, by straight vertical rods $s\,s$. The centre crank C is stationary, and stepped by its short arm in a pedestal N, attached to the basement of the outer framework A^2, while the undermost ring R^1 is attached to a loose boss r, slipped over the short arm of the crank C, so that on a rotating movement being given

3926.

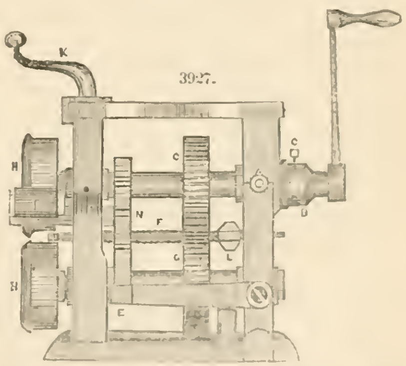


to the ring R^1, it carries round with it the ring R^2 by means of the side-cranks $e\,e$—that is to say, the side-cranks $e\,e$, which may be called live cranks, are made to revolve round the centre or dead crank C; while the ring R^2 in its turn imparts, through the medium of the vertical rods $s\,s$, a simultaneous rotary movement to the top ring R^3. The long arms of the connecting cranks $e\,e$ carry the reels or bobbins $g\,g$, on which the yarn or wire is wound, and as they revolve at fixed and invariable distances round the centre or dead crank C, any twist of the yarn or wire, which is in the course of being laid, is effectually prevented. The requisite rotary motion is given to the machine by means of a pair of bevel-wheels B^1 and B^2, the former of which (B^1) is attached to the loose boss *r* on the short arm of the dead crank C, and the latter (B^2) to a shaft S, which is turned by a steam-engine, or other first mover, through the medium of the riggers *a a*. The long arm of the dead crank C carries at top a reel or bobbin *u*, from which the heart or core for the rope or cordage (of whatever material such heart or core may be) is supplied. The yarns or wires from the different bobbins pass through guide-holes in the topmost ring R^3, and meet and unite with the core at the laying-plates *t t*. To the revolving shaft S, and at a little distance from the riggers *a a*, there is attached a worm-wheel *h*, the threads of which take into a tangent-wheel *i*, and thereby give motion to a whelp-wheel *j*, keyed to the axis k^1, of *i*. The whelp-wheel *j* serves to receive or take away the strand or rope as it is delivered from the twisting or bobbin-frame A over the pulley Q. The whelps *l l* of the wheel *j* are movable to and fro in slots, as usual, so that they may expand or contract (as it were) in proportion to the lay of the strand or rope. On the axis *k* of the wheels *i* and *j*, and outside of both, there is keyed a flat grooved rigger *m*, which is connected by a band *n* to a similar flat grooved rigger *o*, keyed on a separate shaft P, which carries a double whelp-wheel *q*, by which the strand or rope is carried along as it is completed.

And, secondly, my invention, in so far as it regards the fitting and using rope or cordage, has special relation to the application of wire rope or cordage to the standing rigging of ships, and consists in the improved contrivance for the purpose represented in the figure; *a* represents the side of a vessel; B, the chain-plate; D, a spring lanyard of the ordinary form; *f*, a tube, in which the lanyard is inclosed; *c*, a slip shackle; *e*, a stud attached to the front of the tube *f*, and having an orifice in it, through which the forelock c^1 is passed. By taking out the forelock c^1, and pulling down the tube *f*, the shackle slips up and opens out, whereby the rope can be instantly disengaged as may be required.

WIRING MACHINE, *for the manufacture of tin, sheet-iron, and other plate-ware*—Patented by A. W. WHITNEY, Woodstock, Vermont, 1847.

The face-plates or rolls H H are made of cast-steel of an improved form, having the journal-boxes of their shafts in a cast-iron frame. This frame consists of two pieces, fitted together at A, and at the top of the upright piece under K. The journal-box A has two projecting ears or bearings, (one of which is seen at A,) at right angles to the shaft B H, on which ears it is supported, forming a fulcrum to the shaft B H; thus preserving the bearing of the shaft A perfect, while the end H is raised and depressed in the process of working. B is a movable collar for adjusting the shaft and rolls longitudinally, with great nicety. C is a binding screw for keeping the collar in place. In the shaft concealed by the collar B, is a spiral groove, into which the binding screw enters. Thus, by turning the collar on the shaft, a nice longitudinal adjustment can readily be obtained. The movement of the rolls H H is secured in the usual manner by the connecting geering G G. F is a gage extending between the rolls, with a spring F, and a thumb-nut L, for adjustment. I is a forming gage, consisting of a friction roll attached to the side of a short rod or shaft, and having its journal bearing in the frame. On the inner end of this shaft is a ratchet-wheel N, for placing the gage in any desired position. Fitted to the ratchet is a latch E for holding it in place. At D is a spring, pressing the latch into the teeth of the ratchet.



3927.

In the working of the machine the bearing at A always remains perfect; for its journal box, by turning on its ears, accommodates itself to the shaft in all positions. Again, the inclination of the shaft B H is always towards H, so as to bring the collar B in contact with the box. Now to compensate for any wear which may displace the rolls H H, as well as to adjust them to different kinds of work, the collar B is always immediately adequate.

It will readily be seen that the above improvements secure advantages not possessed by any former construction, rendering the machine susceptible of immediate adaptation to plates of different thickness.

The above improvements are applied to other machines.

WOODS, VARIETIES OF, *used in the Mechanical Arts.*—By far the most numerous and important of the materials from the vegetable kingdom are the woods, with which most parts of our globe are abundantly supplied; great numbers of them are used in their respective countries, and are known to the naturalist, although but a very inconsiderable portion of them are familiar to us in our several local practices.

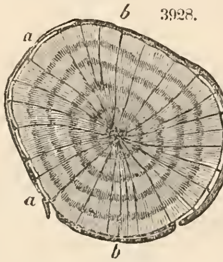
The woods that are most commonly employed in this country are enumerated in an alphabetical list, together with the most authentic information obtainable concerning them.

The general understanding of the principal differences of the woods will be greatly assisted by a brief examination into their structure which is now so commonly and beautifully developed by the sections for the microscope. The Figs. 3928, 3929, 3930 are drawn from thin cuttings of beech wood, prepared by the optician for that instrument; the principal lines alone are represented, and these are magnified to about twice their linear distances for greater perspicuity.

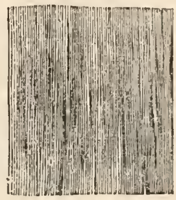
Fig. 3928, which represents the horizontal or transverse section of a young tree or a branch, shows the arrangement of the annual rings around the centre or pith; these rings are surrounded by an exterior covering, consisting also of several thinner layers, which it will suffice to consider collectively, in their common acceptation, or as the bark. The fibres which are seen as rays proceeding from the pith to the bark, are the medullary rays or plates.

Figs. 3929 and 3930 are vertical sections of an older piece of beech-wood. Fig. 3929 is cut through a plane, such as from *a* to *a*, in which the edges of the annual rings appear as tolerably parallel fibres running in one direction, or lengthways through the stem; the few thicker stripes are the edges of some of the medullary rays.

3928.



3929.



3930.

Fig. 3930 is cut radially, or through the heart, as from *b* to *b*. In this the fibres are observed to be arranged in two sets, or to run crossways; there are, first, the edges of the annual rings, as in Fig. 3929; and, secondly, the broad medullary rays or plates.

The whole of these figures, but especially the last, show the character of all the *proper* woods, namely, those possessing *two sets of fibres*, and in which the growth of the plant is accomplished, by the yearly addition of the external ring of the wood, and the internal ring of the bark, whence these rings are called annual rings, and the plants are said to be *exogenous*, from the growth of the *wood* being external.

In Fig. 3928 the medullary rays are the more distinctly drawn, in accordance with the appearance of the section, as they seem to constitute more determinate lines; whereas the annual rings consist rather of series of tubes arranged side by side, and in contact with each other, and which could not be represented on so small a scale. At the outer part of each annual ring these tubes or pores appear to be smaller and closer; the substance is, consequently, more dense, from the greater proportion of the matter forming the walls of the tubes; and the inner or the softer parts of the annual rings have in general larger vessels, and therefore less density.

In many plants the wedge-form plates, intermediate between the medullary rays, only appear as an irregular cellular tissue full of small tubes or pores, without any very definite arrangement.* The medullary rays constitute, however, the most characteristic part of the structure, and greatly assist in determining the difference between the varieties of the exogenous plants, as well as the wide distinction between the entire group and those shortly to be described. The medullary rays also appear, by their distinct continuity, to constitute the principal source of *combination* and strength in the substance of the woods; most of the medullary rays, in proceeding from the centre to the circumference, divide into parts to fill out the increased space.

In the general way, the vertical fibres of the annual rings, and the horizontal fibres of the medullary rays, are closely and uniformly intermingled; they form collectively the substance of the wood, and they also constitute two series of minute interstices, that are viewed to be either separate cells or vessels, the majority of which proceed vertically, the others radially. In many, as the oak, sycamore, maple, and sweet chestnut, the medullary rays, when dissected, exhibit a more expanded or foliated character, and pervade the structure, not as simple radial tubes, but as broad *septa* or divisions, which resemble flattened cells or clefts amongst the general groups of pores, giving rise to the term *silver-grain*, derived from their light and glossy appearance: they vary considerably in size and number.

The beech-wood, Fig. 3930, has been selected as a medium example between this peculiarity and the ordinary crossings of the fibres, which in the firs and several others seem as straight as if they were lines mechanically ruled, and, even in the most dense woods, are in general easily made out under the microscope.

The vessels or cells running amidst the fibres are to the plant what the blood-vessels and air-cells are to the animal; a part of them convey the crude sap from the roots, or the mouths of the plant, through the external layers of the wood to the leaves, in which the sap is evaporated and prepared; the fluid afterwards returns through the bark as the elaborated sap, and combines with that in the external layers of the wood, the two constituting the *cambium*. The latter ultimately becomes consolidated for the production of the new annual ring that is deposited beneath the loosened bark, and which is eventually to constitute a part of the general substance or wood; the bark also receives a minute addition yearly, and the remainder of the fluid returns to the earth as an excretion.†

The other order of the plants grows in an entirely different manner, namely, by a deposition from within, whence they are said to be *endogenous;* these include all the grasses, bamboos, palms, &c. *Endogens* are mostly hollow, and have only one set of fibres, the vertical, which appear in the transverse section, Fig. 3931, as irregular dots closely congregated around the margin, and gradually more distant towards the centre, until they finally disappear, and leave a central cavity, or a loose cellular structure. Fig. 3932 represents the horizontal, and Fig. 3933 the vertical section of portions of the same, or the cocoanut palm (*Cocos nucifera*) of half their full size.

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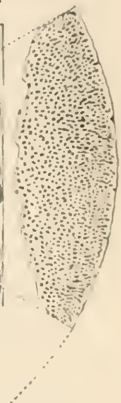
* In the *Cissampelos Pareira*, belonging to the natural order *Menispermaceæ*, this structure is singularly evident; the medullary rays are very thick, and almost detached from the intermediate wedge-form plates, which are nearly solid, except the few pores by which they are pierced, much like the substance of the common cane.

† The reader is referred to the following articles in the three editions of Dr. Lindley's Introduction to Botany, namely, "*Exogenous structure*," and "*Of the stem and origin of wood;*" and also, "*Exogens*," and "*Endogens*," by the same author, in the Penny Cyclopædia; all are replete with physiological interest.

All the *endogens* are considered to commence from a circular pithy stem, which is entirely solid; some, as the canes, maintain this solidity, with the exception of the tubes or pores extending throughout their length. The bamboos extend greatly in diameter, so as to become hollow, except the diaphragms at the knots; these are often used as cases for rolls of papers. The palms generally enlarge still more considerably to their extreme size, which, in some cases, is fifty times the diameter of the original stem, the centre being soft and pithy.

3932.

3931.



3933.

Some of the palms, &c., denote each yearly increase by one of the rings or markings upon their stems, which are always soft in the upper part, like a green vegetable, and terminate in a cluster of broad pendent leaves, generally annual, and when they drop off they leave circular marks upon the stem, which are sometimes permanent, and indicate by their number the age of the plant. The vertical fibres above referred to proceed from the leaves, and are considered to be analogous to their roots, and likewise to assimilate in function to the downward flow of the sap from the leaves of the *exogens:* whereas in the palms they constitute separate and detached fibres, that first proceed inwards, and then again outwards, with a very long and gradual sweep, thereby causing the fibres to be arranged in part vertically, and in part inclined, as in the figure.*

The substance of the stems of the palms is not allowed by physiological botanists to be proper wood, (which in all cases grows exteriorly, and possesses the two sets of fibres shown in Fig. 3930,) whereas the *endogenous* plants have only the one set, or the vertical fibres; and although many of this tribe yield an abundance of valuable gifts to the natives of the tropical climates in which they flourish, only a portion of the lower part of the *shell* of the tree is available as wood; amongst other purposes, the smaller kinds are used by the natives as tubes for the conveyance of water, and the larger pieces as joists and beams.

The larger palms generally reach us in slabs measuring about the sixth or eighth part of the circle, as in Fig. 3931, the smaller sizes are sent entire; Fig. 3932 represents a small piece near the outside, with the fibres half size; but the different palms vary considerably in the shapes, magnitudes, and distances of the fibres, and the colors and densities of the two parts.

In the vertical section, Fig. 3933, which is also drawn half size, the fibres look like streaks or wires imbedded in a substance similar to cement or pith, which is devoid of fibrous structure. The inhabitants of the Isthmus of Darien pick out the fibres from some of the palms and use them as nails; they are generally pointed, and in the specimens from which the drawing was made, they are as hard as rosewood, whereas the pithy substance is quite friable. Some of the smallest palms are imported into this country for walking-sticks, under the names of partridge and Penang canes, &c. The ordinary canes and bamboos are too well known to require more than to be named.

To return to the more particular examination of the woods that most concern us, it will be observed that the central pith in Fig. 3928 happens to be of an irregular triangular shape. This, the primary portion of the plant, is, in the first instance, always cylindrical; it is supposed to assume its accidental form (which is very frequently hexagonal) from the compression to which it is subjected. The pith governs, in a considerable degree, the general figure or section, as all the series of rings will be observed, in Fig. 3928, to have a disposition to project at three points; but with the successive additions, the angular form is gradually lost, as it would be if we wound a ribbon upon a small triangular wire; for, after a time, no material departure from the circular form would be observable.

A greater variation amongst the rings is due to the more or less favorable growth of the successive years, and to the different exposure of the tree to the sun and air, which develop that side of the plant in an additional degree; whereas the tree growing against a wall or any other obstruction, becomes remarkably stunted on that side of its axis, from being so shielded.

The growth of a tree is seldom so exactly uniform that its section is circular, or its heart central; often far from it; and as every annual ring is more consolidated, and of a deeper color on its outer surface, they frequently serve to denote very accurately, in the woods growing in cold and temperate climates, the age of the plant, the differences of the seasons, the circumstances of its situation, and the general rapidity of its growth. "But in many hot countries the difference between the growing season and that of rest, if any occur, is so small, that the zones are as it were confounded, and the observer finds himself incapable of distinguishing with exactness the formation of one year from that of another."†

It is, however, difficult to arrive at any satisfactory conclusion respecting the qualities of woods, from the appearance of their annual rings; for instance, in two specimens of larch, considered by Mr. Fincham‡ to be exceedingly similar, in specific gravity, strength, and durability; in the one, Scotch larch, there were only three annual rings in five eighths of an inch, whereas in Italian larch there were twenty four layers in the same space. In some of the tropical woods the appearance of the rings can scarcely be defined, and in a specimen of the lower or butt-end of teak, now before us, three annual rings alone cover the great space of one inch and three-eighths.

* The leaves of the exogens are by some thought to send down similar roots or fibres between the bark and wood to the formation of the annual ring.

† Dr. Lindley's Introduction to Botany, second edition, p. 74.

‡ Principal builder of the Chatham Dock-yard, England, and a writer on ship-building.

The horizontal section of a tree occasionally looks as if it were the result of two, three, or more separate shoots or stems consolidated into one; in some of the foreign woods in particular this irregularity often gives rise to deep indentations, and most strange shapes, which become eventually surrounded by one single covering of sap; so that a stem of considerable girth may yield only an insignificant piece of wood, scarcely available for the smallest purposes of turnery, much less for cabinet-work.*

The circulation of the sap is considered to be limited to a few of the external layers, or those of the sap-wood, or *alburnum*, which are in a less matured state than the perfect wood, or *duramen*, beneath. The last act of the circulation, as regards the heart-wood, is supposed to be the deposition of the coloring matter, resin or gum, through the agency of the medullary rays that proceed from the bark towards the centre, and leave their contents in the layer outside the true wood perfected the year previous. We may fairly suppose by analogy, that as one ring is added each year, so one is perfected annually, and thrown out of the circulatory system.

That the circulation has ceased in the heart-wood, and that the connection between it and the bark has become broken, is further proved by the fact, that numbers of trees may be found in tolerably vigorous growth within the bark, whereas at the heart they are decayed and rotten. In fact, some of the hardest foreign woods, as kingwood, tulip-wood, and others, are rarely sound in the centre, and thus indicate very clearly that their decay commenced whilst they were in their parent soil; and as in these the appearance of annual rings is scarcely to be distinguished, this also appears to indicate a great term of age, enough to account for this relatively premature decay.

The quantity of sap-wood is various in different plants, and the line of division is usually most distinctly marked; in some, as boxwood, the sap-wood is very inconsiderable, and together with the bark is on the average only about the thickness of a stout card, whereas in others, as the snakewood, it constitutes fully two-thirds of the diameter, so that a large tree yields but an inconsiderable stick of wood, of one-third or fourth the external diameter.

It may be presumed that, in the same variety of wood, about an average number of the layers exist as sap-wood, as in cutting up a number of pieces of the same kind, such as the black Botany-Bay wood, and others, it is found that, in those measuring about two inches diameter, the piece of heart-wood is only about as large as the finger, but in pieces one, two, or three inches larger, the heart-wood is also respectively one, two, or three inches larger, or nearly to the full extent of the increase of the diameter.

The sap-wood may be therefore, in general, considered as of about an average thickness in each kind of wood: it is mostly softer, lighter, more even in color, and more disposed to decay than the heart-wood, which prove it to be in a less matured or useful state, whether for mechanical or chemical purposes.

At the time the tree is separated from its root, its organic life ceases, and then commences the gradual evaporation of the sap, and the drying and contracting of the tubes, or tissues, previously distended by its presence.

The woods are in general felled during the cold months, when the vegetative powers of the plant are nearly dormant, and when they are the most free from sap; but none of the woods are fit for use in the state in which they are cut down, for although no distinct circulation is going on within the heart-wood still the capillary vessels keep the trees continually moist throughout their substance, in which state they should not be employed.

If the green or wet woods are placed in confined situations, the tree or plank first becomes stained or doated, and this speedily leads to its decomposition or decay, effects that are averted by careful drying with free access of air.†

Other mischiefs almost as fatal as decay also occur to unseasoned woods; round blocks cut out of the entire circular stem of green wood, or the same pieces divided into quarterings, split in the direction of the medullary rays, or radially, also, though less frequently, upon the annual rings. Such of the round blocks as consist of the entire section contract pretty equally, and nearly retain their circular form, but those from the quarterings become oval from their unequal shrinking.

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* This is not peculiar to the tropical woods; for example, some of the yew-trees in Hampton Court gardens appear to have grown in this manner from three or four separate stems, that have joined into one at a short distance above the ground. As an instance of the singular manner in which the separate branches of trees thus combine, I may mention that stones, pieces of metal, and other substances, are occasionally met with in the central parts of timber, from having been accidentally deposited in a cleft, or the fork of a branch, and entirely inclosed or overgrown by the subsequent increase of the plant.

† On this account the timbers for ships are usually cut out to their shape and dimensions for about a year before they are framed together, and they are commonly left a twelvemonth longer in the skeleton state, to complete the seasoning, as in that condition they are more favorably situated as regards exposure to the air than when they are closely covered in with the planking.

Mr. Fincham considers that the destruction of timber by the decay commonly known as dry-rot cannot occur, unless air, moisture, and heat, are all present, and that the entire exclusion of any of the three stays the mischief. By way of experiment, he bored a hole in one of the timbers of an old ship, built of oak, whose wood was at the time perfectly sound; the admission of air, the third element, to the central part of the wood, (the two others being to a certain degree present,) caused the hole to be filled up in the course of twenty-four hours with mouldiness, a well-known vegetation, which very speedily became so compact a fungus as to admit of being withdrawn like a stick. He considers the shakes or splits in timber to predispose it to decay, in damp and confined situations, from admitting the air in the same manner.

The woods differ amazingly in their resistance to decay; some perish in one or two years, whereas others are very durable, and even preserve their fragrance when they are opened after many years, or almost centuries.

Mr. G. Loddiges says the oak-boxes, for the plants in his green-houses, decay in two or three years, whereas he has found those of teak to last fully six or seven times as long: the situation is one of severe trial for the wood.

There are two quarto works on dry-rot; the one by Mr. M'William, 1818; the other by Mr. John Knowles, Surveyor of Her Majesty's Navy, 1821.

The process of Kyanizing is intended to prevent the re-vegetation of timber, by infusing into its pores an antiseptic salt: the corrosive sublimate is generally employed, other metallic salts are also considered to be applicable, but the general utility of the process, especially in thick timbers, or those exposed to much wet, is still unsettled amongst practical men.

The Kyanizing is sometimes done in open tanks, at others, (by Timperley's process, Hull and Selby Railway,) in close vessels from which the air is first exhausted to the utmost, and the fluid is then admitted under a pressure of about 100 pounds on the inch.

As a general observation, it may be said the woods do not alter in any material degree in respect to length. Boards and flat pieces contract, however, in width, they warp and twist, and when they are fitted as panels into loose grooves, they shrink away from that edge which happens to be the most slightly held; but when restrained by nails, mortises, or other unyielding attachments, which do not allow them the power of contraction, they split with irresistible force, and the materials and labor thus improperly employed will render no useful service.

In general, the softest woods shrink the most in width, but no correct observations on this subject have been published. Mr. Fincham considers the rock-elm to shrink as much as any wood, namely, about half an inch in the foot, whereas the teak scarcely shrinks at all; in the "Tortoise" store-ship, when fifty years old, no openings were found to exist between the boards.

In the woods that have been partially dried, some of these effects are lessened when they are defended by paint or varnish, but they do not then cease, and, with dry wood, every time a new surface is exposed to the air, even should the work have been made for many years, these perplexing alterations will in a degree recommence, even independently of the changes of the atmosphere, the fluctuations of which the woods are at all times too freely disposed to obey.

The disposition to shrink and warp, from atmospheric influence, appears indeed to be never entirely subdued; some bog-oak, supposed to have been buried in the island of Sheppy not less than a thousand years, was dried for many months, and ultimately made into chairs and furniture; it was still found to shrink and cast, when divided into the small pieces required for the work.

Seasoning and preparing the woods.—Having briefly alluded to the mischiefs consequent upon the use of woods in an improper condition, I shall proceed to describe the general modes pursued for avoiding such mischiefs by a proper course of preparation:

The woods, immediately after being felled, are sometimes immersed in running water for a few days, weeks, or months, at other times they are boiled or steamed; this appears to be done under the expectation of diluting and washing out the sap, after which it is said the drying is more rapidly and better accomplished, and also that the colors of the white woods are improved, (see article Holly in Catalogue, also Ebony;) but the ordinary course is simply to expose the logs to the air, the effect of which is assisted by the preparation of the wood into smaller pieces, approaching to the sizes and forms in which they will be ultimately used, such as square logs and beams, planks or boards of various thicknesses, short lengths or quarterings, &c.

The stems and branches of the woods of our own country, such as alder, birch, and beech, that are used by the turner, frequently require no reduction in diameter; but when they are beyond the size of the work, they are split into quarterings and stacked in heaps to dry, which latter proceeding should never be forgotten under any circumstances.

We know but little of the early treatment of the foreign woods used for cabinet-work and turning; some few of them, as mahogany and satin-wood, are imported in square logs; others, as rosewood, ebony, or Coromandel, are sometimes shipped in the halves of trees, or in thick planks; but the generality of those used for turning are small, and do not require this reduction; these only reach us in billets, sometimes with the rind or bark upon them, and sometimes cleaned or trimmed.

The smaller hard woods are very much more wasteful than the timber woods; in many of the former, independently of their thick bark, the section is very far from circular, as they are often exceedingly irregular, indented, and ill-defined; others are almost constantly unsound in their growth, and either present central hollows and cavities, or cracks and radial divisions, which separate the stem into three or four irregular pieces.

Probably none of the hard woods are so defective as the black Botany-Bay wood, in which the available produce, when it is trimmed ready for the lathe, may be considered to be about one third or fourth of the original weight, sometimes still less; but unfortunately many others approach too nearly to this condition, as a very large proportion of them partake of the imperfections referred to, more especially the cracks; the larger hard woods are by comparison much less wasteful.

All the harder woods require increased care in the seasoning, which is often badly begun by exposure to the sun or hot winds in their native climates: their greater impenetrability to the air the more disposes them to crack, and their comparative scarcity and expense are also powerful arguments on the score of precaution. It is therefore desirable to prepare them for the transition from the yard or cellar to the turning-room, by removing the parts which are necessarily wasted, the more intimately to expose them to the air some time before they are placed in the house, and they should be always kept away from the fire, or at first in a room altogether without one.

It is usual to begin by cutting the logs into pieces a few inches or upwards in length, to the general size of the work; and if possible to prepare every piece into a round block, or into two or three, when the wood is irregular, hollow, or cracked. In the latter case, a thin wedge is inserted into the principal crack, and driven down with a wooden maul; or a cleaver which has a sharp edge, and a poll to receive the blow, is used in the same manner; these tools, or the hatchet, are likewise used in splitting up the English woods, when they are beyond the diameters required.* The cleft pieces are next roughly trimmed with the hatchet, or else with the paring-knife, a tool of safer and more economical application in the hands of the amateur: it is a lever knife, from two and a half to three feet long, the cutting-edge is near that end which terminates in a hook, the other extremity has a transverse handle; an eye bolt for the hook to act against is screwed into the bench or block, and a detached cutting-board is fixed under the blade, to serve as the support for the wood, and for the knife to cut upon. To avoid waste of material, it is advisable, until the eye is well accustomed to the work, to score with the compasses upon each end of the rough block as large a circle as it will allow, to serve as a guide for the knife.

The block is adapted to the bearers of the lathe, but any other support will serve equally well. The paring knife is also employed for other purposes besides those of the turner; it is sometimes made with

* Sometimes the glazier's chipping knife is used for small pieces of wood instead of the cleaver.

a curved edge like a gouge, and is used in many shaping operations in wood, as in the manufacture of shoe-lasts, clogs, pattens, and toys.*

In the absence of the paring-knife or hatchet, the work is fixed in the vice, and rounded with a coarse rasp, but this is much less expeditious: by some manufacturers the preparation both of the foreign and English woods is prosecuted still further, by cutting the material into smaller pieces, rough turned and hollowed in the lathe, to the forms of boxes, or other articles for which they are specifically intended; and in fact every measure that tends to make the change of condition gradual, assists also in the economy, perfection, and permanence of the work.

Many of the timber-woods are divided at the saw-pit into planks or boards, at an early stage, in order to multiply the surfaces upon which the air may act, and also to leave a less distance for its penetration: after sawing, they should never be allowed to rest in contact, as the partial admission of the air often causes stains or doating; but they are placed either perpendicularly or horizontally in racks, or they are more commonly stacked in horizontal piles, with parallel slips of wood placed between at distances from about three to six or eight feet, according to the quantity of support required; the pile when carefully stacked forms a press, and keeps the whole flat and straight.

Thin pieces will be sufficiently seasoned in about one year's time, but thick wood requires two or three years, before it is thoroughly fit to be removed to the warmer temperature of the house for the completion of the drying. Mahogany, cedar, rosewood, and the other large foreign woods, require to be carefully dried after they are cut into plank, as notwithstanding the length of time that sometimes intervenes between their being felled and brought into use, they still retain much of their moisture whilst they remain in the log.†

In some manufactories the wood is placed, for a few days before it is worked up, in a drying-room heated by means of stoves, steam, or hot water, to several degrees beyond the temperature to which the finished work is likely to be subjected.

Such rooms are frequently made as air-tight as possible, which appears to be a mistake, as the wood is then surrounded by a warm but stagnant atmosphere, which retains whatever moisture it may have evaporated from the wood. Of late, a plan has been more successfully practised in seasoning timber for building purposes, by the employment of heated rooms with a free circulation of air, which enters at the lower part in a hot and dry state, and escapes at the upper charged with the moisture, which it freely absorbs in the heated condition. The continual ingress of hot dry air, greedy of moisture, so far expedites the drying, that it is accomplished in one-third of the time that is required in the ordinary way in the open air.‡

Hard and soft woods, etc.—The relative terms hard and soft, elastic or non-elastic, and the proportions of resins, gums, &c., as applied to the woods, appear to be in a great measure explained by their examination under the microscope, which develops their structure in a very satisfactory manner.

The fibres of the various woods do not appear to differ so materially in individual size or bulk, as in their densities and distances: those of the soft woods, such as willow, alder, and deal, appear slight and loose; they are placed rather wide asunder, and present considerable intervals for the softer and more spongy cellular tissue between them; whereas in oak, mahogany, ebony, and rosewood, the fibres appear rather smaller, but as if they possessed a similar quantity of matter, just as threads containing the same number of filaments are larger or smaller, accordingly as they are spun. The fibres are also more closely arranged in the harder woods, the intervals between them are necessarily less, and the whole appears a more solid and compact formation.

The very different tools used by the turner for the soft woods and hard woods respectively, may have assisted in fixing these denominations as regards his art; a division that is less specifically entertained by the joiner, who uses the same tools for the hard and soft woods, excepting a trifling difference in their angles and inclinations; whereas the turner employs, for the soft woods, tools with keen edges of thirty or forty degrees, applied obliquely, and as a tangent to the circle; and for the hard woods, tools of from seventy to ninety degrees upon the edge, applied as a radius, and parallel with the fibres, if so required. The tools last described answer very properly for the dense woods, in which the fibres are close and well united; but applied to the softer kinds, in which the filaments are more tender and less firmly joined, the hard-wood tools produce rough, torn, and unfinished surfaces.

In general, the weight or specific gravity of the woods may be taken as a sure criterion of their hardness; for instance, the hard lignum-vitæ, boxwood, iron-wood, and others, are mostly so heavy as to sink in water; whereas the soft firs, poplar, and willow, do not, on the average, exceed half the weight of water, and other woods are of intermediate kinds.§

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* A paring-knife working in a guide, and with an edge twelve or fourteen inches long, is a most effective instrument in the hands of the toy-makers. The pieces of birch, alder, &c., are boiled in a cauldron for about an hour to soften them, and whilst hot they may be worked with great expedition and perfection. The workmen pare off slices, the plankway of the grain, as large as four by six inches, almost as quickly as they can be counted: they are wedged tight in rows, like books, to cause them to dry flat and straight, and they seldom require any subsequent smoothing. In making the little wheels for carts, &c., say of one or two inches diameter, and one-quarter or three-eighths of an inch thick, they cut them the *cross-way of the grain*, out of cylinders previously turned and bored; the flexibility of the hot moist wood being such that it yields to the edge of the knife, without breaking transversely as might be expected.

† Scientifically considered, the drying is only said to be complete when the wood ceases to lose weight from evaporation: this does not occur after twice or thrice the period usually allowed for the process of seasoning.

In many modern buildings small openings are left, through the walls to the external air, to allow a partial circulation amidst the beams and joists, as a preservative from decay, and for the entire completion of the seasoning.

‡ Price's Patent.

§ The most dense wood is the Iron Bark wood from New South Wales: in appearance it resembles a close hard mahogany, but more brown than red; its specific gravity is 1·426,—its strength (compared with English oak, taken as usual at 1·000) is 1·557. On the other hand, the lightest of the *true* woods is probably the *Cortiça*, or the *Anona palustris*, from Brazil, in Mr. Mier's collection; the specific gravity of this is only 0·206, whereas that of cork is 0·240; it has only one-seventh the weight of Iron Bark wood. The *Cortiça* resembles ash in color and grain, except that it is paler, finer, and much softer; it is used by the natives for wooden shoes, &c.

The density or weight of many of the woods may be increased by their mechanical compression, which may be carried to the extent of fully one-third or fourth of their primary bulk, and the weight and hardness obtain a corresponding increase. This has been practised for the compression of tree-nails for ships, by driving the pins through a metal ring smaller than themselves directly into the hole in the ship's side;* at other times, (for railway purposes,) the woods have been passed through rollers, but this practice has been discontinued, as it is found to spread the fibres laterally, and to tear them asunder,† an injury that does not occur when they are forced through a ring, which condenses the wood at all parts alike without any disturbance of its fibrous structure,‡ even when tested by the microscope; after compression, the wood is so much harder that it cuts very differently, and the pieces almost ring when they are struck together; fir may be thus compressed into a substance as close as pitch-pine.

In many of the more dense woods, we also find an abundance of gum or resin, which fills up many of those spaces that would be otherwise void: the gum not only makes the wood so much the heavier, but at the same time it appears to act in a mechanical manner, to mingle with the fibres as a cement, and to unite them into a stronger mass; for example, it is the turpentine that gives to the outer surface of the annual rings of the red and yellow deals the hard, horny character, and increases the elasticity of those timbers.

Those woods which are the more completely impregnated with resin, gum, or oil, are in general also the more durable, as they are better defended from the attacks of moisture and insects.

Timbers alternately exposed to wet and dry, are thought, by Tredgold and others, to suffer from losing every time a certain portion of their soluble parts; if so, those which are naturally impregnated with substances insoluble in water may, in consequence, give out little or none of their component parts in the change from wet to dry, and on that account the better resist decay: this has been artificially imitated by forcing oil, tar, &c., through the pores of the wood from the one extremity.§

Many of the woods are very durable when constantly wet; the generality are so when always dry, although but few are suited to withstand the continual change from one to the other state; but these particulars, and many points of information respecting timber-woods that concern the general practice of the builder, or naval architect, such as their specific gravities, relative strengths, resistances to bending and compression, and other characters, are treated of in Tredgold's Elements of Carpentry, at considerable length.‖

Elastic and non-elastic woods.—The most elastic woods are those in which the annual or longitudinal fibres are the straightest, and the least interwoven with the medullary rays, and which are the least interrupted by the presence of knots; such woods are also the most easily rent, and the plainest in figure, as the lancewood, hickory, and ash; whereas other woods, in which the fibres are more crossed and interlaced, are considerably tougher and more rigid; they are also less disposed to split in a straight or economical manner, as oak, beech, and mahogany, which, although moderately elastic, do not bend with the facility of those before named.

Fishing-rods, unless made of bamboo, have generally ash for the lower joint, hickory for the two middle pieces, and a strip cut out of a bamboo of three or four inches diameter as the top joint. Archery bows are another example of elastic works; the "single-piece bow" is made of one rod of hickory, lancewood, or yew-tree, which last, if perfectly free from knots, is considered the most suitable wood: the "back or union bow" is made of two or sometimes three pieces glued together. The *back-piece*, or that furthest from the string, is of rectangular section, and always of lancewood or hickory; the *belly*, which is nearly of semicircular section, is made of any hard wood that can be obtained straight and clean, as ruby-wood, rosewood, greenheart, kingwood, snakewood, and several others: it is in a great measure a matter of taste, as the elasticity is principally due to the back-piece; the palmyra is also used for bows.¶

The elasticity, or rather the flexibility of the woods, is greatly increased for the time, when they are heated by steaming or boiling; the process is continually employed for bending the oak and other timbers for ship-building, the lancewood shafts for carriages, the staves of casks, and various other works.

The woods are steamed in suitable vessels, and are screwed or wedged, at short intervals throughout their length, in contact with rigid patterns or moulds, and whilst under this restraint they are allowed to become perfectly cold; the pieces are then released. These bent works suffer very little departure from the forms thus given, and they possess the great advantage of the grain being parallel with the curve, which adds materially to their strength, saves much cost of material and time in the preparation, and gives, in fact, a new character to the timber.

The inner and outer plankings of ships are steamed or boiled before they are applied; they are brought into contact with the ribs by temporary screw-bolts, which are ultimately replaced by the cop-

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The *Pita* wood, that of the *Fourcroya gigantea*, of the Brazils, an *endogen* almost like pith, (used by the fishermen of Rio Janeiro, as a slow match, for lighting cigars, &c.; also like cork for lining the drawers of cabinets for insects,) and the rice-paper plant of India and China, which is still lighter and more pithy, can hardly be taken into comparison.

* Mr. Annersley's Patent, 1821, for building vessels of planks only, without ribs.

† Dublin and Kingston Railway.

‡ The mode at present practised by the Messrs. Ransome, of Ipswich, (under their patent,) is to drive the pieces of oak into an iron ring by means of a screw-press, and to expose them within the ring to a temperature of about 180° for twelve or sixteen hours before forcing them out again.

The tree-nails may be thus compressed into two-thirds their original size, and they recover three-fourths of the compression on being wetted; they are used for railway purposes, but appear equally desirable for ship-building, in which the tree-nails fulfil an important office, and in either case their after expansion fixes them most securely.

§ The durability of *pitch* pine, when "wet and dry," is however questioned.

‖ The work contains a variety of the most useful tables.

¶ The union bow is considered to be "softer," that is, more agreeably elastic than the single-piece bow, even when the two require the same weight to draw them to the length of the arrow. In the act of bending the bow the back is put into tension, and the inner piece into a state of compression, and each wood is then employed in its most suitable manner. Sometimes the union bow is imitated by one solid piece of straight cocoa-wood, (of the West Indies, not that of the *cocoa-nut palm*,) in which case the tough fibrous sap is used for the back, and in its nature sufficiently resembles the lancewood more generally used.

per bolts inserted through the three thicknesses and riveted: or they are secured by oak or locust tree nails, which are caulked at each end.*

Boiling and steaming are likewise employed for softening the woods, to facilitate the cutting as well as bending of them.†

When the two sets of fibres meet in confused angular directions, they produce the tough cross-grained woods, such as lignum-vitæ, elm, &c., and, like the diagonal braces in carpentry and shipping, they deprive the mass of elasticity, and dispose it rather to break than to bend, especially when the pieces are thin, and the fibres crop out on both sides of the same; the confusion of the fibres is, at the same time, a fertile source of beauty in appearance to most woods.

Elm is perhaps the toughest of the European woods; it is considered to bear the driving of bolts and nails better than any other, and it is on this account, and also for its great durability under water, constantly employed for the keels of ships, for boat-building, and a variety of works requiring great strength and exposure to wet.

A similar rigidity is also found to exist in the crooked and knotted limbs of trees from the confusion amongst the fibres, and such gnarled pieces of timber, especially those of oak, were in former days particularly valued for the knees of ships: of later years they have been in a great measure superseded by iron knees, which can be more accurately and effectively moulded at the forge to suit their respective places, and they cause a very great saving in the available room of the vessel.

The lignum-vitæ is a most peculiar wood, as its fibres seem arranged in moderately thick layers, crossing each other obliquely, often at as great an angle as thirty degrees with the axis of the tree; when the wood is split, it almost appears as if the one layer of annual fibres grew after the manner of an ordinary screw, and the succeeding layer wound the other way so as to cross them like a left-hand screw. The interlacement of the fibres in lignum-vitæ is so rigid and decided, although irregular, that it exceeds all other woods in resistance to splitting, which cannot be effected with economy; the wood is consequently always prepared with the saw. It is used for works that have to sustain great pressure and rough usage, several examples of which are given under the head LIGNUM-VITÆ in the Catalogue already referred to.

Fibre or grain, knots, etc.—The ornamental figure or grain of many of the woods appears to depend as much or more upon the particular directions and mixings of the fibres, as upon their differences of color. We will first consider the effect of the fibre, assisted only by the slight variation of tint, observable between the inner and outer surfaces of the annual layers, and the lighter or more silky character of the medullary rays.

If the tree consisted of a series of truly cylindrical rings, like the tubes of a telescope, the horizontal section would exhibit circles; the vertical, parallel straight lines; and the oblique section would present parts of ovals; but nature rarely works with such formality, and but few trees are either exactly circular or straight, and therefore although the three natural sections have a general disposition to the figures described, every little bend and twist in the tree disturbs the regularity of the fibres, and adds to the variety and ornament of the wood.

The horizontal section, or that parallel with the earth, only displays the annual rings and medullary rays, as in Fig. 3928; and this division of the wood is principally employed by the turner, as it is particularly appropriate to his works, the strength and shrinking being alike at all parts of the circumference, in the blocks and slices cut out of the entire tree, and tolerably so in those works turned out of the quarterings or parts of the transverse pieces.

But as the cut is made intermediate between the horizontal line and the one parallel with the axis, the figure gradually slides into that of the ordinary plank, magnified portions of which are shown in Figs. 3929 and 3930; and these are almost invariably selected for carpentry, &c.

The oblique slices of the woods possess neither the uniformity of grain of the one section, nor the strength of the other, and it would be likewise a most wasteful method of cutting up the timber; it is therefore only resorted to for thin veneers, when some particular figure or arrangement of the fibres has to be obtained for the purposes of ornamental cabinet-work.

The perpendicular cut through the heart of the tree is not only the hardest but the most diversified because therein occurs the greatest mixture and variety of the fibres, the first and the last of which, in point of age, are then presented in the same plank; but of course the density and diversity lessen as the board is cut further away from the axis. In general the radial cut is also more ornamental than the tangential, as in the former the medullary rays produce the principal effect, because they are then displayed in broader masses, and are considered to contain the greater proportion of the coloring matter of the wood.

The section through the heart displays likewise the origin of most of the branches, which arise first as

* See the description of Mr. William Hookey's apparatus for bending ships' timbers, rewarded by the Society of Arts, and described in their Trans., vol. 32, p. 91.

Preference is now given to the "Steam Kiln" over the "Water Kiln," and the time allowed is one hour for every inch of the thickness of the timber; it loses much extractive matter in the process, which is never attempted a second time, as the wood then becomes brittle.

Colonel G. A. Lloyd devised an ingenious and economical mode of bending the timbers to constitute the ribs of a teak-bridge which he built in the Mauritius. Every rib was about 180 ft. long, and of 8 ft. rise, and consisted of five thicknesses of wood of various lengths and widths. The wood had been cut down about a month; it was well steamed and brought into contact with a strong mould, by means of an iron chain attached to a hook at the one extremity of the mould and passed under a roller fixed at the other; the chain was drawn tight by a powerful capstan. Whilst under restraint the neighboring pieces were pinned together by tree-nails, after which a further portion of the rib was proceeded with: the seasoning of the timber was also effected by the process.

† Thus in Taylor's Patent Machinery for making casks, the blocks intended for the staves are cut out of white Canada oak to the size of thirty inches by five, and smaller. They are well steamed, and then sliced into pieces one-half or five-eighths inch thick, at the rate of 200 in each minute, by a process far more rapid and economical than sawing; the instrument being a revolving iron plate of 12 or 14 feet diameter, with two radial knives, arranged somewhat like the irons of an ordinary plane or spokeshave.

knots, in or near the central pith, and then work outwards in directions corresponding with the arms of the trees, some of which, as in the cypress and oak, grow out nearly horizontally, and others, as in the poplar, shoot up almost perpendicularly.

Those parts of wood described as curls are the result of the confused filling in of the space between the forks, or the springings of the branches. Fig. 3934 represents the section of a piece of yew-tree, which shows remarkably well the direction of the main stem A B, the origin of the branch C, and likewise the formation of the curl between B and C; Fig. 3935 is the end view of the stem at A. In many woods, mahogany especially, the curls are particularly large, handsome, and variegated, and are generally produced as explained.

3934.

B

A

3935.

It would appear as if the germs of the primary branches were set at a very early period of the growth of the central stem, and gave rise to the knots, many of which, however, fail to penetrate to the exterior so as to produce branches, but are covered over by the more vigorous deposition of the annual rings. All these knots and branches act as so many disturbances and interruptions to the uniformity of the principal zones of fibres, which appear to divide to make way for the passage of the offshoots, each of which possesses in its axis a filament of the pith, so that the branch resembles the general trunk in all respects except in bulk; and again from the principal branches smaller ones continually arise, ending at last in the most minute twigs, each of which is distinctly continuous with the central pith of the main stem, and fulfils its individual share in causing the diversity of figure in the wood.

The knots are commonly harder than the general substance, and that more particularly in the softer woods; the knots of the deals, for example, begin near the axis of the tree, and at first show the mingling of the general fibres with those of the knot, much the same as in the origin of the branch of the yew, in Fig. 3934; but after a little while it appears as if the branch, from elongating so much more rapidly than the deposition of the annual rings upon the main stem, soon shot through and became entirely detached, and the future rings of the trunk were bent and turned slightly aside when they encountered the knot, but without uniting with it in any respect.

This may explain why the smooth cylindrical knots of the outer boards of white deal, pine, &c., so frequently drop out when exposed on both sides in thin boards; whereas the turpentine in the red and yellow deals may serve the part of a cement, and retain these kinds the more firmly.

The elliptical form of the knots in the plank is mostly due to the oblique direction in which they are cut, and their hardness (equal to that of many of the tropical hard woods) to the close grouping of the annual rings and fibres of which they are themselves composed. These are compressed by the surrounding wood of the parent stem, at the time of the deposition; whereas the principal layers of the stem of the tree are opposed alone by the loosened and yielding bark, and only obtain the ordinary density.

The knots of large trees are sometimes of considerable size. The writer has portions of one of those of the Norfolk Island pine, (*Araucaria excelsa*,) which attained the enormous size of about four feet long, and four to six inches diameter. In substance it is throughout compact and solid, of a semi-transparent hazel-brown, and it may be cut almost as well as ivory, and with the same tools, either into screws, or with eccentric or drilled work, &c.; it is an exceedingly appropriate material for ornamental turning.

It is by some supposed, that the root of a tree is divided into about as many parts or subdivisions as there are branches, and that, speaking generally, the roots spread around the trunk under ground to about the same distance as the branches wave above; the little germs or knots from which they proceed being in the one case distributed throughout the length of the stem of the tree, and in the other crowded together in the shorter portion buried in the earth.

If this be true, we have a sufficient reason for the beautiful but gnarled character of the roots of trees when they are cut up for the arts; many a block of the root of the walnut tree, thus made up of small knots and curls, and that was first intended for the stock of a fowling piece, has been cut into veneers and arranged in angular pieces to form the circular picture of a table; and few pictures of this natural kind will be found more beautiful. The roots of many trees also display very pretty markings; some are cut into veneers, and those of the olive tree, and others, are much used on the continent for making snuff boxes.

The tops of the pollard-trees, such as the red oak, elm, ash, and other trees, owe their beauty to a similar crowding together of the little germs, whence have originated the numerous shoots which proceeded from them after they have been lopped. The burrs or excrescences of the yew, and some other trees, appear to arise from a similar cause, apparently the unsuccessful attempts at the formation of branches from one individual spot; from this may arise those bosses or wens, which almost appear as the result of disease, and exhibit internally crowds of knots, with fibres surrounding them in the most fantastic shapes. Sometimes the burrs occur of immense size, so as to yield a large and thick slab of highly ornamental wood of most confused and irregular growth: such pieces are highly prized, and are cut into thin veneers to be used in cabinet-work.

It appears extremely clear likewise that the beautiful East Indian wood, called both Kiabooca and

Amboyna, is, in like manner, the excrescence of a large timber-tree. Its character is very similar to the burr of the yew-tree, but its knots are commonly smaller, closer, and the grain or fibre is more silky The Kiabooca has also been supposed to be cut from around the base of the cocoanut palm, a surmise that is hardly to be maintained, although the latter may resemble it, as the Kiabooca is imported alone from the East Indies, whereas the cocoanut palm is common and abundant both in the eastern and western hemispheres. (See *Kiabooca* in the Catalogue.*)

The bird's-eye maple shows, in the finished work, the peculiar appearance of small dots or ridges, or of little conical projections with a small hollow in the centre, (to compare the trivial with the grand like the summits of mountains, or the craters of volcanoes,) but without any resemblance to knots, which are the apparent cause of ornament in woods of somewhat similar character, as the burrs of the yew and kiabooca, and the Russian maple, (or birch-tree:) this led us to seek a different cause for its formation.

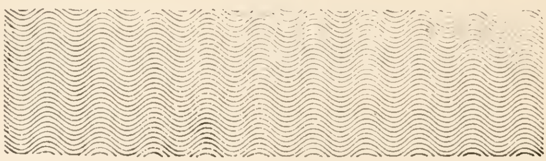
On examination, we found the stem of the American bird's-eye maple, stripped of its bark, presented little pits or hollows of irregular form, some as if made with a conical punch, others ill-defined and flattened like the impression of a hob-nail; suspecting these indentations to arise from internal spines or points in the bark, a piece of the latter was stripped off from another block, when the surmise was verified by their appearance. The layers of the wood being moulded upon these spines, each of their fibres is abruptly curved at the respective places, and when cut through by the plane, they give, in the *tangential* slice, the appearance of projections, the same as in some rose-engine patterns, and the more recent medallic glyptographic or stereographic engravings, in which the closer approximation of the lines, at their curvatures, causes those parts to be more black, (or shaded,) and produces upon the plane surfaces the appearances of waves and ridges, or of the subject of the medal.

The short lines observed throughout the maple-wood, between the dots or eyes, are the edges of the medullary rays; and the same piece of wood, when examined upon the radial section, exhibits the ordinary silver grain, such as we find in the sycamore, (to which family the maple-tree belongs,) with a very few of the dots, and those displayed in a far less ornamental manner.

The piece examined measured eight inches wide, and five and a half inches radially, and was apparently the produce of a tree of about sixteen inches diameter; the effect of the internal spines of the bark was observable entirely across the same; that is, through each of the 130 zones of which it consisted. The curvature of the fibres was in general rather greater towards the centre, which is to be accounted for by the successive annual depositions upon the bark, detracting in a small degree from the height or magnitude of the spines within the same, upon which the several deposits of wood were formed. Other woods also exhibit spines, which may be intended for the better attachment of the bark to the stem, but, from their comparative minuteness, they produce no such effect on the wood as that which exists, we believe exclusively, in the bird's-eye maple.

This led me to conclude that in woods, the figures of which resemble the undulations, or the ripple-marks on the sands, that frequently occur in satin-wood and sycamore, less frequently in boxwood, and also in mahogany, ash, elm, and other woods, to be due to a cause explained by Fig. 3936, namely, a serpentine or *guilloche* form in the grain: and on inspection, the fibres of all such pieces will be found to be wavy, on the face, at right angles to that on which the ripple is observed, if not on both faces. Those parts of the wood which happen to receive the light appear the brightest, and form the ascending sides of the ripple, just as some of the medallic engravings appear in cameo or in intaglio, according to the direction in which the light falls upon them.

3936.



The woods possessing this wavy character generally split with an undulating fracture, the ridges being commonly at right angles to the axis of the tree, or square across the board; but in a specimen of an Indian red wood, the native name of which is *Caliatour*, the ridges are inclined at a considerable angle, presenting a very peculiar appearance, seen as usual on the polished surface.

In those woods which possess in abundance the *septa* or *silver grain*, described by the botanist as the medullary plates or rays, the representations of which, as regards the beech-tree, are given in Fig. 3930, another source of ornament exists; namely, a peculiar damask or dappled effect, somewhat analogous to that artificially produced on damasked linens, moreens, silks, and other fabrics, the patterns on which result from certain masses of the threads on the face of the cloth running lengthways, and other groups crossways. This effect is observable in a remarkable degree in the more central planks of oak, especially the light-colored wood from Norway, and the neighborhood of the Rhine, called wainscot and Dutch oak, &c., and also in many other woods, although in a less degree.

In the oak plank, the principal streaks or lines are the edges of the annual rings, which show, as usual

* Mr. G. Loddiges considers the burrs may occur upon almost all *old* trees, and that they result from the last attempt of the plant to maintain life, by the reparation of any injury it may have received.

parallel lines more or less waved from the curvature of the tree, or the neighboring knots and branches and the damask pencillings, or broad curly veins and stripes, are caused by groups of the medullary rays or *septa*, which undulate in layers from the margin to the centre of the tree, and creep in betwixt the longitudinal fibres, above some of them and below others. The plane of the joiner, here and there, intersects portions of these groups, exactly on a level with their general surface, whereas their recent companions are partly removed in shavings, and the remainder dip beneath the edges of the annual rings, which break their continuity; this will be seen when the *septa* are purposely cut through by the joiner's plane.

Upon inspecting the ends of the most handsome and showy pieces of wainscot oak and similar woods, it will be found that the surface of the board is only at a *small* angle with the lines of the medullary rays, so that *many* of the latter "crop out" upon the surface of the work: the medullary plates being seldom flat, their edges assume all kinds of curvatures and elongations from their oblique intersections. All these peculiarities of the grain have to be taken into account in cutting up woods, when the most showy character is a matter of consideration.

The same circumstances occur in a less degree in all the woods containing the silver grain, as the oriental plane-tree, or lacewood, sycamore, beech, and many others, but the figures become gradually smaller, until at last, in some of the foreign hard woods, they are only distinguishable on close inspection under the magnifier. Some of the foreign hard woods show lines very nearly parallel, and at right angles to the axis of the tree, as if they were chatters or utters arising from the vibration of the plane-iron. The medullary rays cause much of the beauty in all the showy woods, notwithstanding that the rays may be less defined than in the woods cited.*

In many of the handsomely figured woods, some of the effects attributed to color would, as in damask, be more properly called those of light and shade, as they vary with the point of view selected for the moment. The end grain of mahogany, the surfaces of the table-cloth, and of the mother-of-pearl shell, are respectively of nearly uniform color, but the figures of the wood and the damask arise from the various ways in which they reflect the light.

Had the fibres of all these substances been arranged with the uniformity and exactitude of a piece of plain cloth, they would have shown an even uninterrupted color, but fortunately for the beautiful and picturesque, such is not the case; most fibres are arranged by nature in irregular curved lines, and therefore almost every intersection through them, by the hand of man, partially removes some and exposes others, with boundless variety of figure.

If further proof were wanted, that it is only the irregular arrangement that causes the damask or variegated effect, we might observe that the plain and uniform silk, when passed in two thicknesses face to face, between smooth rollers, comes out with the watered pattern; the respective fibres mutually emboss each other, and with the loss of their former regular character they cease to reflect the uniform tint.†

To so boundless an extent do the interferences of tints, fibres, curls, knots, &c., exist, that the cabinet-maker scarcely seeks to match any pieces of ornamental wood for the object he may be constructing. He covers the nest of drawers, or the table, with the neighboring veneers from the same block, the proximity of the sections causing but a gradual and unobserved difference in the respective portions: as it would be in vain to attempt to find two different pieces of handsomely figured wood exactly alike.

Variations of color.—The figures of the woods depend also upon the color as well as on the fibre; in some the tint is nearly uniform, but others partake of several shades of the same hue, or of two or three different colors, when a still greater change in their appearance results.

In the horizontal sections of such woods, the stripes wind partly round the centre, as if the tree had clothed itself at different parts with coats of varied colors with something like caprice: tulip-wood, kingwood, zebra-wood, rosewood, and many others, show this very distinctly; and in the ordinary plank these markings get drawn out into stripes, bands, and patches, and show mottled, dappled, or wavy figures of the most beautiful or grotesque characters, upon which it would be needless to enlarge, as a glance at the display of the upholsterer will convey more information than any description, even when assisted by colored figures.‡

Those woods which are variegated both in grain and color, such as Amboyna, kingwood, some mahogany, maple, partridge, rosewood, satin-wood, snakewood, tulip-wood, zebra-wood, and others, are more generally employed for objects with *smooth* surfaces, such as cabinet-work, vases, and turned ornaments, as the beauties of their colors and figures are thereby the best displayed. Every little detail in the object causes a diversion in the forms of the stripes and marks existing in the wood: these terminate abruptly round the mouldings which have sharp edges, and upon the flowing lines they are undulated with infinite variety into curves of all kinds, which often terminate in fringes from the accidental intersections of the stripes in the woods.

The elegant works in marquetry, in which the effect of flowers, ornamental devices, or pictures, is attempted by the combination of pieces of naturally colored woods, are invariably applied to smooth

* The *Cuticaem branco*, from Carvalho da Terra, Brazils, and *Cuticaem vermo*, brought over by Mr. Morney, (Admiralty Museum,) show the silver grain very prettily; the first in peculiar straight radial stripes, the other in small close patches. The *Rewa-rewa*, (*Knightia excelsa*,) from New Zealand, is of similar kind; all would be found handsome light-colored furniture woods.

† The brilliant prismatic colors of the pearl are attributed to the decomposition and reflection of the light by the numerous minute grooves or striæ, a more vivid effect of the same general kind.

A beautiful artificial example of the same description was produced by Sir John Barton, comptroller of the English mint; he engraved with the diamond the surfaces of hard steel dies in lines as fine as 2000 in the inch, arranged in hexagons, &c. The gold buttons struck from these dies display the brilliant play of iridescent colors of the crystals.

‡ Attempts have been made to stain some European woods during their growth, by inserting certain portions of their roots in vessels filled with coloring matters, but we are not aware with what success. It is not, however, to be expected that such a mode would be either so effective or permanent as that produced by the natural absorption during the entire period of the life of the plant, an experiment of too lengthened and speculative a character to be readily undertaken.

surfaces. In the same manner the beautifully tesselated wood floors, abundant in the buildings of one or two centuries back, which exhibit geometrical combinations of the various ornamental woods, (an art that has been recently pursued in miniature by the Tunbridge turners in their Mosaic works,) are other instances, that in such cases the plain smooth surface is the most appropriate to display the effect and variety of the colors, for such of the last works as are turned into mouldings fail to give us the same pleasure.

Even-tinted woods are best suited to the work of the eccentric chuck, the revolving cutters, and other instruments to be explained; in which works, the *carving* is the principal source of ornament: the variation of the wood, in grain or color, when it occurs, together with the cutting of the surface, is rather a source of confusion than otherwise, and prevents the effect either of the material, or of the work executed upon it, from being thoroughly appreciated.

The transverse section, or end grain of the plain woods, is the most proper for eccentric turning, as all the fibres are then under the same circumstances; many of the woods will not admit of being worked with such patterns, the plankway of the grain: and of all the woods the black Botany Bay wood, or the Black African wood, by which name soever it may be called, is most certainly the best for eccentric turning; next to it, and nearly its equal, is the cocoa-wood, (from the West Indies, not the cocoa-nut palm;) several others may also be used, but the choice should always fall on those which are of *uniform* tint, and sufficiently hard and close to receive a polished surface from the *tool*, as such works admit of no subsequent improvement.

Contrary to the rule that holds good with regard to most substances, the colors of the generality of the woods become considerably *darker* by exposure to the light; tulip-wood is, we believe, the only one that fades. The tints are also rendered considerably darker from being covered with oil or lacker, and although the latter checks their assuming the deepest hues, it does not entirely prevent the subsequent change. The yellow color of the ordinary varnishes greatly interferes also with the tints of the light woods, for which the whitest possible kinds should be selected.* When it is required to give to wood that has been recently worked the appearance of that which has become dark from age, as in repairing any accident in furniture, it is generally effected by washing it with lime-water; or, in extreme cases, by laying on the lime as water-color, and allowing it to remain for a few minutes, hours, or days, according to circumstances. In many cases the colors of the woods are heightened or modified, by applying coloring matters either before, or with the varnish; and in this manner handsome birchwood is sometimes converted into factitious mahogany, by a process of coloring rather than dyeing, that often escapes detection.

The bog-oak is by some considered to assume its black color from the small portion of iron contained in the bog or moss, combining with the gallic acid of the wood, and forming a natural stain, similar to writing ink. Much of the oak timber of the Royal George, that was accidentally sunk at Spithead, in 1782, and which has been recently extricated by Colonel Pasley's sub-marine explosions, is only blackened on its outer surface, and the most so in the neighborhood of the pieces of *iron;* the inside of the thick pieces is, in general, of nearly its original color and soundness. Some specimens of camwood have maintained their original beautiful red and orange colors, although the inscription says that they were "washed on shore at Kay Haven, in October, 1840, with part of the wreck of the Royal Tar, lost near the Needles twenty years ago, when all the crew perished."

The recent remarks on color apply equally to the works of statuary, carving, and modelling generally: the materials for which are either selected of one uniform color, or they are so painted. Then only is the full effect of the artist's skill apparent at the first glance; otherwise it frequently happens either that the eye is offended by the interference of the accidental markings, or fails to appreciate the general form or design, without a degree of investigation and effort that detracts from the gratification which would be otherwise *immediately* experienced on looking at such carved works.

This leads me to advert to modes sometimes practised to produce the effect of carving; thus, in the Manuel du Tourneur† a minute description will be found of the mode of making embossed wooden boxes, which are pressed into metallic moulds, engraved with any particular device. The wood is first turned to the appropriate shape, and then forced by a powerful screw-press into the heated mould, (which is made just hot enough to avoid materially discoloring the wood;) it is allowed to remain in that situation until it is cold; this method, however, only applies to subjects in small relief, and is principally employed on knotty pieces of boxwood and olive-wood of irregular curly grain.

The following method may be used for bolder designs, more resembling ordinary carving: the fine sawdust of any particular wood it is required to imitate, is mixed with glue or other cementitious matter, and squeezed into metallic moulds; but in the latter case the peculiar characteristic of the wood, namely, its fibrous structure, is entirely lost, and the eye only views the work as a piece of cement or composition, which might be more efficiently produced from other materials, and afterwards colored.

Each of these processes partakes rather of the proceeding of the manufacturer than of the amateur; extensive preparations, such as very exact moulds consisting of several parts, a powerful press and other apparatus, are required, and the results are so proverbially alike, from being "formed in the same mould," that they lose the interest attached to original works, in the same manner that engravings are less valued than the original paintings from which they are copied.

Another method of working in wood may be noticed, which is at any rate free from the objections recently advanced: we will transcribe its brief description.‡

"Raised figures on wood, such as are employed in picture-frames and other articles of ornamental cabinet-work, are produced by means of carving, or by casting the pattern in Paris plaster or other

* Specimens of woods for cabinets should be left in their natural state, or at most they should be polished by friction only; or, if varnished, then upon the one side alone. Their colors are best preserved when they are excluded from the light, either in drawers or in glass cases covered with some thick blind.

† Second edition, vol. ii., pp. 441-451.

‡ Transactions of the Society of Arts, xlii., p. 52.

composition, and cementing or otherwise fixing it on the surface of the wood. The former mode is expensive, the latter is inapplicable on many occasions.

"The invention of Mr. Straker may be used either by itself or in aid of carving; and depends on the facts, that if a depression be made by a blunt instrument on the surface of wood, such depressed part will again rise to its original level by subsequent immersion in water.

"The wood to be ornamented having first been worked out to its proposed shape, is in a state to receive the drawing of the pattern; this being put in, a blunt steel tool, or burnisher, or die, is to be applied successively to all those parts of the pattern intended to be in relief, and at the same time is to be driven very cautiously, without breaking the grain of the wood, till the depth of the depression is equal to the subsequent prominence of the figures. The ground is then to be reduced by planing or filing to the level of the depressed part; after which, the piece of wood being placed in water, either hot or cold, the parts previously depressed will rise to their former height, and will thus form an embossed pattern, which may be finished by the usual operations of carving."

Shrinking and warping.—The permanence of the form and dimensions of the woods require particular consideration, even more than their comparative degrees of ornament, especially as concerns those works which consist of various parts, for unless they are combined with a due regard to the strength of the pieces in different directions, and to the manner and degree in which they are likely to be influenced by the atmosphere, the works will split or warp, and may probably be rendered entirely useless.

The piece of dried wood is materially smaller than in its first or wet state, and as it is at all times liable to re-absorb moisture from a damp atmosphere, and to give it off to a dry one, even after having been thoroughly seasoned, the alterations of size again occur, although in a less degree.

The change in the direction of the *length* of the fibres is in general very inconsiderable.* It is so little in those of straight grain, that a rod split out of clean fir or deal is sometimes employed as the pendulum of a clock, for which use it is only inferior to some of the compensating pendulums: whereas a piece of the same wood taken diametrically out of the centre of a tree, or the crossway of the grain, forms an excellent hygrometer, and indicates by its change of length the comparative degree of moisture of the atmosphere. The important difference in the general circumstances of the woods, in the two directions of the grain, we propose to notice, first as regards the purposes of turning, and afterwards those of joinery work, which will render it necessary to revert to the wood in its original, or unseasoned state.

The turner commonly employs the transverse section of the wood, and we may suppose the annual rings then exhibited to consist of circular rows of fibres of uniform size, each of which, for the sake of explanation, I will suppose to be the one-hundredth of an inch in diameter.

When the log of green wood is exposed to a dry atmosphere, the outer fibres contract both at the sides and ends, whereas those within are in a measure shielded from the immediate effect of the atmosphere, and nearly retain their original dimensions. Supposing all the outside fibres to be reduced to the one hundred and tenth, or the one hundred and twentieth of an inch, as the external series can no longer fill out the original extent of the annual ring, the same as they did before they were dried; they divide, not singly, but into groups, as the unyielding centre, or the incompressible mass within the arch, causes the parts of which the latter is composed to separate, and the divisions occur in preference at the natural indentations of the margin, which appear to indicate the places where the splits are likely to commence.

3937.

The ends being the most exposed to the air, are the first attacked, and there the splits are principally radial, with occasional diversions concentric with the layers of fibres, as in Fig. 3937, and on the side of the log the splits become gradually extended in the direction of its length. The air penetrates the cracks, and extends both cause and effect, and an exposure of a few weeks, days, or even one day, to a hot, dry atmosphere, will sometimes spoil the entire log, and the more rapidly the harder the wood, from its smaller penetrability to the air. This effect is in part stayed by covering the ends of the wood with grease, wax, glue, or paper, to defend them, but the best plan is to transfer the pieces very gradually from the one atmosphere to the other, to expose them equally to the air at all parts, and to avoid the influence of the sun and hot, dry air.

The horizontal slice or block of the entire tree is the most proper for the works of the lathe, as it is presented by nature the most ready prepared to the hand, and its appearance, strength, grain, and shrinking, are the most uniform. The annual rings, if any be visible, are, as in Fig. 3938, nearly concentric with the object, the fibres around the circumference are

* Good boxwood and lancewood were approved as materials for the verified scales to be employed in laying down the plans for the recent parliamentary survey, as being next in accuracy to those of metal; whereas scales of ivory are entirely rejected by them, owing to their material *variation in length* under hygrometrical influence. See their printed papers.

Mr. Fincham says he has found a remarkable variation in the New Zealand pine, the Kowrie or Cowrie, corrupted into Cowdie, which expands so much as to cause the strips constituting the inside mouldings of ships to expand and buckle, probably from the comparative moisture of our atmosphere; and Colonel Lloyd says he found the teak timbers used by him in constructing a large room in the Mauritius, to have shrunk three-quarters of an inch in length in thirty-eight feet, although this wood is by many considered to shrink sideways least of all others.

alike, and the contraction occurs without causing any sensible departure from the circular form. Although thin transverse slices are necessarily weak from the inconsiderable length of the fibres of which they are composed, (equal only in length to the *thickness* of the plate,) they are strengthened in the generality of turned works by the margin, such as we find in the rim of a snuff-box, which supports the bottom like the hoop of a drum or tamborine.

The entire circular section is therefore most appropriate for turning; next to it the quartering, Fig. 3939, should be chosen, but its appearance is less favorable; and a worse effect happens, as the shrinking causes a sensible departure from the circle, the contraction being invariably greater upon the circular arcs of fibres, than the radial lines or medullary rays. If such works be turned before the materials

3938.

3939.

3940.

are thoroughly prepared, they will become considerably oval; so much so, that a manufacturer who is in the habit of working up large quantities of pear-tree, informs me that hollowed pieces rough-turned to the circle, alter so much and so unequally in the drying, that works of three inches will sometimes shrink half an inch more on the one diameter than the other, and become quite oval; it is therefore necessary to leave them half an inch larger than the intended size. Even in woods that were comparatively dry, a small difference may in general be detected by the callipers, when they have been turned some time, from their unequal contraction.

In pieces cut lengthways, such as Fig. 3940, circumstances are still less favorable; there being no perceptible contraction in the length of the fibres, the whole of the shrinking takes place laterally, at right angles to them, and the work becomes oval to the full extent of the contraction that occurs in the fibres.

The plank-wood is almost solely employed for large disks which would be too weak if cut out transversely; and in some cases for objects made of those ornamental woods which are best displayed in that section, as the tulip, rose, king, zebra, partridge, and satin woods. Specimens of oak from ancient buildings are sometimes thus worked, but in all such cases the wood should be exceedingly well dried beforehand; otherwise, in addition to the inconvenience arising from the greater departure from the circle, the pieces will warp and twist, an effect that more generally concerns the joiner's art, and to the consideration of which we will now proceed.

When the green wood is cut up into planks, boards, and veneers, the splitting which occurs in the transverse section is less to be feared than distortion or warping, from the unequal contraction of the fibres. Thick planks are partially stayed from splitting and opening, by cleets nailed upon each end; boards are left unprotected, and veneers are protected from accidental violence by slips of cloth glued upon each end.

One plank only in each tree can be exactly diametrical, the others are parallel therewith, and, as shown in Fig. 3937, the two sides of all the boards, but that from the centre are differently circumstanced as regards the arrangement of the fibres, and contract differently. It will be generally found that the boards exposed to similar conditions on both sides, become, from the simple effect of drying, convex on the side towards the centre of the tree; this will be explained by a reference to the diagram.

3941.

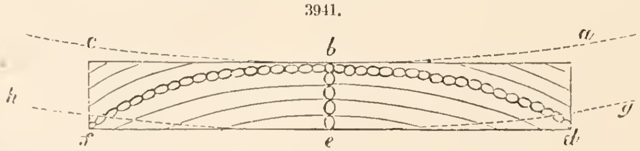
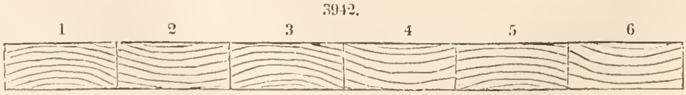


Fig. 3941, which shows that the longest continuous line of fibres is concentric with the axis of the tree. Thus let *a*, *b*, *c*, *d*, *e*, *f* represent the section of a board, the line *b e* of which is supposed to contain five fibres, and the arc *d b f* thirty: therefore, supposing every fibre to shrink alike in general dimensions, the contraction on the arc will be six times that upon the short radial line, and the new margin of the board will be the dotted line which proceeds from *g* to *h*, the departure of which from the original straight line will be five times as much at *d* as at *e*.

3942.



This is not imaginary, as it is in all cases borne out by observation, where the pieces are exposed to similar circumstances on both sides. When a true flat board is wanted, it is a common practice to saw the wide plank in two or four pieces, to change sides with them alternately, and glue them together again, as in Fig. 3942, so that the pieces 1, 3, 5 may present the sides towards the axis of the tree, and 2, 4, 6 those towards its circumference; the curvature from shrinking will then become a serpentine line consisting of six arcs, instead of one continuous circular sweep.

When the opposite sides of a board are exposed to *unequal* conditions, the moisture will swell the fibres on the one side and make that convex, and in the opposite manner that exposed to the dry air or heat will contract and become concave; from these circumstances, when several pieces of wood are placed around the room or before the fire, "*to air*," the sides should be continually changed, that both may have equal treatment, so as to lessen the tendency to curvature. To remedy the defect when it may have occurred, the joiner exposes the convex side to the fire, but it is obviously better to be sparing of these sudden changes.

Any unequal treatment of the two sides is almost sure to curl the board; if, for instance, we paste a sheet of paper upon one side of a board, it will in the first instance swell the surface and make it convex; as the paper dries it contracts, it forces the wood to accompany it, and the papered side becomes hollow; when two equal papers are pasted on opposite sides, this change does not generally occur. A similar effect is often observed when a veneer is glued on a piece of wood; hence it is usual to swell the surface on which the veneer is to be laid, by wetting it with a sponge dipped in thin size, so as to make it moderately round; in this case, the wetted surface of the board, and the glued surface of the veneer, are expanded nearly alike by the moisture, and in drying they also contract alike, so that under favorable management the board recovers its true flat figure.

The woods are much less disposed to become curved in the direction of their *length*, than crossways; but another evil equally or more untractable is now met with, as the general figure of the board is more or less disposed to twist and warp, so that when it is laid upon a flat surface it touches only at the two diagonal corners, and is said to be "*in winding*." This error is the less experienced in the straight-grained pines and mahogany, which are therefore selected for works in which constancy of figure is a matter of primary importance, as in models for the foundry, and objects exposed to great vicissitudes of climate.

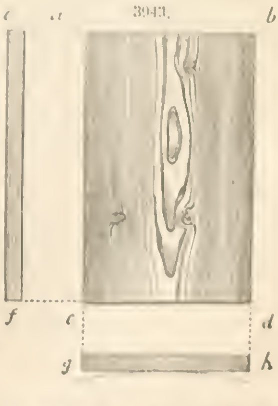
The warping may arise from the curved direction of the fibres in respect to the length of the plank, and also from the *spiral* direction in which many trees grow; in some, for example, the furrows of the bark are frequently twisted as much as fifteen or twenty degrees from the perpendicular, and sometimes even thirty and forty. The woods themselves when split through the centre of the tree differ materially; they sometimes present a tolerably flat surface, at others they are much in winding or twisted, a further corroboration of the "spiral growth;" we cannot be therefore much surprised that the planks cut out from such woods should in a degree pursue the paths thus early impressed upon them.

Boxwood is often very much twisted in this manner. The writer had a block, the diameter of which was nine inches; its surface was split at five parts, with spiral grooves, at an angle of nearly thirty degrees with the axis; these made exactly *one complete revolution*, or one turn of a screw in the length of the piece, which was just three feet.

On the other hand, the *Alerce*, a pine growing in the island of Chiloe in South America, to the diameter of about four feet, and whose wood resembles the cedar of Lebanon in color, is so remarkably straight in the grain, that it is the custom of the country to *split* it into planks about eight feet long and seven inches wide, which are almost as true as if they were cut with the saw, although of course not quite so smooth.

To correct the errors of winding and curvature in length, the joiner, in working upon rigid pieces, first planes off the higher points so as to produce the true form by reduction. But when the objects are long and thin, they are corrected by the hands, just as we should straighten a cane, or a walking stick, except that the one angle of the board is rested upon the bench or floor, the other is held in the hand, and the pressure is applied between them.

Broad thin pieces are sometimes warmed on both sides before the fire to lessen their rigidity; they are then fixed between two stout flat boards by means of several hand-screws, and allowed to remain until they are quite cold; this is just the reverse of the mode of bending timber for ship-building and other purposes, but applied in a less elaborate manner.



3943.

In concluding this division of the subject, we may observe that the shrinking and contracting of the straight-grained woods, especially deal and mahogany, cause but little distortion of their general shape after they have been properly dried; but the diversity of grain, a principal cause of beauty of figure in the ornamental woods, is at the same time a source of confusion in their shrinking, which being called on to pursue many paths, (which are parallel with the fibres, however tortuous,) gives rise to a greater disturbance from the original shape, or in extreme cases, even causes them to split where the contraction is restrained by the peculiarity of growth.

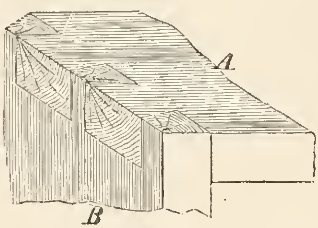
In the handsome furniture woods the economy of manufacture corrects this evil, as from their great value they are cut into very thin slices or veneers, and glued upon a stout fabric of straight-grained wood, commonly inferior mahogany, cedar, or deal, by which the opposite characters, of beauty of appearance and permanence of form, are combined at a moderate expense; these processes will be explained.

Combining different pieces of wood.—In combining several pieces of wood for works in carpentry and cabinet-making, the different circumstances of the plank as respects its length and width should be always borne in mind. Provision must be made that the shrinking and swelling are as little restrained as possible, otherwise the pieces may split and warp with an irresistible force: and the principal reliance for permanence or standing, should be placed on those pieces, (or lines of the work,) cut out the lengthway of the plank, which are, as before explained, much less disposed to break or become crooked, than the crossway sections: these particulars will be more distinctly shown by one or two illustrations.

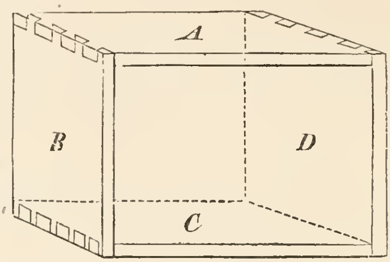
Let *a b c d* represent the flat surface of a board; *c f*, the edge of the same, and *g h* the end; no contraction will occur upon the line *c f*, or the length, and in the general way, that line will remain pretty straight and rigid; but the whole of the shrinking will take place on *g h*, the width, which is slender, flexible, and disposed to become curved from any unequal exposure to the air; the four marginal lines of *a b c d*, are not likely to alter materially in respect to each other, but they will remain tolerably parallel and square, if originally so formed.

A dovetailed box consists of six such pieces, the four *sides* of which, A B C D, Fig. 3944, are interlaced at the angles by the dovetails, so that the flexible lines, as *g h*, on B, are connected with, and strengthened by, the strong lines, as *c d*, on A, and so on: the whole collectively form a very rigid frame, the more especially when the bottom piece is fixed to the sides by glue or screws, as it entirely removes from them the small power of racking upon the four angles, (by a motion like that of the jointed parallel rule,) which might happen if the dovetails, shown on a larger scale in Fig. 3945, were loosely fitted.

3945.



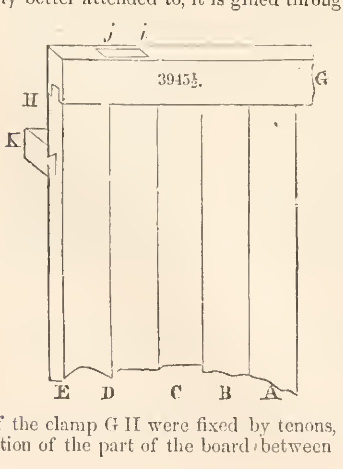
3944.



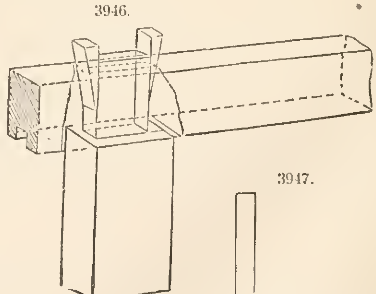
When the grain of the four sides A B C D runs in the *same* direction, or parallel with the edges of the box or drawer, as shown by the shade lines on A and B, and the pieces are equally wet or dry, they will contract or expand equally, and without any mischief or derangement happening to the work; to insure this condition, the four sides are usually cut out of the same plank. But if the pieces had the grain in different directions, as C and D, and the two were nailed together, D would entirely prevent the contraction or expansion of C, and the latter would probably be split or cast, from being restrained. When admissible, it is therefore usual to avoid *fixing* together those pieces, in which the grain runs respectively lengthways and crossways, especially where apprehension exists of the occurrence of swelling or shrinking.

A wide board, Fig. 3945½, composed of the slips A B C D E, (reversed as in Fig. 3942,) is rendered still more permanent, and very much stronger, when its ends are confined by two clamps, such as G H, (one only seen;) the shade lines represent the direction of the grain. The group of pieces, A to E, contract in width upon the line A E, and upon it they are also flexible, whereas the clamp G H is strong and incapable of contraction in that direction, and therefore unless the wood is thoroughly dry the two parts should be connected in a manner that will allow for the alteration of the one alone. This is effected by the tongue and groove fitting as represented; the end piece G H is sometimes only fastened by a little glue in the centre of its length, but in cabinet-work, where the seasoning of the wood is generally better attended to, it is glued throughout.

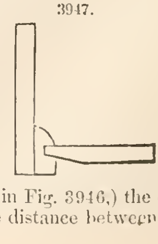
3945½.



3946.



3947.



If the clamp G H were fixed by tenons, (one of which, *i j*, is shown detached in Fig. 3946,) the contraction of the part of the board between the tenons might cause it to split, the distance between the mortises in G H being unalterable; or the swelling of the board might cause it to bulge, and become rounding; or the entire frame would twist and warp, as the expansion of the centre might be more powerful than the resistance to change in the two clamps, and force them to bend.

It is therefore obvious that if any question exist as to the entire and complete dryness of the wood, the use of clamps is hazardous: although in their absence, the shrinking might tear away the wood from the plain glue-joint, even if it extended entirely across, without causing any further mischief, but more generally the shrinking would split the solid board.

Another mode of clamping is represented at K; it is there placed edgeways, and attached by an undercut or dovetailed groove, slightly taper in its length, and is fixed by a little glue at the larger end, which holds the two in firm contact: each of these modes, and some others, are frequently employed for the large drawing-boards required by architects and engineers for the drawings made with squares and instruments.

From a similar motive, the thin bottom of a drawer is grooved into the two sides and front, and only fixed to the back of the drawer by a few small screws or brads, so that it may swell or shrink without splitting, which might result were it confined all around its margin. It is more usual, however, to glue thin slips along the *sides* of large drawers, as in Fig. 3947, which strengthen the sides, and being grooved to receive the bottom, allow it to shrink without interfering either with the front or back of the drawer.

In an ordinary door with two or more panels, all the marginal pieces run lengthways of the grain, the two sides, called the *stiles*, extend the whole height, and receive the transverse pieces or *rails*, now mortised through the stiles, and wedged tight, but without risk of splitting, on account of their small width; every panel is fitted into a groove within four edges of the frame. The width of the panel should be a trifle less than the extreme width of the grooves, and even the mouldings, when they are not worked in the solid, are fixed to the frame alone, and not to the panel, that they may not interfere with its alterations; therefore in every direction, we have the framework in its strongest and most permanent position as to grain, and the panel is unrestrained from alteration in width if so disposed.

This system of combination is carried to a great extent in the tops of mahogany billiard-tables, which consist of numerous panels about 8 inches square, the frames of which are 3½ in. wide and 1½ in. thick; the panels are ploughed and tongued, so as to be level on the upper side, and from their small size the individual contraction of the separate pieces is insignificant, and consequently the general figure of the table is comparatively certain. Of late years, we are told that slate, a material uninfluenced by the atmosphere, has been almost exclusively used; the top of a full-sized table, of 12 by 6 feet, consists of four slabs one inch thick, ground on their lower, and planed by machinery on their upper surfaces; the iron tables are almost abandoned for several reasons. Large thin slates, from their permanence of form, are sometimes used by engineers and others for drawing upon, and also in carpentry for the panels of superior doors.

On glueing various works in wood.—Glue is the cement used for joining different pieces of wood; it is a common jelly, made from the scraps that are pared off the hides of animals before they are subjected to the tan-pit for conversion into leather. The inferior kinds of glue are often contaminated with a considerable portion of the lime used for removing the hair from the skins, but the better sorts are transparent, especially the thin cakes of the Salisbury glue, which are of a clear amber color.

In preparing the glue for use, it is most usually broken into small pieces, and soaked for about twelve hours in as much water as will cover it; it is then melted in a glue-kettle, which is a double vessel or water-bath, the inner one for the glue, the outer for the water, in order that the temperature applied may never *exceed* that of boiling water. The glue is allowed at first to simmer gently for one or two hours, and if needful it is thinned by the addition of hot water, until it runs from the brush in a fine stream; it should be kept free from dust and dirt by a cover, in which a notch is made for the brush. Sometimes the glue is covered with water, and boiled without being soaked.

Glue is considered to act in a twofold manner, first by simple adhesion, and secondly by excluding the air, so as to bring into action the pressure of the atmosphere. The latter, however, alone is an insufficient explanation, as the strength of a well made glue-joint is frequently greater than the known pressure of the atmosphere: indeed, it often exceeds the strength of the solid wood, as the fracture does not at all times occur through the joint, and when it does, it almost invariably tears out some of the fibres of the wood; mahogany and deal are considered to hold the glue better than any other woods.

It is a great mistake to depend upon the quantity or thickness of the glue, as that joint holds the best in which the neighboring pieces of wood are brought the most closely into contact; they should first be well wetted with the glue, and then pressed together in various ways to exclude as much of it as possible, as will be explained.

The works in turnery do not in general require much recourse to glue, as the parts are more usually connected by screws cut upon the edges of the materials themselves; but when glue is used by the turner, the mode of proceeding is so completely similar to that practised in joinery works, that no separate instructions appear to be called for, especially as those parts in which glue is required, as for example in Tunbridge ware, partake somewhat of the nature of joinery-work.

When glue is applied to the end grain of the wood, it is rapidly absorbed in the pores; it is therefore usual first to glue the end wood rather plentifully, and to allow it to soak in to fill the grain, and then to repeat the process until the usual quantity will remain upon the face of the work; but it never holds so well upon the endway as the lengthway of the fibres.

In glueing the edges of two boards together they are first planed very straight, true, and square; they are then carefully examined as to accuracy, and marked, to show which way they are intended to be placed. The one piece is fixed upright in the chaps of the bench the other is laid obliquely against it, and the glue-brush is then run along the angle formed between their edges, which are then placed in contact, and rubbed hard together lengthways, to force out as much of the glue as possible. When the joint begins to feel stiff under the hand, the two parts are brought into their intended position and left to dry; or as the bench cannot in general be spared so long, the work is cautiously removed from it, and rested in contact with a slip of wood placed against the wall, at a small inclination from the perpendicular. Two men are required in glueing the joints of long boards.

In glueing a thin slip of wood on the edge of a board, as for a moulding, it is rubbed down very close and firm, and if it show any disposition to spring up at the ends, it is retained by placing thereon heavy weights, which should remain until the work is cold; but it is a better plan to glue on a wide piece, and then to saw off the part exceeding that which is required.

Many works require screw-clamps and other contrivances, to retain the respective parts in contact whilst the glue is drying; in others, the fittings by which the pieces are attached together supply the needful pressure. For instance, in glueing the dovetails of a box, or a drawer, such as Fig. 3944, dovetails, if properly fitted, hold the sides together in the requisite manner, and the following is the order of proceeding.

The dovetail pins, on the end B, Fig. 3944, are first sparingly glued, that piece is then fixed in the chaps of the bench, glue upwards, and the side A, held horizontally, is driven down upon B by blows of a hammer, which are given upon a waste piece of wood, smooth upon its lower face, and placed over the dovetail pins, which should a little exceed the thickness of the wood, so that when their superfluous length is finally planed off, they may make a good clean joint. When the pins of the dovetails come flush with the face, the driving-block is placed *beside* them to allow the pins to rise above the surface. The second end, D, is then glued the same as B, it is also fixed in the bench, and A is driven down upon it as before; this unites the three sides of the square. The other pins on the ends B and D are then glued, and the first side, A, is placed downwards on the bench, upon two slips of wood placed close under the dovetails, that it may stand solid, and the remaining side, D, is driven down upon them to complete the connection of the four sides.

The box is then measured with a square, to ascertain if it have accidentally become rhomboidal, or *out of square*, which should be immediately corrected by pressure in the direction of the longer diagonal; lastly, the superfluous glue is scraped off whilst it is still soft with a chisel, and a sponge dipped in the hot water of the glue-kettle is occasionally used, to remove the last portion of glue from the work.

The general method pursued in glueing the angles of the frame for a panel is somewhat similar, although modified, to meet the different structure of the joints. The tenons are made quite parallel both ways, but the mortises are a little bevelled or made longer outside, to admit the small wedges by which the tenons are fastened; and the stiles are made somewhat longer than when finished, to prevent the mortises from being broken out in driving the wedges, which are mostly cut out of the waste pieces sawn off from the tenons in forming their *shoulders* or *haunches*. These details are seen in Fig. 3946.

In glueing the frame for a single panel which is fitted into a groove, the whole of the frame is put together before commencing the glueing, and the stiles are knocked off one at a time, by which the misplacement of the pieces is avoided. The tenons are glued, and a little glue is thrust into the two mortises with a thin piece of wood; when the stiles have been driven down close, the joint is completed by the insertion of a wedge on each side of the tenon; their points are dipped in the glue, and they are driven in like nails, so as to fill out the mortises, after which the tenons cannot be withdrawn: sometimes the wedges are driven into saw-kerfs, previously made near the sides of the tenons; the other stile is then knocked off, glued, and fixed in the same manner. Occasionally all four tenons are glued at the same time, and the two stiles are pressed together by screw-clamps, stretching across the frame just within the tenons; the wedges are lastly driven in, before the removal of the clamps, and the door, if square and true, is left to dry.

In many other cases also, the respective pieces are pressed together by screws variously contrived; the boards employed to save the work from being disfigured by the screws are planed flat, and are warmed before the fire, to supply heat to keep the glue fluid until the work is screwed up, and the warmth afterwards assists in drying the glue: such heated boards are named *cauls*, and they are particularly needed in laying down large veneers, which process is thus accomplished.

The surfaces of the table or panel, and both sides of the veneer, are scratched over with a tool called a toothing-plane, which has a perpendicular iron full of small grooves, so that it always retains a notched or serrated edge; this makes the roughness on the respective pieces, called the *tooth* or *key*, for the hold of the glue. A caul of the size of the table is made ready; and several pairs of clamps, each consisting of two strong wooden bars, placed edgeways, and planed a little convex or rounding on their inner edges, and connected at their extremities with iron screw-bolts and nuts, are adjusted to the proper opening; the table is warmed on its face, and the veneer and caul are both made very hot.*

All being ready, the table is brushed over quickly with thin glue or size, the veneer is glued and laid on the table, then the hot caul, and lastly the clamping-bars, which are screwed down as quickly as possible, at distances of three or four inches asunder, until they lie exactly flat. The slender veneer is thereby made to touch the table at every point, and almost the whole of the glue is squeezed out, as the heat of the caul is readily communicated through the thin veneer to the glue and retains it in a state of fluidity for the short space of time required for screwing down, when several active men are engaged in the process. The table is kept under restraint until entirely cold, generally for the whole night at least, and the drying is not considered complete under two or three days.†

* If the clamps were straight, their pressure would be only exerted at the sides of the table; but being curved to the extent of one inch in three or four feet, their pressure is first exerted in the centre, and gradually extends over their entire length, when they are so far strained as to make the rounded edge bear flat upon the table and caul respectively.

† In some of the large manufactories for cabinet-work, the premises are heated by steam-pipes, in which case they have frequently a close stove in every workshop, heated many degrees beyond the general temperature, for giving the final seasoning to the wood, for heating the cauls, and for warming the glue, which is then done by opening a small steam-pipe into the outer vessel of the glue-pot. The arrangement is extremely clean, safe from fire, and the degree of the heat is very much under control.

When the objects to be glued are curved, the cauls, or moulds, must be made of the counterpart curve, so as to fit them; for example, in glueing the sounding-board upon the body of a harp, which may be compared to the half of a cone, a trough or caul is used of a corresponding curvature, and furnished all along the edge with a series of screws to bring the work into the closest possible contact.

In glueing the veneers of maple, oak, and other woods upon curved mouldings, such as those for picture-frames, the cauls or counterpart moulds are made to fit the work exactly. The moulding is usually made in long pieces and polished, previously to being mitred or joined together to the sizes required.

In works that are curved in their length, as the circular fronts of drawers, and many of the foundry patterns that are worked to a long sweep, the pieces that receive the pressure of the screws used in fixing the work together "whilst it is under glue," are made in narrow slips, and pierced with a small hole at each end; they are then strung together like a necklace, but with two strings. This flexible caul can be used for all curves; the strings prevent the derangement of the pieces whilst they are being fixed, or their loss when they are not in use.

We have mentioned these cases to explain the general methods, and to urge the necessity of thin glue, of a proper degree of warmth to prevent it from being chilled, and of a pressure that may cause the greatest possible exclusion of glue from the joint. But for the comparatively small purposes of the amatuer, four or six hand-screws, or ordinary clamps, or the screw-chaps of the bench, aided by a string to bind around many of the curvilinear and other works, will generally suffice.

As, however, the amateur may occasionally require to glue down a piece of veneer, we will, in conclusion, describe the method of "laying it with the hammer," which requires none of the apparatus just described, but the *veneering hammer* alone. This is either made of iron with a very wide and thin plane, or more generally of a piece of wood from three to four inches square, with a round handle projecting from the centre; the one edge of the hammer-head is sawn down for the insertion of a piece of sheet-iron or steel, that projects about one-quarter of an inch, the edge of which is made very straight, smooth, and round; and the opposite side of the square wooden head of the veneering hammer is rounded, to avoid its hurting the hand.

The table and both sides of the veneer having been toothed, the surface of the table is warmed, and the *outer* face of the veneer and the surface of the table are wetted with very thin glue or with a stiff size. The inner face of the veneer is next glued; it is held for a few moments before a blazing fire of shavings to render the glue very fluid, it is turned quickly down upon the table, and if large is rubbed down by the outstretched hands of several men; the principal part of the remainder of the glue is then forced out by the veneering hammer, the edge of which is placed in the centre of the table; the workman leans with his whole weight upon the hammer, by means of one hand, and with the other he wriggles the tool by its handle, and draws it towards the edge of the table, continuing to bear heavily upon it all the time.

The pressure being applied upon so narrow an edge, and which is gradually traversed or scraped over the entire surface, squeezes out the glue before it, as in a wave, and forces it out at the edge; having proceeded along one line, the workman returns to the centre, and wriggles the tool along another part close by the side of the former; and in fact as many men are generally engaged upon the surface of the table as the shop will supply, or that can cluster around it. The veneer is from time to time wetted with the hot size, which keeps up the warmth of the glue, and relieves the friction of the hammers, which might otherwise tear the face of the wood.

The wet and warmth also render the veneer more pliable, and prevent it from cracking and curling up at the edges, as should the glue become chilled the veneer would break from the sudden bending to which it might be subjected, by the pressure of the hammer just behind the wave of glue, which latter would be then too stiff to work out freely, owing to its gradual loss of fluidity; the operation must, therefore, be conducted with all possible expedition.

The concluding process is to tap the surface all over with the back of the hammer, and the dull hollow sound will immediately indicate where the contact is incomplete, and here the application of the hammer must be repeated; sometimes when the glue is too far set in these spots, the inner vessel of the glue-pot or heated irons are laid on to restore the warmth. By some, the table is at the conclusion laid flat on the floor, veneer downwards, and covered over with shavings, to prevent the too sudden access of air. Of course, the difficulty of the process increases with the magnitude of the work; the mode is more laborious and less certain than that previously described, although it is constantly resorted to for the smaller pieces and strips of veneer.

CHARACTERS AND USES OF THE WOODS COMMONLY EMPLOYED IN MECHANICAL AND ORNAMENTAL ARTS.

ABELE. See *Poplar*.

ACACIA, true. The *Acacia proxima Mordi*, A. Guillard's MSS., called in Cuba *Sabicu*, and in England *Savico* and *Savacu*, is a heavy, durable wood of the red mahogany character, but rather darker and plainer; it is highly esteemed in ship building.

The true acacias are found in warm parts of the world, and yield valuable though usually small timber, which is remarkable for being hard and tough, as *Acacia tortuosa*, called Cashaw tree in the West Indies. On the west coast of Africa, *Acacia verek* has very hard white wood, as well as other species. *A. melanoxylon*, black wattle tree and blackwood, and *A. decurrens*, green wattle, occur in New Holland.

In India, *Acacia arabica* and *farnesiana*, commonly called *babool*, *A. speciosa*, and *A. sundra* yield timber valued for different purposes. Many of these trees exude gum, and their bark is employed in tanning leather.

ACACIA, false, the common acacia or locust tree. See *Locust-tree*.

AFRICAN BLACK WOOD. See *Black Botany Bay Wood*.

ALDER, (*Alnus glutinosa*,) Europe and Asia. There are other species in North America and the Himalayas. The common alder seldom exceeds 40 feet in height, is very durable under water, and was used for the piles of the Rialto at Venice, the buildings at Ravenna, &c.: the wood is also much used for pipes, pumps, and sluices. The color of alder is reddish-yellow of different shades, and nearly uniform; the wood is soft, and the smaller trees are much used for inferior turnery, as tooth-powder boxes, common toys, brushes and bobbins, and occasionally for foundry patterns. The roots and knots are sometimes beautifully veined, and used in cabinet-work. The charcoal of the alder is employed in the manufacture of gunpowder.

ALOES-WOOD. See *Calembeg*.

ALMOND-TREE, (*Amygdalus communis*,) is very strongly recommended by Desormeaux, as being hard, heavy, oily or resinous, and somewhat pliable; he says, the wood towards the root so much resembles *lignum-vitæ* as to render it difficult to distinguish between them. It is sometimes called false *lignum-vitæ*, and is used for similar purposes, as handles, the teeth and bearings of wheels, pulleys, &c., and any work exposed to blows or rough usage. It is met with in the south of Europe, Syria, Barbary, &c. The wood of the bitter almond, grown in exposed rocky situations, is preferred.

AMBOYNA-WOOD. See *Kiabooca-wood*.

ANGICA-WOOD. See *Cangica-wood*.

APS. See *Poplar*.

APPLE-TREE, (*Pyrus Malus*.) The woods of the apple-trees, especially of the uncultivated, are in general pretty hard and close, and of red-brown tints, mostly lighter than the hazelnut. The butt of the tree only is used; it is generally very straight and free from knots up to the crown, whence the branches spring. The apple-tree splits very well, and is one of the best woods for standing when it is properly seasoned; it is very much used in Tunbridge turnery, for bottle-cases, &c.: it is a clean-working wood, and being harder than chestnut, sycamore, or lime-tree, is better adapted than they are for screwed work, but is inferior in that respect to pear-tree, which is tougher. The millwright uses the crab-tree for the teeth of mortise-wheels.

APRICOT-TREE, (*Armeniaca vulgaris*,) a native of Armenia, is mentioned in all of the French works on turning, beginning with Bergeron, (1792,) who says the wood of the apricot-tree is very rarely met with sound, but that it is agreeably veined, and better suited to turning than carpentry. He elsewhere very justly adds, that we are naturally prejudiced in favor of those trees from which we derive agreeable fruits, and expect the respective woods to be either handsome in appearance or agreeable in scent, but in each of which expectations we are commonly disappointed: this applies generally to the orange and lemon trees, and we may add, to the quince, pomegranate, and coffee trees, the vine, and many others occasionally met with, rather as objects of curiosity than as materials applicable to the arts.

ARBOR VITÆ. The different species of *Thuja* are called *Arbor vitæ*, and are chiefly found in North America and China. *T. occidentalis*, or American *Arbor vitæ*, attains a height of from 40 to 50 feet, and has reddish-colored, somewhat odorous, very light, soft and fine-grained wood. It is softer than white pine, and much used in house-carpentry, and also for fences.

The Chinese *Arbor vitæ*, or *T. orientalis*, is smaller, but the wood is harder. *T. articulata*, a native of the north coast of Africa, is the *Alerce* of the Moors, and was employed in the wood-work of the mosque, now the cathedral, of Cordova. The plant is now called *Callitris quadrivalvis*.

ASH, (*Fraxinus excelsa*;) Europe and north of Asia; mean size, 38 feet long by 23 inches diameter, sometimes much larger. The young wood is brownish-white with a shade of green; the old oak-brown, with darker veins. Some specimens from Hungary with a zigzag grain, and some of the pollards, are very handsome for furniture.

Ash is superior to almost any other timber for its toughness and elasticity; it is excellent for works exposed to sudden shocks and strains, as the frames of machines, wheel-carriages, agricultural implements, the felloes of wheels, and the inside work of furniture, &c. The wood is split into pieces for the springs of bleachers' rubbing-boards, which are sometimes 40 feet long; also for handspikes, billiard cues, hammer handles, rails for chairs, and numerous similar works, which are much stronger when they follow the natural fibre of the wood.

Ash is too flexible and insufficiently durable for building purposes; the young branches serve for hoops for ships' masts, tubs, churns, &c.

Several species are found in North America: of these it is thought that the white-ash, or *Fraxinus americana*, comes the nearest in quality of wood to the common ash. *F. floribunda* and *zanthoxyloides* are two ashes found in the Himalayas.

Fraxinus ornus produces manna; *Fraxinus excelsa* produces a manna somewhat similar.

Ash, the *Mountain Ash*, or Quicken or Rowan tree, *Pyrus Aucuparia*, grows in almost every soil or situation, has fine-grained hard wood, which may be stained of any color, and takes a high polish, and is applied to the same purposes as the wood of the Beam and Service trees. See *Service-tree*.

ASPEN. See *Poplar*.

BARBERRY-WOOD, (*Berberis vulgaris*,) is of small size, generally about 4 inches diameter; the rind is yellow, and about half an inch thick: the wood resembles elder, and is tolerably straight and tenacious.

BARWOOD, Africa. Two kinds are imported from Angola and Gaboon respectively, in split pieces 4 to 5 feet long, 10 to 12 inches wide, and 2 to 3 inches thick. It is used as a red dyewood—the wood is dark-red, but the dye rather pale; it is also used for violin-bows, ramrods, and turning.

BAY-TREE. The sweet bay-tree, (*Laurus nobilis*,) a native of Italy and Greece, grows to the height of 30 feet, and is an aromatic wood. It is the laurel that was used by the ancients for their military crowns.

Beech. Only one species (*Fagus sylvatica*) is common to Europe; in England the Buckinghamshire and Sussex beech are esteemed the best. Mean dimensions of the tree, 44 feet long and 27 inches diameter. The color (whitish-brown) is influenced by the soil, and is described as white, brown and black.—(*Tredgold.*)

Beech is used for piles in wet foundations, but not for building; it is excellent from its uniform texture and closeness for in-door works, as the frames of machines, common bedsteads and furniture, it is very much used for planes, tools, lathe-chucks, the keys and cogs of machinery, shoe-lasts, pattens, toys, brushes, handles, &c. Carved moulds for the composition ornaments of picture-frames, and for pastry, and large wooden types for printing, are commonly made of beech: the wood is often attacked by worms when stationary, as in framings, but tools kept in use are not thus injured.

Beech is stained to imitate rosewood and ebony, and it is considered to be almost chemically free from foreign matters; for example, the glass-blowers use the wood almost exclusively in *welding*, or fusing on, the handles of glass jugs, which process fails when the smallest portion of sulphur, &c., is present: oak is next in estimation for the purpose.

The white-beech of North America, *Fagus sylvestris*, is little valued in this country; the bark, however, is employed in tanning.

Beefwood. Red-colored woods are sometimes thus named, but it is generally applied to the Botany-bay oak—which see.

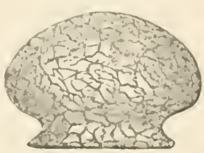
Betle-nuts, or **Areca-nuts,** are the fruit of the *Areca catechu*, or *Faufel*; they have a thin, brown rind, and in size are intermediate between walnuts and hazelnuts; their general substance is of a faint oily-gray color, thickly marked with curly streaks of dark-brown or black. The betle-nuts, although softer, resemble ivory, as regards the art of turning; they are made into necklaces, the tops of walking-sticks, and other small objects. The substance of the betle-nut, together with quicklime, is chewed by the generality of the natives of India.

Fig. 3947 is the section of the betle-nut full size, and at right angles to the stalk. Fig. 3948 is the section through the line of the stalk, which shows the central cavity. Externally the marks constitute a tortuous running pattern, as seen in the turned knob, Fig. 3949.

3947.

3948.

3949.



Birchwood. A forest-tree common to Europe and North America; the finest is from Canada, St. John's, and Pictou. It is an excellent wood for the turner, being light-colored, compact, and easily worked: it is in general softer and darker than beech, and unlike it in grain.

Birchwood is not very durable; it is considerably used in furniture. Some of the wood is almost as handsomely figured as Honduras mahogany, and when colored and varnished is not easily distinguished from it. The bark of the birch-tree is remarkable for being harder and more durable than the wood itself: amongst the Northern nations it is used for tiles for roofs, for shoes, hats, &c., and in Canada for boats. The Russians employ the tan of one of the birch-trees to impart the scent to Russia leather, which is thereby rendered remarkably durable. The inner bark is used for making the Russia mats.

The English birch is much smaller than the American, and lighter in color; it is chiefly used for common turnery. Some of the Russian birch (called Russian maple) is very beautiful, and of a full yellow color.

Betula alba is the common birch of Europe, and the most common tree throughout the Russian Empire. The Russian maple of commerce is thought to be the wood of the birch. *Betula lenta*, mahogany birch and mountain mahogany of America, has close grained, reddish brown timber, which is variegated, and well adapted to cabinet-work. It is exported in considerable quantities to England under the name of American birch.

Betula excelsa, tall, also called yellow-birch, has wood much like the last, and *B. nigra*, or black, is also much esteemed. *B. papyracea*, paper or canoe birch, is employed by the North American Indians in constructing their portable canoes. *B. Bhojputtra* is a Himalayan species, of which the bark is used for writing upon, and for making the snakes of hookahs.

Bitter-nut wood, a native of America, is a large timber wood measuring 30 inches when squared, plain and soft in the grain, something like walnut.

Juglans amara, white or swamp hickory or bitter nut, and *J. aquatica*, or water bitter-nut hickory, are probably the trees which yield this wood.

Black Botany Bay wood, called also African Blackwood, is perhaps the hardest and also the most wasteful of all the woods; the billets are very knotty and crooked, and covered with a thick rind of the color and hardness of boxwood; the section of the heart wood is very irregular, and mostly either indented from without, or hollow and unsound from within; many of the pieces have the irregular scrawling growth that is observed in the wood of the vine. The largest stem of Black Botany-Bay wood we have ever seen, measured transversely 11 inches the longest and 7½ the shortest way, but it would only produce a circular block of 5 inches, and this is fully two or three times the ordinary size.

The wood, when fresh cut, is of a bluish-black, with dark-gray streaks, but soon changes to an intense jet black; of the few sound pieces that are obtained, the largest may perhaps be five inches, but the majority less than two inches in diameter. It is most admirably suited to eccentric turning, as the wood is particularly hard, close, free from pores, but not destructive to the tools, from which, when they are in proper condition, it receives a brilliant polish. It is also considered to be particularly free from any matter that will cause rust, on which account it is greatly esteemed for the handles of surgeons' instruments.

The exact locality of this wood has long been a matter of great uncertainty. It has been considered to be a species of African ebony, but its character is quite different and peculiar; we have however recently heard, from two independent sources, that it comes from the Mauritius, or Isle of France. Col. Lloyd says the wood is there called *Cocobolo prieto;* that it is not the growth of the Mauritius, but of Madagascar, to the interior of which island Europeans are not admitted; and that it is brought in the same vessels that bring over the bullocks, for the supply of food. The stone-masons of the country use splinters of it as a pencil for marking the lines upon their work; it makes a dark-blue streak not readily washed off by rain.

We have only met with one specimen of this wood in the numerous collections we have searched, namely, in Mr. Fincham's: he assures us that his specimen grew in Botany Bay, and was brought direct from thence, with several others, by Captain Woodroffe, R.N. As we have recently purchased a large quantity imported from the Mauritius, it is probable that this wood, in common with many others, may have several localities.

It would be very desirable for the amateur turner that the wood should be selected on the spot, and the better pieces alone sent, as a large proportion is scarcely worth the expense of shipment, but the fine pieces exceed all other woods for eccentric-turned works.

Blue Gumwood. See *Gumwood.*

Botany-Bay Oak, sometimes called Beefwood, is from New South Wales; it is shipped in round logs, from 9 to 14 in. diam. In general color it resembles a full red mahogany, with darker red veins; the grain is more like the evergreen oak than the other European varieties, as the veins are small, slightly curled, and closely distributed throughout the whole surface. It is used in veneer for the backs of brushes, Tunbridge ware, and turnery; some specimens are very pretty.

The trees called oaks in New South Wales do not belong to the genus *Quercus,* like the European, North American, and Himalayan oaks. There, the tree called Forest Oak, is *Casuarina torulosa;* Swamp Oak is *C. paludosa;* He-Oak is *C. equisitifolia;* while *C. stricta* is called She-Oak, and also Beefwood.

Boxwood (*Buxus sempervirens*) is distinguished as Turkey and European boxwood. The former is imported from Constantinople, Smyrna, and the Black Sea, in logs felled with the hatchet, that measure from 2 to 6 ft. long, and 2½ to 14 in. diam. The wood is yellow, inclining to orange; it has a thin rind with numerous small knots and wens; some of it is much twisted, and such pieces do not stand well when worked; on the whole, however, it is an excellent, sound, and useful wood.

Boxwood is much used for clarionets, flutes, and a great variety of turned works; it makes excellent lathe-chucks, and is selected by the wood-engraver to the exclusion of all other woods. It is also used for carpenters' rules and drawing-scales; although lancewood, satin-wood, and elder, are sometimes substituted for it. Boxwood is particularly free from gritty matter, and on that account its sawdust is much used for cleaning jewelry; it is frequently mentioned by the Roman authors as a wood in great esteem at the period in which they wrote.

Some of the boxwood is as handsomely mottled as fine satin-wood; but it differs much in color, apparently according to the age and season at which it is cut, as only a small portion of the Turkey boxwood is of the full yellow so much admired.

European boxwood is imported from Leghorn, Portugal, &c. The English boxwood is plentiful at Boxhill in Surrey, and in Gloucestershire; it is more curly in growth, softer and paler than the Turkey boxwood; its usual diameters are from 1 to 5 in.; it is used for common turnery, and is preferred by brass-finishers for their lathe-chucks, as it is tougher than the foreign box and bears rougher usage. It is of very slow growth, as in the space of 20 to 25 years it will only attain a diameter of 1½ to 2 inches. A similar wood, imported from America under the name of Tugmutton, was formerly much used for making ladies' fans.

Murraya, (*Mackay B. fr. Tavoy,*) specimen of Dr. Wallich's and of Captain Baker's Collection of Indian woods, and the *Garipe apugne bravo,* from the Brazils, seem fully equal to boxwood in most respects.

Buxus sempervirens, or common evergreen box, is found throughout Europe, attaining a height sometimes of from 15 to 20 feet. Turkey box is yielded by *Buxus balcarica,* which is found in Minorca, Sardinia, and Corsica, and also in both European and Asiatic Turkey.

A new species has lately been introduced from the Himalayas, *Buxus emarginatus,* of Dr. Wallich: this is found of considerable size and thickness, and the wood appears as good and compact as that of the boxwood in use in Europe. Royle, Illust. Himal. Bot. p. 327. On actual comparison the Himalayan boxwood is found to be softer than the common kinds, but is like them in other respects.

Brazil-wood, called also Pernambuco, was supposed by Dr. Bancroft to have been known as a red dyewood before the discovery of the Brazils, which country, he says, was so named by Europeans from its abounding in this wood. The best kind is from Pernambuco, where it is called *Pao da rainha,* or queen's-wood, and by the natives *Ibirapitanga;* it is also found in the West Indies generally, and is often called Pernambuco-wood. The tree is large, crooked, and knotty, and the bark is so thick that the wood only equals the third or fourth of the entire diameter; the leaves are of a beautiful red, and exhale an agreeable odor. The *Pao da rainha* grows to the diameter of 15 or 16 inches, the *Pao Brazil*, an inferior kind, to 50 or 60 in. Brazil-wood is a royal monopoly, and the best quality has the imperial brand mark at the end; it is shipped in trimmed sticks from 1 to 4 in. diam. and 3 to 8 ft. long, and its color becomes darker by exposure to the air. Its principal use is for dyeing; the best pieces are selected for violin-bows and turning.

Cæsalpinia echinata, the *Ibirapitanga* of Piso, yields the Brazil-wood of commerce. De Candolle inquires whether it is not rather a species of *Guilandina*. *C. crista*, a native of the West Indies, is called *Bresillet*, because its wood is reddish-colored like Brazil-wood. *C. Sapan* is a native chiefly of the Asiatic Isles and of the Malayan Peninsula; its wood is like Brazil-wood, and well known in commerce as Sapan-wood.

Braziletto is quite unlike the Brazil-wood; its color is ruddy orange, sometimes with streaks; it is imported from Jamaica in sawn logs from 2 to 6 ft. long and 2 to 8 in. diam., with the bark (which is of the ordinary thickness) left on them; and also from New Providence, in small cleaned sticks. Braziletto is thought to be an inferior species of Brazil-wood; it is principally used for dyeing, also for turnery and violin-bows.

It is considered to be botanically allied to the above, and is called *Cæsalpinia braziliensis*, a native of the West Indies, but also found in Brazil.

Bullet-wood, from the Virgin Isles, West Indies, is the produce of a large tree, with a white sap; the wood is greenish-hazel, close and hard. It is used in the country for building purposes, and resembles the Greenheart.

The name of Bullet-wood is perhaps taken from the *Bois de balle* or Bullet-wood of the French, *Guarea trichilioides*, which in Jamaica is called musk or alligator wood. Bullet is perhaps a change from Bully-wood, which is that of the bully-tree, called also Naseberry bullet-tree, or *Achras Sapota* of botanists, described as one of the best timber-trees. The bully-tree of Guiana is also an Achras. The bastard bully-trees of Jamaica are species of *Bumelia*.

Bullet-wood, another species so called, is supposed to come from Berbice; its color is hazel-brown, of an even tint without veins; it is a very close, hard, and good wood, well adapted to general and to eccentric turning, but is not common.

The latter agrees pretty closely with a wood described by Dr. Bancroft as Bow-wood, or *Waseeba*, of Guiana.

Different specimens marked Naseberry bullet-wood, and one of an iron-wood, were exceedingly near to the above, if not identical with it, and the Bull Hoof and Bread-nut Heart, all from Jamaica, approached more distantly.

Button-wood Tree. See *Plane-tree*.

Cabbage-wood. See *Partridge-wood*.

Calamander, *Diospyros hirsuta*. See *Coromandel*.

Calamberri. See *Coromandel*.

Calembeg. A wood similar to Sandal-wood in grain, and similarly, but less powerfully, scented; its color is olive-green, with darker shades. It appears entitled to the name of Green Sandal-wood

Calembeg, or Calambac, sometimes called Aloes-wood, is the Agallochum of the ancients, and the Agila or Eagle-wood of the moderns. It is produced in Siam and Silhet by *Aquilaria Agallocha*.

Campeachy Logwood. See *Logwood*.

Camphor-wood is imported from China, the East Indies, and Brazils, in logs and planks of large size; it is a coarse and soft wood, of a dirty grayish-yellow color, sometimes with broad iron-gray streaks, and is frequently spongy, and difficult to work. It is principally used in England for cabinet-work and turnery, on account of its scent.

The Camphor-tree of Sumatra is *Dryobalanops Camphora*, of which the wood is hard, compact, and brownish-colored; there is a genuine specimen in the museum of King's College, London. The fragrant light-colored soft wood of which the trunks and boxes from China are made, is supposed to be that of the Camphor-tree of Japan, *Laurus Camphora*, now *Camphora officinalis*. One or more of the tribe of Laurels yield the *Sirwabali* wood of Guiana, which is light, fragrant, and much used in the building of boats.

Camwood, an African dyewood, is shipped from Rokella, Sierra Leone, &c., in short logs, pieces, roots, and splinters. When first opened, it is tinted with red and orange; the dust is very pungent, like snuff; it would be a beautiful wood if it retained its original colors, but it changes to dark red, inclining to brown. Camwood is the best and hardest of the red dyewoods; it is very fine and close in the grain, and suitable to ornamental and eccentric turning.

Canary-wood from the Brazils, Para, &c.; known at the Isthmus of Darien as *Amarillo*. It is imported in round logs from 9 to 14 in. diam., and sometimes in squared pieces. The wood is of a light orange color, and generally sound; it is straight and close in the grain, and very proper for cabinet work, marquetry, and turnery; is similar, if not the same, to a wood called Vantatico and Vignatico corrupted from *Vinhatico*, a Portuguese name for several yellow woods, besides that imported from the Brazils under the same name.

Laurus indica, or Royal Bay, is a native of the Canary Isles. The wood is of a yellow color not heavy, but well suited to furniture; it is called *Vigniatico* in the island of Madeira.

Cangica-wood, from the Brazils, also called in England Angica, is of the rosewood character, but of a lighter and more yellow brown, less abrupt, and more fringed, sometimes straight in grain and plain in figure. It is imported in trimmed logs from 6 to 10 in. diam., and is used for cabinet-work and turning.

Cedar. The name cedar has been given to trees of very different natural orders, and has occasioned much confusion.

The cedar of Lebanon, or great cedar, (*Pinus Cedrus*,) is a cone-bearing, resinous tree, and one of the pines. It is tall and majestic, and grows to a great size; the mean dimensions of its trunk are 50 feet high and 39 inches diameter. The wood is of a rich yellowish brown, straight-grained and it has a peculiar odor. The tree is famous in Scripture for its size and durability, (Ezekiel xxxi 3, 5, 8;) it was used in the construction of Solomon's temple at Jerusalem, and many Grecian temples and statues. A few fine trees are said still to remain on Mount Lebanon; but the wood was also procured, in the time of Vitruvius, from other parts of Syria, and from Crete, Africa, &c.—*Tredgold.*

The Pencil cedar is the *Juniperus virginiana;* it is also of the same natural order as the pine-tree. It is a native of North America. The grain of the wood is remarkably regular and soft, on which account, principally, it is used for the manufacture of pencils, and from its agreeable scent, for the inside work of small cabinets; from the same reason it is made into matches for the drawing-room.

Another species is the *Juniperus bermudiana;* it is a much harder and heavier wood than the pencil cedar, with a similar smell and appearance. It was formerly much used in ship-building; many of the timbers of the Spanish ships taken in the last war were of the Bermuda cedar.

The cedar known to cabinet-makers by the name of Havana cedar, is the wood of the *Cedrela odorata* of Linnæus, and belongs to the same natural order as mahogany, which it resembles, although it is softer and paler, and without any variety of color. It is imported in considerable quantities from the island of Cuba, and is excellent for the insides of drawers and wardrobes: all the cigar-boxes from Havana are made of this kind of cedar; the wood is brittle and porous. Some kinds of the Havana cedar are not proper for cabinet-work, as the gum oozes out and makes the surface of the work very sticky and unpleasant.

There is another kind more red in color, called red cedar; there are also white cedars common to America: one kind is called prickly cedar, from its being covered with spines; this is very like the white hemlock, and grows to 4 feet diameter, and 60 to 70 feet high, and is much used for railway works.

Another sort, from New South Wales, is the wood of the *Cedrela Toona;* it is somewhat similar to the Havana, but more red in color, and of a coarser grain; it sometimes measures 4 feet diameter. This kind is also found in the East Indies; it is in common use in joinery-work. Most of the cedars have been used for ship-building.

The Himalayan cedar (*Juniperus excelsa*) is harder and less odoriferous than the pencil cedar, but is an excellent light wood between pencil cedar and deal in general character.

The cedar of Lebanon is usually called *Pinus Cedrus*, but sometimes *Cedrus Libanus;* the lofty *Deodara*, a native of the Himalayas, with fragrant and almost imperishable wood, and often called the Indian cedar, is sometimes referred to the genus *Pinus*, and sometimes to that of *Cedrus* or *Larix*, with the specific name of *Deodara*.

The wood of several of the Coniferæ is, however, called cedar. The wood of *Juniperus virginiana* is called red or pencil cedar, and that of *J. bermudiana* is called Bermuda cedar; of *J barbadensis* is called Barbadoes cedar; while the Juniper of the North of Spain, and South of France, and of the Levant, is called *J. oxycedrus:* the white cedar of North America, a less valuable wood than the red cedar, is yielded by *Cupressus Thyoides*, and the cedar-wood of Japan, according to Thunberg, is a species of cypress.

The name cedar is, however, applied to a number of woods in our different colonies, which are in no way related to the *Coniferæ:* thus the cedar of Guiana is the wood of *Icica altissima*, white wood or white cedar of Jamaica is *Bignonia leucoxylon*, and bastard cedar is *Guazuma ulmifolia*. In New South Wales, again, the term white cedar is applied to *Melia Azederach*, and red cedar to that of *Flindersia australis*, as well as to the wood of the Toon-tree, or *Cedrela Toona*.

CHERRY-TREE is a hard, close-grained wood, of a pale red brown, that grows to the size of 20 or 24 inches, but it is more usually of half that size. When stained with lime, and oiled or varnished, it closely resembles mahogany; it is much used for common and best furniture and chairs, and is one of the best brown woods of the Tunbridge turners. The wood of the black-heart cherry-tree is considered to be the best. The Spanish American cherry-tree is very elastic, and is used for felucca masts.

Cerasus avium is the wild cherry. *C. duracina* is the heart cherry or Bigarreau. The wood of C. Mahaleb is much used by the French, and is called *bois de Sainte Lucie*.

CHESTNUT (*Castanea vesca*) is common to Europe; mean size 44 feet high, 37 inches diameter; is very long-lived and durable. The sweet, or Spanish chestnut, is very much like oak, and is sometimes mistaken for it; it was formerly much used in house-carpentry and furniture. The young wood is very elastic, and is used for the rings of ships' masts, the hoops for tubs, churns, &c., but the old wood is considered to be rather brittle. See *Horse-chestnut*.

The edible or sweet chestnut is the *Castanea vesca*, but the horse-chestnut (which see) belongs to a very different genus. The wood, formerly much used in house-building and carpentry, and which, famed for its durability, has been mistaken for chestnut, is now considered to be that of an oak, *Quercus sessiliflora*.

COCOA-WOOD, or Cocus, is imported from the West Indies in logs from 2 to 8 inches diameter, sawn to the length of 3 to 6 feet, tolerably free from knots, with a thick yellow sap: the heart, which is rarely sound, is of a light yellow brown, streaked, when first cut, with hazel and darker brown, but it changes to deep brown, sometimes almost black. Cocoa-wood is much used for turnery of all kinds, and for flutes; it is excellent for eccentric turning, and in that respect is next to the African blackwood.

An apparent variety of cocoa-wood, from 2 to 6 or 7 inches diameter, with a large proportion of hard sap of the color of beechwood, and heartwood of a chestnut-brown color, is used for tree-nails and pins for ship-work, and purposes similar to lignum-vitæ, to which it bears some resemblance, although it is much smaller, has a rough bark, the sap is more red, and the heart darker and more handsomely colored when first opened than lignum-vitæ; it is intermediate between it and cocoa-wood. Another but inferior wood exactly agrees with the ordinary cocoa-wood, but that the heart is in wavy rings, alternately hard and soft.

Cocoa-wood has no connection with the cocoanut, which is the fruit of a palm-tree common to the East and West Indies, the *Cocos nucifera;* neither can it have any relation to the other endogenous trees which produce the coquilla-nut, the *Attalia funifera* according to Martius, and *Cocos lapidea* of Gærtner, or of the *Cacao Theobroma,* or the chocolate-nut tree.

It is really singular that the exact localities and the botanical name of the cocoa-wood that is so much used, should be uncertain: it appears to come from a country producing sugar, being often imported as *dunnage,* or the stowage upon which the sugar hogsheads are packed: it is also known as brown ebony, but the *Amerimnum Ebenus* of Jamaica seems dissimilar.

The cocus-wood of commerce is not easy to trace to any of the trees of the West Indies; the cocoa plum is *Chrysobalanus Icaco,* which forms only a shrub; *Coccoloba uvifera,* or mangrove grape-tree, grows large and yields a beautiful wood for cabinet-work, but which is light and of a white color. In appearance and description it comes near to the Greenheart or *Laurus chloroxylon,* which is also called Cogwood.

Cocoanut-tree. See *Palms.*

Cocoanut-shell. The general characters of this fruit, the produce of the palm *Cocos nucifera,* are too well known to need particular description: in India its thick fibrous husk is made into the coir-rope, and in Europe into rope, matting, brushes, &c. The substance of the shell is very brittle, and its structure is somewhat fibrous, but it admits of being turned in an agreeable manner. Those shells which are tolerably circular are used for the bodies of cups and vases, the feet and covers being made of wood or ivory. Common buttons are also made of the cocoanut-shell, and are considered better than those of horn, as they do not, like that material, absorb moisture, which causes them to swell and twist.

Cocus. See *Cocoa-wood.*

Coffee-tree, (*Coffea arabica.*) The wood is of a light greenish-brown or dusky-yellow, with a bark externally resembling boxwood, but thicker and darker; it has no smell, and but little taste. The tree does not grow more than a few feet high, and it is cut down in the plantations to five or six feet, and is not therefore useful in manufactures.

The tree called Kentucky coffee-tree, or hardy *bonduc,* is very different from the common coffee; it forms a large tree called *Gymnocladus canadensis;* the wood is compact, of a rosy hue, and used by cabinet-makers.

Coral-wood, says Bergeron, is so named from its color. When first cut it is yellow, but soon changes to a fine red or superb coral; it is hard, and receives a fine polish: he also speaks of a damasked coral-wood. It is difficult to associate these with the red woods; they are, perhaps, from the descriptions, nearest to the camwood from Africa.

The coral-tree, so called from the color of its flowers, is *Erythrina Corallodendron;* but the *bois de corail* of the French is the wood of *Adenanthera pavonina,* which is hard, reddish-colored, and sometimes confounded with red sanders-wood.

Coquilla-nuts are produced in the Brazils by *Attalia funifera,* according to Martius, or the *Cocos lapidea* of Gærtner; the latter title is highly descriptive. The coquilla-nut is represented in section, half size, in Fig. 3950: the shell is nearly solid, with the exception of the two separate cavities represented, each containing a hard, flattened, greasy kernel, generally of a disagreeable flavor: the cells occasionally inclose a grub or chrysalis similar to that figured, which consumes the fruit.

3950.

3951.

3952.

The passages leading into the chambers are lined with filaments or bristles, and the end of the shell terminates exteriorly in a covering of these bristles, which conceal the passages; this end is consequently almost useless, but the opposite is entirely solid, and terminates in the pointed attachment of the stalk. Sometimes the shell contains three kernels, less frequently but one only, and we have heard of one coquilla-nut that was entirely solid. The substance of the shell is brittle, hard, close, and of a hazel brown, sometimes marked and dotted, but generally uniform. Under the action of sharp turning tools it is very agreeable to turn, more so than the cocoanut-shell; it may be eccentric-turned, cut into excellent screws, and admits of an admirable polish, and of being lackered. On the whole it is a very useful material, and suitable for a great variety of small ornamental works, both turned and filed; coquilla-nuts are extensively manufactured into the knobs of umbrellas and parasols, small toys, &c.

Coromandel, or Calamander, the produce of Ceylon, and the coast of India, is shipped in logs and planks from Bombay and Madras. The figure is between that of rosewood and zebra-wood; the color of the ground is usually of a red hazel-brown, described also as chocolate-brown, with black stripes and marks. It is said to be so hard as almost to require grinding rather than cutting; this is not exactly true, as the veneer saws cut it without particular difficulty: it is a very handsome furniture wood, and turns well; it is considered to be a variety of ebony.

There are three varieties of Coromandel: the *Calamander* or *Coromandel*, which is the darkest, and the most commonly seen in this country, the *Calemberri*, which is lighter colored and striped, and the *Omander*, the ground of which is as light as English yew, but of a redder cast, with a few slight veins and marks of darker tints. The wood is scarce, and almost or quite limited to Ceylon; it grows between the clefts of rocks; this renders it difficult to extract the roots, which are the most beautiful parts of the trees.

The Calamander-wood tree is *Diospyros hirsuta*, and Kadum Bèriya is *D. Ebenaster*, according to Moore's Catalogue of Ceylon Plants, and therefore of the same genus as the true ebony.

Coromandel, falsely so called, has a black ground, and is either striped, mottled, or dappled, with light yellow, orange, or red; it is a description of accidental or imperfect East Indian black ebony. Some of the pieces are very handsome; it is used for similar purposes to the true coromandel, from which, however, it is entirely different, and generally inferior, although it is considered a variety of the same group.

Corosos, or Ivory-nuts, are produced by *Phytelephas macrocarpa*, growing in Central America and Columbia.—(*Humboldt.*) They are described as seeds with osseous albumen; the tree is a genus allied to the *Pandaneæ*, or Screw Pines, and also to the Palms. The nuts are of irregular shapes, from one to two inches diameter, and when inclosed in their thin husks, they resemble small potatoes covered with light-brown earth: the coat of the nut itself is of a darker brown, with a few loose filaments folded upon it. The internal substance of the ivory-nut resembles white wax rather than ivory; it has, when dried, a faint and somewhat transparent tint, between yellow and blue, but when opened it is often almost green from the quantity of moisture it contains, and in losing which it contracts considerably. Each nut has a hole, which leads into a small, central, angular cavity; this, joined to the irregularity of the external form, limits the purposes to which they are applied—principally the knobs of walking-sticks, and a few other small works. Fig. 3951 is the section of the ivory-nut at right angles with the stalk, and half size; and Fig. 3952 is the section through the stalk itself, which proceeds from *s*.

Cowdie. See *Pines.*

Crab-tree, the wild Apple-tree; principally used by millwrights for the teeth of wheels. See *Apple-tree.*

Cypress-tree. Of this there are many varieties; the principal are the *Cupressus sempervirens*, and the white cypress or white cedar of North America, the *Cupressus Thyoides;* the latter is much used as a timber wood; it is an immense tree, and is considered to be more durable even than the cedar of Lebanon. The *Cupressus sempervirens* is said to have been much used by the ancients; by the Egyptians for the cases for some of their mummies, by the Athenians for coffins, and for the original doors of St. Peter's at Rome, which, on being replaced after six hundred years by gates of brass, were found to be perfectly free from symptoms of decay, and within, to have retained part of the original odor of the wood.—*Tredgold.*

It is probable that the wood of *Thuja articulata* (see *Arbor vitæ*) was also used by the ancients, and has sometimes been mistaken for that of Cypress.

Deal. See *Pines.*

Dogwood, a small underwood, which is so remarkably free from silex, that little splinters of the wood are used by the watchmaker for cleaning out the pivot-holes of watches, and by the optician for removing the dust from small deep-seated lenses; dogwood is also used for butchers' skewers, and tooth-picks.

The charcoal of the black dogwood is employed in the manufacture of the best sporting gun powder, alder and willow charcoal for the government powder.—*Wilkinson's Engines of War* 1841.

Cornus sanguinea is the wild cornel or common dogwood, *C. mas.* is the male dogwood or Cornelian cherry, while *C. florida* is an American species; others are found in the Himalayas. The name dogwood is applied in Jamaica to *Piscidia Erithrina.*

East Indian Blackwood, (*Dalbergia latifolia,*) called Blackwood-tree by the English and *Sit Sál* by the natives of India, on the Malabar coast, where it grows to an immense size. The wood of the trunk and large branches is extensively used for making furniture; it is heavy, sinking in water, close-grained, of a greenish or greenish-black color, with lighter-colored veins running in various directions, and takes a fine polish.

Ebony is described as of several colors, as yellow, red, green, and black. The existence of yellow and red ebonies appears questionable. The black ebony is the kind always referred to when the name is mentioned alone; in fact, "as black as ebony" is an old proverb. The wood is surrounded by a white sap 3 or 4 inches thick. The green ebony is an entirely different tree, with a thin smooth bark, growing in the West Indies.

Three kinds are imported: No. 1, from the Mauritius, in round sticks like scaffold poles, they seldom exceed 14 in. diameter; No. 2, the East Indian, which grows in Ceylon, the East India islands, and on the continent of India; this is mostly shipped from Madras and Bombay in logs from 6 to 20 and sometimes even 28 in. diameter, and also in planks; and No. 3, the African ebony, shipped from the Cape of Good Hope in billets, the general sizes of which are from 3 to

6 ft. long, 2 to 6 in. wide, and 2 to 4 in. thick; these are rent out of the trees, and are thence often called billet-wood.

No. 1, the Mauritius, is the blackest and finest in the grain, as well as the hardest and most beautiful of the three, but also the most costly and unsound; No. 2, the East Indian, is less wasteful, but of an inferior grain and color to the above; and No. 3, the African, is the least wasteful, as all the refuse is left behind, and all that is imported is useable, but it is the most porous, and the worst in point of color.

They are all used for cabinet, mosaic, and turnery works; also for flutes, the handles of doors, knives, and surgeons' instruments, and many other purposes. Piano-forte keys are generally made of the East Indian variety.

The African stands the best, and is the only sort used for sextants.

Colonel Lloyd says, the Mauritius ebony when first cut is beautifully sound, but that it splits like all other woods from neglectful exposure to the sun. The workmen who *use* it, immerse it in water as soon as it is felled for 6 to 18 months; it is taken out, and the two ends are secured from splitting by iron rings and wedges. He considers the Mauritius ebony to be the finest, next the Madagascar, and afterwards the Ceylon.

The black ebony is also met with in South America, but much less generally than in Asia and Africa.

The ebony of Mauritius is yielded by *Diospyros Ebenus*, that of Ceylon is *D. Ebenaster*, while the ebony-tree of the Coromandel coast is *D. melanoxylon;* other species, as *D. tomentosa* and *D. Roylei*, yield ebony on the continent of India. The tree yielding the African ebony is not ascertained. A kind of ebony is produced by *Amerimnum Ebenus*, in the West Indies, and called Jamaica ebony.

Mountain Ebony. The different species of *Bauhiniæ* are so called: *B. porrecta* grows on the hills in Jamaica, and has wood which is hard and veined with black.

See *Green Ebony* and *Coromandel.*

Elder, (*Sambucus nigra*). The branches of the elder contain a very light kind of pith, which is used when dried for electrical purposes. The surrounding wood is peculiarly strong and elastic. The trunk-wood is tough and close-grained; it is frequently used for common carpenters' rules and inferior turnery-work, for weavers' shuttles, (many of which are also made of boxwood,) for fishermen's netting pins, shoemakers' pegs, &c.

Elm, (*Ulmus*,) a timber-tree, of which there are five species; mean size, 44 ft. long, 32 in. diameter. The heartwood is red brown, darker than oak, the sap yellowish or brownish white with pores inclining to red; the wood is porous, cross-grained, and shrinks and twists much in drying. Elm is not liable to split, and bears the driving of nails or bolts better than any other timber, and it is exceedingly durable when constantly wet; it is therefore much used for the keels of vessels, and for wet foundations, waterworks, piles, pumps, and boards for coffins; from its toughness, elm is selected for the naves of wheels, shells for tackle-blocks, and sometimes for the gunwales of ships, and also for many purposes of common turnery, as it bears very rough usage without splitting.

Wych Elm. This sometimes grows to the height of 70 feet, and the diameter of 3½ feet; the branches are principally at the top, the wood is lighter and more yellow in color than the above, also straighter and finer in the grain. It is tough, similar to young sweet chestnut for bending, and is much used by coachmakers, and by shipwrights for jolly-boats.

Rock Elm appears very like the last; it is extensively used for boat-building, and sometimes for archery bows, as it is considered to bend very well.

Ulmus campestris is the common small-leaved elm, *U. effusa* is the spreading-branched, *U. glabra* is the smooth-leaved, and *U. montana* the Wych elm. *Ulmus Americana*, or the American elm, is used for the same purposes as the European species, though the wood is inferior in quality. *U. fulva* and *alata* are other American species, and several species are found in the Himalayas.

[F]irs and Pines. See *Pine.*

Fustic is the wood of a species of Mulberry, (*Morus tinctoria,*) growing in most parts of South America, the United States, and West Indies. It is a large and handsome tree; it is shipped in trimmed logs from 2 to 4 ft. long, 3 to 8 in. diameter; the color of the wood is a greenish-yellow; it is principally used for dyeing greens and yellows, and also in mosaic cabinet-work and turning.

Grenadillo, Granillo, or Grenada Cocus, from the West Indies, is apparently a lighter description of the common cocoa or cocus wood, but changes ultimately to as dark a color, although more slowly. It is frequently imported without the sap.

The tree yielding this has not been ascertained; the *bois de Grenadille* of the French is also called red ebony by their cabinet makers.

Green Ebony, from Jamaica, and the West Indies generally. It is cut in lengths of 3 to 6 ft., has a bark much like cocus, but thinner and smoother; the heartwood is of a brownish green, like the green fig. It is used for round rulers, turnery, and marquetry work, and it cleaves remarkably well. The dust is very pungent, and changes to red when the hands are washed with soap and water. The wood is very much used for dyeing, and it contains so much resinous matter, that the negroes in the West Indies employ it in fishing as a torch. The candle-woods of the West Indies obtain their name probably from the same circumstance; they are allied to the rosewoods, but are of lighter yellow colors.

The ebony of Jamaica is *Amerimnum Ebenus*, and has been mentioned under Ebony. The wood is described as being of a fine greenish-brown color, hard, durable, and capable of taking a fine polish; *B. leucoxylon* of South America yields *le bois d'ebène verte*.

Greenheart; from Jamaica, Demerara and the Brazils, bears a general resemblance to cocoa-wood both in size and bark, but the latter has a redder tint. Greenheart when first cut is of a light green brown, and striped, but it changes to the color of *Lignum-vitæ*, and is by some considered to be pernicious. It is used for turnery and other works, but its texture is coarse, and it will not cleave at all profitably.

Greenheart used in ship-building is entirely different from the above, and runs into several varieties.

Dr. Bancroft describes Greenheart, or the *Sipiera*-tree, to be in size like the locust-tree, say 60 or 70 feet high: there are two species, the black and the yellow, differing only in the color of their bark and wood. He says there is also a purple-heart wood, of a bright crimson color, but which changes to purple, and is esteemed more valuable than the preceding.

The Greenheart of Jamaica and Guiana is the *Laurus Chloroxylon* of botanists; it is also called Cogwood in the former, and *Sipieri* in the latter locality.

Gumwood, or blue Gumwood, is the produce of New South Wales; it is sent over in large logs and planks; the color is similar to that of dark Spanish mahogany, with a blue, sometimes a purple-gray cast: it is used in ship-building. There is also a variety of a redder tint, called red Gumwood, which is used for ramrods; both are also employed by the turner.

Eucalyptus piperita is the blue gum-tree of New South Wales, while red gum-tree is another species, probably *E. resinifera.*

Hackmetack Larch. See *Pines.*

Harewood. See *Sycamore.*

Hawthorn (*Cratægus oxyacantha*) has hard wood of a whitish color, with a tinge of yellow; the grain is fine, and the wood takes a good polish; but being small and difficult to work, it is not much used.

Hazel, a small underwood, but little used for turning, except for a few toys. It is very elastic, and is used, as well as the ground-ash, for the rods of blacksmiths' chisels, hoops of casks, &c. Its botanical name is *Corylus Avellana.*

Hickory, or White Walnut, (*Juglans alba,*) is a native of this country; it is a large tree, sometimes exceeding 3 ft. diameter. The wood of young trees is exceedingly tough and flexible, and makes excellent handspikes, and other works requiring elasticity. The bark of hickory is recommended by Dr. Bancroft as a yellow dye.

Holly (*Ilex æquifolium*) is a very clean, fine-grained wood, the whitest and most costly of those used by the Tunbridge-ware manufacturer, who employs it for a variety of his best works, especially those which are to be painted in water-colors. It is closer in texture than any other English woods, and does not readily absorb foreign matters, for which reason it is used for painted screens, the squares of draft-boards, and for the stringings or lines of cabinet-work, both in the white state and when dyed black, also for some of the inside works of piano-fortes, harps, for calico-printers' blocks, &c. When larger wood than holly is required, the horse-chestnut is employed, but the latter is much softer.

The holly requires very particular care in its treatment: immediately it is felled it is prepared into pieces of the form ultimately required, as planks, veneers, or round blocks for turning. The veneers are hung up separately to dry, as resting in contact even for two or three hours would stain them; the round blocks are boiled in plain water for two or three hours, and on removal from the copper they are thrown in a heap and closely covered up with sacking to exclude the air, which would otherwise cause them to split. The heap is gradually exposed as it dries; at the end of about four weeks the pieces look greenish, and are covered with mildew sometimes as thickly as one-sixteenth of an inch; this is brushed off at intervals of three or four weeks, and in about six months the wood is fit for use.

Holly is a remarkably tough, clean wood, and is used for chucks; but this troublesome preparation to whiten the wood (and which is not generally practised on other woods) is not then required, although a good boil hastens the extraction of the sap, and the subsequent seasoning of the wood.

The American species of this genus is the *Ilex opaca*, opaque-leaved or American holly, of which the wood is employed in turnery and cabinet-making; there are other species in the Himalayas.

Hornbeam, (*Carpinus Betulus,*) sometimes also called yoke-elm, is a very tough and stringy wood, which is used by millwrights for the cogs of wheels, plumbers' dressers or mallets, and a variety of things required to bear rough usage. Hornbeam is sometimes used for planes; it turns very well.

Horse-chestnut (*Æsculus hippocastum*) has no relation to the Spanish or sweet chestnut, which latter is more nearly allied to the oaks. The horse-chestnut is one of the white woods of the Tunbridge turner; it is close and soft, even in the grain, and is much used for brush-backs; it turns very well in the lathe, and is a very useful wood. It is softer than holly, but is preferable to it for large painted and varnished works, on account of its greatly superior size. It is but little used in this country.

Horse-flesh Wood, one of the Mangroves, which see.

Indian Blackwood. See *East Indian Blackwood.*

Iron-wood is imported from the Brazils, the East and West Indies, and other countries, in square and round logs, 6 to 9 in. and upwards through. Its colors are very dark browns and reds, sometimes streaked, and generally straight-grained.

The iron-woods are commonly employed by the natives of uncivilized countries for their several sharp-edged clubs and offensive weapons; in England they are principally used for ramrods, walking-sticks, for turning, and various purposes requiring great hardness and durability: the more red varieties are frequently called beefwood.

Iron-wood is a term applied to a great variety of woods, in consequence of their hardness, and almost every country has an iron-wood of its own. *Mesua ferrea,* which has received its specific name from the hardness of its wood, is a native of the peninsula of India and of the islands.

Metrosideros vera is called true iron-wood: the Chinese are said to make their rudders and anchors of it, and among the Japanese it is so scarce and valuable, that it is only allowed to be manufactured for the service of their king. The iron-wood of Southern China is *Baryxylum rufum;* of the island of Bourbon *Stadmannia Sideroxylon,* and of the Cape of Good Hope *Sideroxylon melanophleum,* which latter is very hard, close-grained, and sinks in water.

The iron-wood of Guiana is *Robinia Panacoco,* (of Aublet;) that of Jamaica is *Fagara Pterota,* and also *Erythroxylum areolatum,* which is also called redwood. *Ægiphila martinicensis,* and *Cocoloba latifolia,* are other West Indian trees, to the woods of which the name of iron-wood has been applied.

Ostrya virginica, called American hop hornbeam, has wood exceedingly hard and heavy, whence it is generally called iron-wood in this country, and in some places lever-wood.

Jakwood is the wood of *Artocarpus integrifolia,* or the entire-leaf bread-fruit tree, a native of India; is imported in logs from 3 to 5 feet diameter, and also in planks; the grain is coarse and crooked, and often contains sand. The wood is yellow when first cut, but changes to a dull red or mahogany color. It is very much used in India for almost every purpose of house-carpentry and furniture. The jakwood is very abundant, and its fruit is commonly eaten by the natives, and also sometimes by Europeans at dessert, with salt and water, like olives. The jakwood is sometimes misnamed orange-wood from its color, and also jackwood, *Jaack*-wood, and *Kuthul.* See *Baker's Papers.*

Jackaranda, the Portuguese and continental name for Rosewood, which see.

Juniper-wood. The wood of all the species is more or less aromatic, and very durable; they are found in the cold and temperate parts of the world. Some have already been mentioned under the head of Cedar. The common juniper, *Juniperus communis,* has wood which is aromatic, finely veined, and of a yellowish-brown color; *J. excelsa,* lofty or Himalayan cedar, is found on those mountains, as well as in Siberia and North America.

Kiabooca-wood, or *Amboyna-wood,* imported from Sincapore, appears to be the excrescence or burr of some large tree; it is sawn off in slabs from 2 to 4 ft. long, 4 to 24 in. wide, and 2 to 8 in. thick; it resembles the burr of the yew-tree, is tolerably hard, and full of small curls and knots; the color is from orange to chestnut-brown, and sometimes red-brown. It is a very ornamental wood, that is also much esteemed in China and India, where it is made into small boxes and writing-desks, and other ornamental works, the same as by ourselves.

The Kiabooca is said by Prof. Reinwardt, of Leyden, to be the burr of the *Pterospermum indicum;* by others that of *Pterocarpus draco,* from the Moluccas, the island of Borneo, Amboyna, &c. The native name appears, from Mr. Wilson Saunders' specimen, to be *Serioulcut:* the wood itself is of the same color as the burr, or rather lighter, and in grain resembles plain mahogany.

"The root of the cocoanut-tree is so similar, when dry and seasoned, to the 'bird's-eye' part of the wood here termed kiabooca, that I can perceive no difference; the cocoa has a tortuous and silky fracture, almost like indurated asbestos."—*Col. G. A. Lloyd.*

The comparison of the palmwood with the kiabooca renders the question uncertain, as amongst the multitudes of ordinary curly woody fibres, that one cannot account for in a palm, there are a few places with soft friable matter much resembling its cement.

Kingwood, called also Violet-wood, is imported from the Brazils, in trimmed logs from 2 to 7 in. diameter, generally pipy, or hollow in the heart. It is beautifully streaked in violet tints of different intensities, finer in the grain than rosewood, and is principally used in turning and small cabinet-work; being generally too unsound for upholstery. It is perhaps one of the most beautiful of the hard woods in appearance.

Kowrie. See *Pines.*

Laburnum (*Cytisus Laburnum*) possesses poisonous seeds, and a small dark greenish brown wood, that is sometimes used in ornamental cabinet-work and marquetry. Mr. Aikin says: "In the Laburnum there is this peculiarity, which I have not observed in any other wood, namely, that the medullary plates, which are large and very distinct, are white, whereas the fibres are a dark brown; a circumstance that gives quite an extraordinary appearance to this wood."

The Alpine laburnum, with blackish wood, is *Cytisus alpinus.*

Lancewood is imported in long poles from 3 to 6 in. diameter from Cuba and Jamaica; it has a thin rind, externally similar to that of cocoa-wood; it is called one of the rough-coated woods, and has a bark distinct from the sap-wood, but together they are very thin. Lancewood is of a paler yellow than box, and rends easily; it is selected for elastic works, such as gig-shafts, archery bows and springs; these are bent by boiling or steaming; lancewood is also used for surveyors' rods, billiard cues, and for ordinary rules, which are described as being made of boxwood.

The lancewood of Jamaica is *Guatteria virgata,* formerly *Uvaria lanceolata.* That of Guiana is an *Anonaceous* plant, and probably the same species.

Larch. See *Pines.*

Letter wood. See *Snakewood.*

Lemon tree. See *Orange tree.*

Leopard wood. See *Palms.*

Lignum vitæ, or *Guaiacum,* is a very hard and heavy wood. It is shipped from Cuba, Jamaica, St. Domingo, and New Providence, in logs from 2½ to 36 in. diameter, and is one of the heaviest of the woods. It grows in the Isthmus of Darien to the size of 5 or 6 ft., and is there called *Gual* *lacum*, and is one of the most abundant woods of the country. When first cut, it is soft and easily worked, but it becomes much harder on exposure to the air. The wood is cross grained, covered with a smooth yellow sap like box, almost as hard as the wood, which is of a dull brownish-green, and contains a large quantity of the gum guaiacum, which is extracted for the purposes of medicine. Lignum-vitæ is much used in machinery, &c., for rollers, presses, mills, pestles and mortars, sheaves for ship-blocks, and a great variety of other works requiring hardness and strength. It was employed by the Spaniards for making gun-carriages and wheels.

The fibrous structure of this wood is very remarkable: the fibres cross each other sometimes as obliquely as at an angle of 30 degrees with the axis, as if one group of the annual layers wound to the right, the next to the left, and so on, but without much apparent exactitude.

The wood can hardly be split, it is therefore divided with the saw; and when thin pieces, such as old sheaves, are broken asunder, they exhibit a fracture more like that of a mineral than an ordinary wood. The chips, and even the corners of solid blocks, may be lighted in the candle, and will burn freely from the quantity of gum they contain, which is most abundant in the heart-wood.

The Bahama lignum-vitæ has a very large proportion of sap-wood; pieces of 8 or 10 inches diameter have heart-wood that scarcely exceeds 1 or 2 inches diameter. One variety of cocoa-wood, and also the almond-wood, are somewhat similar to lignum-vitæ.

There are two species, *Guaiacum officinale* and *G. sanctum*, both of which probably yield the lignum-vitæ of commerce. This name is also sometimes applied to the wood of *Arbor vitæ*.

Lime-tree, called also the Linden-tree, *Tilia*. This wood is very light-colored, fine and close in the grain, and when properly seasoned it is not liable to split or warp. It is nearly or quite as soft as pine, and is used in the construction of piano-fortes, harps, and other musical instruments, and for the cutting-boards for curriers, shoemakers, &c., as it does not draw or bias the knife in any direction of the grain, nor injure its edge; it turns very cleanly; this wood has recently been used for the frames of the best japanned chairs inlaid with mother-of-pearl. Lime-tree is particularly suitable for carving, from its even texture and freedom from knots: the works of Gibbons, at Windsor Castle and St. Paul's, London, are of lime-tree.

The lime-tree, *Tilia europea*, is usually divided into several species: as *T. intermedia, microphylla, rubra*, and *platyphylla*.

Locust-tree. The locust-tree of North America is *Robinia pseudacacia*. The wood is greenish-yellow, with a slight tinge of red in the pores; it is used like oak. Locust is much esteemed for tree-nails for ships, and for posts, stakes, pales, &c., as it is very tough and durable; it works similarly to ash, and is very good for turning.

It grows most abundantly in the Southern States; but it is pretty generally diffused throughout the whole country. It sometimes exceeds four feet in diameter and seventy feet in height. There are no less than 140 species of forest-trees indigenous to the United States which exceed thirty feet in height. In France there are about thirty, and in Great Britain nearly the same number.

The locust-tree of the West Indies and Guiana is *Hymenea Courbaril*, (Semiri,) a tree from 60 to 80 feet in height, and five or six feet in diameter: the color of the wood of West Indian locust-tree is light reddish-brown, with darker veins, and the main size 36 inches. The wood in its native country is used for mill-rollers and cogs of wheels. Another tree, called honey locust, *Gleditschia triacanthus*, of which the wood splits with great ease, is coarse-grained, and but little used.

Logwood, called also Campeachy logwood, is from the bay of that name, and from Jamaica, Honduras, &c. It is scarcely used for turning, and is a dark purple-red dyewood, that is consumed in large quantities: its botanical name is *Hæmatoxylon campechianum*.

Mahogany, the *Swietenia Mahogoni*, is a native of the West Indies and the country round the Bay of Honduras. It is said to be of rapid growth, and so large that its trunk often exceeds 40 feet in length and 6 feet in diameter. This wood was first brought to London in the year 1724; its Spanish name is *Caôba*.

Spanish mahogany is imported from Cuba, Jamaica, Hispaniola, St. Domingo, and some other of the West India islands, and the Spanish Main, in logs from about 20 to 26 in. square, and 10 ft. long. It is close-grained, hard, sometimes strongly figured, and generally of a darker color than Honduras mahogany; but its pores frequently appear as if chalk had been rubbed into them.

Honduras mahogany is imported in logs of larger size than the above, that is, from 2 to 4 ft. square, and 12 to 18 ft. in length: sometimes planks have been obtained 6 or 7 ft. wide. Honduras mahogany is generally lighter than the Spanish, and also more open and irregular in the grain: many of the pieces are of a fine golden color, with showy veins and figures. The worst kinds are those the most filled with gray specks, from which the Spanish mahogany (except the Cuba) is comparatively free.

Both Spanish and Honduras mahogany are supposed to be produced by the same tree, *Swietenia Mahogoni* of botanists, but some suppose that the Honduras is the wood of a different species, (V. Don, Syst. 1. p. 688;) but Long, in his history of Jamaica, says, "What grows on rocky grounds is of small diameter, but of closer grain, heavier weight, and more beautifully veined; what is produced in low, rich, and moist land is larger in dimensions, more light and porous, and of a pale complexion. This constitutes the difference between the Jamaica wood and that which is collected from the coast of Cuba and the Spanish Main; the former is mostly found on rocky eminences, the latter is cut in swampy soils near the sea-coast."

African mahogany, (*Swietenia senegalensis*,) from Gambia, is a more recent importation; it twists much more than either of the above, and is decidedly inferior to them in all respects, except hardness. It is a good wood for mangles, curriers' tables, and other uses where a hard and cheap wood of great size is required: it admits of being turned equally as well as the others.

African mahogany is the wood of *Khaya senegalensis*, a genus very closely allied to the Swietenia.

Mahogany shrinks but little in drying, and twists and warps less than any other wood; on which account it is used for founders' patterns, and other works in which permanence of form is of primary importance. For the same reason, and from its comparative size, abundance, soundness, and beauty, it is the most useful of the furniture woods, and it holds the glue the best of all. Mahogany is also used for a variety of turned works, apart from upholstery and cabinet-work. The Spanish mahogany is, in general, by far the best, although some of the Honduras nearly approaches it, except in hardness and weight. The African is by no means so useful or valuable as either of the above, especially as it alters very much in drying.

There are two other species of *Swietenia*, besides the mahogany-tree, which are natives of the East Indies: the one, a large tree of which the wood is of a dull red color, and remarkably hard and heavy; the other is only a middle-sized tree, the wood of which is close-grained, heavy, and durable, of a deep yellow color, and much resembles boxwood; but neither of these species is in common use in this country.—*Tredgold.*

The first of these trees was formerly referred to Swietenia, but is now *Soymida febrifuga;* the second is probably *Chloroxylon Swietenia*, which is the satin-wood of India and Ceylon. A third species, much admired for its light color, close grain, and being elegantly veined, is the *Chikrassee* of the natives, and *Chikrassia tabularis* of botanists: the wood is much employed in making furniture and cabinet-work. The wood of the Toon-tree, *Cedrela Toona*, is sometimes called Indian Mahogany.

Manchineel, a large tree of the West Indies and South America; the wood possesses some of the general characters of mahogany, and is similarly used, but it is much less common. The wood is described as being yellow-brown, beautifully clouded, and very close, hard, and durable. It is said the Indians poison their arrows with its juice, and that the wood-cutters make a fire around it before felling it, to cause the poisonous sap to run out, to avoid injuring their eyes.

This has been accurately described in Bancroft's Guiana, p. 36–7: "The juice of this tree is a deadly poison; it bears a little apple appearing so tempting, that many new-comers have been poisoned by eating it. The tree is poisonous while green; sleeping under it has been said to have the most deadly effect.

Hippomane Mancinella is the Manchineel-tree of the West Indies. *Cameraria latifolia* is called bastard Manchineel.

Mangrove. Native woods of the shores of the tropics, bearing this name, and those of Mango, Mangle, *Maniglier*, (Fr.) &c., differ very much in kind: some bear the appearance of very indifferent ash and elm, others of good useful woods of the same kind, some are dark-colored, and many of them have the red mahogany character.

One of the latter kind known to cabinet-makers has less of the brown and more of the red tint than mahogany; it becomes darker on exposure, but not in general as much so as mahogany. This Mangrove is straight-grained, hard, and elastic, and stands better than Spanish mahogany, and it is therefore preferred for straight edges and squares.

The Mangrove-tree is *Rhizophora Mangle*, of which the wood is employed in making staves for sugar hogsheads. Growing in the same situations with it are two trees to which the name mangrove is also applied: the *Conocarpus racemosa* is called the white Mangrove by Sloane, and *Avicennia tomentosa*, olive Mangrove. *Coccoloba uvifera*, sea-side grape, also grows in the same situations, and is a large tree, of which the wood is of a reddish color.

Maple is considered to be allied to the sycamore, which is sometimes called the great maple, (*Acer Pseudo-platanus*,) or the plane-tree. The English, or common maple, is of this kind; its color is pale yellow-brown.

The American is very beautiful, and distinguished as bird's-eye maple and mottled maple. The latter is principally used for picture-frames; the former is full of small knots that give rise to its name: the grain varies accordingly as the saw has divided the eyes transversely or longitudinally, as pieces cut out in circular sweeps, such as chair backs, sometimes exhibit both the bird's-eye and mottled figures at different parts. Much sugar is made from this variety of maple. The common maple (*Acer campestris*) is very much used for house-carpentry and furniture.

The so-called Russian maple is considered to be the wood of the birch tree; it is marked in a manner similar to the American maple, but is unlike it, inasmuch as there are little stripes that appear to connect the eyes, which in the American are quite distinct, and arise from a different cause. All but the first are much used in handsome cabinet-work, and their diversities of grain are very beautifully shown in turned works.

Acer campestre is the common maple, and *A. platanoides* the platanus like or Norway maple, while *A. pseudo-platanus* is the great maple, sycamore, or mock plane-tree. *A. saccharinum* is the sugar-maple, and its wood is often called bird's-eye maple. *A. rubrum*, *circinatum*, *striatum*, and *eriocarpum*, are other American species of which the timber is employed and more or less valued. *Acer oblongum*, *cultratum*, *caudatum*, *sterculiaceum*, and *villosum*, are Himalayan species, of which the timbers may be employed for the same purposes.

Maracaybo is a furniture wood of moderate size, as hard as good mahogany, and in appearance between it and tulip-wood. It is sometimes called Maracaybo-cedar, but it has no resemblance to the cedar, although it may grow in the vicinity of the Bay of Maracaybo.

Medlar-tree, (*Mespilus germanica*:) the wood is white, soft, and being small, is not much used, except for walking sticks.

Micocoulier. See *Nettle tree.*

Mora-wood. Specimens of the Mora tree have been described by Mr. Bentham under the head *Mora excelsa;* the tree is 100 feet high, and abundant; the wood is close grained like teak, and superior to oak, esteemed for ship building, and likewise fitted for knees from the branches growing crooked; in color it resembles moderately red mahogany.

Mosatahiba. See *Mustaiba.*

Mulberry-tree, (*Morus,*) consists of about twenty varieties, of which the yellow fustic is one that is imported in considerable quantities from Rio de Janeiro. Bergeron very strongly recommends the white mulberry, which he describes as similar to elm, but very close in the grain, and suitable for furniture. He says the white is greatly superior to the black mulberry.

Morus nigra is the black, and *Morus Alba* the white mulberry; there are several other species of which the wood is esteemed for its toughness, as of *Morus parvifolia* in India, for hardness and tenacity. See *Fustic.*

Mustaiba, from the Brazils and Rio Janeiro, is imported in logs about 7 by 10 in., also in planks; it is generally of an inferior rosewood character, but harder, and is sometimes equally good; the veins are of a chestnut brown, running into black. In its grain it resembles some of the iron-woods and black partridge-wood; it has fewer resinous veins than the rosewoods. Mosatahiba, as well as lignum-vitæ, cocoa-wood, &c., is used at Sheffield for the handles of glaziers' and other knives; some of the better kinds are very good for turning, as the wood is close, sound, and heavy.

Nettle-tree, (*Celtis australis.*) *Micocoulier* of the French, has wood that is compact, between oak and box for density, and takes a high polish; it is described in the French works as a heavy, dark, close wood, without bark, very durable and free from flaws. It is said to be used for flutes, and for carving; it is also called *bois de Perpignan.*

Nicaragua-wood, a native of South America, is imported from the bay of Nicaragua, and also from St. Lucia, Rio de la Hache, Mexico, &c., in rough groovy logs without sap, that measure from 2 to 9 inches through, and 2 to 3 feet long.

Another sort, from Lima, Jamaica, and Peru, called by the dyers Peachwood, apparently from the color for which it is used, is shipped in logs sometimes as large as 18 inches diameter, and 6 feet long. Both are similar to Brazil-wood in color, and are generally too unsound for turning.

The trees yielding Nicaragua and Peach woods have not been yet ascertained, but have been supposed to be species of *Cæsalpinia*, or of *Hæmatoxylon*, but they may be very distinct, as colored woods belong to other genera.

Nutmeg-wood. See *Palm.*

Oak, (*Quercus.*) Of this valuable timber there are great varieties. Oak of good quality is more durable than any other wood that attains the same size; its color is a well-known brown. Oak is a most valuable wood for ship-building, carpentry, frames, and works requiring great strength or exposure to the weather; also for the staves of casks, spokes of wheels generally, and the naves of wagon-wheels, for tree-nails, and numerous small works. The red varieties are inferior, and are only employed for ornamental furniture.

The English oak is one of the hardest of the species; it is considerably harder than the American, called white and red oak, or than the wainscot oak from Memel, Dantzic, and Riga; the latter, which are the more interspersed with the ornamental markings or flower, from the septa or medullary rays in the wood, are the least suitable as timber.

The wainscot oak of Norway is remarkably straight, and splits easily; so much so, that it is the practice of the country to bore a small hole in the top of the tree at the beginning of the winter, and to fill it with water, the expansion of which in freezing rends the tree from top to bottom.

The live oak is a fine tree, that is met with in the Southern States; it is very different in appearance from the others, as the veins are small, and more evenly distributed throughout the wood; it is used in this country, along with the North American red cedar, for our finest ships; it is considered to be durable when dry, but not when exposed to wet.

"The sea air seems essential to its existence, for it is rarely found in the forests upon the mainland, and never more than 15 or 20 miles from the shore." "The live oak is commonly 40 or 50 feet in height, and from 1 to 2 feet in diameter, but it is sometimes much larger."

There is also a fine evergreen oak in the Cordilleras of the Andes.

The African oak is well adapted to the construction of merchant vessels, but it is apt to splinter when struck by shot; it is therefore less used for ships of war. They are all softened by steaming, and are then much more easily cut or bent; the African bends less than the others, and is the darkest in color, but it has not the silver grain nor the variegated appearance of the others: it is sometimes called Teak, (which see.)

Of the British oak there are two distinct species according to modern botanists. The *Quercus Robur*, sometimes called *pedunculata*, has acorns which are supported on long footstalks or peduncles; this timber is considered by some superior to that of the other species *Q. sessiliflora*, but this probably depends on situation, as the strength and toughness of this kind, as well as its durability, have been proved to be great. Dr. Lindley says its wood may be known by its medullary rays or silver grain being so far apart that it cannot be rent, and this gives it quite a peculiar aspect.

Quercus Ilex, the evergreen or holm oak, is common to the South of Europe; the wood is hard, heavy, and tough. *Q. Suber* is the cork-tree. *Q. Cerris*, called the Turkey oak, is common in the southeast of Europe; its timber is ornamental, being beautifully mottled, in consequence of the abundance of its silvery grain, and is supposed to be often as good as any other; the Sardinian oak is apparently produced by it. The Wainscoat oak is supposed by some to be produced by *Q. Cerris.* Dr. Lindley considers it to be a variety of *Q. sessiliflora*, grown fast in rich oak land. *Q. hispanica*, the Spanish oak, and *Q. austriaca*, the Austrian oak, are found in the countries from which they are named; and *Q. Ægilops* is the Valonia oak abounding in Greece and Asia Minor, from which countries such large quantities of its acorns are imported into England. *Q. Crinita* is common in Asia Minor, yields excellent timber, and is employed by the Turks in naval architecture.

The American oaks are numerous, but the timber of *Quercus alba*, or the white oak, comes near est to the English oak, and is largely exported to England as well as to the West Indies. *Q. virens*, the live oak, is confined to the southern of the United States, and is also found in Texas; it is said to yield the best oak in America, the timber being heavy, compact, and fine-grained.

Q. tinctoria, dyers' or black oak, is best known from its inner bark being used as a yellow dye, under the name of Quercitron; its wood is strong, but coarse. The other American oaks are inferior in the quality of their timber. Besides these there are Indian and Himalayan oaks: the timber of some of the latter is excellent in quality.

The African oak, or Teak, as it is also called, is not a species of *Quercus*, V. Teak.

Olive-wood, principally imported from Leghorn, is the wood of the fruit-tree, (*Olea europea*;) it is much like box, but softer, with darker gray-colored veils. The roots have a very pretty knotted and curly character; they are much esteemed on the Continent for making embossed boxes, pressed into engraved metallic moulds.

There is another wood, apparently from South America, called Olive-wood, but it does not agree in color, either with the fruit or wood of the olive-tree, but is of a greenish orange, with broad stripes and marks of a darker brown tint; it is a handsome wood for turning, but not very hard.

Elæodendron glaucum is called *bois d'olive*, but there is no proof that it yields the olive-wood alluded to, as the country from which this is imported is not distinctly known.

Omander. See *Coromandel*.

Orange-tree. The orange, lemon, and lime trees, (*Citrus*,) are evergreens that seldom exceed about 15 feet in height. The wood is only met with as an object of curiosity: it is of a yellow color, but devoid of smell. See *Apricot-tree*.

The orange is *Citrus Aurantium*, the lemon *C. Limonum*, the lime *C. Limetta*, and the citron *C. Medica*.

Palm-trees. Several varieties of the four or five hundred which are said to exist are imported from the East and West Indies: they are known by the names palm, palmetto, palmyra, and nutmeg leopard, and porcupine wood, &c., from their fancied resemblances, as when they are cut horizontally they exhibit dots like the spice, and when obliquely, the markings assimilate to the quills of the porcupine.

The trunks of the palms are not considered by physiological botanists to be true wood; they all grow from within, and are always soft and spongy in the centre, but are gradually harder towards the outside: they do not possess the medullary rays of the proper woods, but only the vertical fibres, which are held together by a much softer substance, like *pith* or cement, so that the horizontal section is always dotted, by which they may be readily distinguished from all true woods.

The *Areca Catechu*, or betle-nut palm, is remarkably perpendicular; it grows to the height of about 30 feet, and rarely exceeds 4 or 5 inches diameter; it bears a small tuft of leaves, and the fruit is in clusters like grapes. The betle-nut is chewed by the Indians along with quicklime, and the leaf of the Piper Betle, in the manner of tobacco. The general color of the wood is a light yellow-brown; the fibres are large, hard, and only a few shades darker than the cementitious portions.

The *Cocos nucifera*, or cocoanut palm, flourishes the best in sandy spots near the sea-beach, and sometimes grows to 90 feet in height and 3 feet in diameter, but is generally less; it is rarely quite straight or perpendicular, and has broad pendent leaves from 12 to 14 feet long, in the midst of which is a sort of cabbage, which, as well as the fruit, the cocoanut, is eaten; the husk of the nut supplies the material for coir-rope and matting. No part of this interesting tree is without its grateful service to the Indian: the leaves are used for making baskets, mats, and the covering of his dwelling; he also obtains from this tree oil, sugar, palm-wine, and arrack; and although the upper part of the trunk is soft and stringy, the lower supplies a useful wood, the fibres of which are of a chestnut brown, and several shades darker than the intermediate substance; the wood is employed for joists, troughs for water, and many purposes of general carpentry. The Asiatic Society has specimens marked male, 1st, 2d, 3d, 4th sorts, and the same number of female varieties; no material distinction is observable between them.

The *Neepere* palm is much darker than either of the preceding kinds; the fibres are nearly black and quite straight, and the cement is of a dark brown, but in other varieties with these black fibres, the softer part is very light colored, and so friable that it may be picked out with the fingers. In the Isthmus of Darien, they use the fibres of some of the palms as nails for joinery work.

Palmyra-wood, or that of *Borassus flabelliformis*, says Mr. Laird, is largely imported into Madras and Pondicherry, from the Jaffna district at the northern part of Ceylon, for the construction of flat roofs, the joists of which consist of two slabs, the third or fourth part of the tree, bolted together by their flat sides so as to constitute elliptical rafters. They are covered first with flat tiles, and then with a white concrete called *Chunam*, consisting of shell lime, yolks of eggs, and *Jaggery*, (sugar,) beaten together with water in which the husks of cocoanuts have been steeped.

The prickly pole (*Cocos guianensis*) of Jamaica, &c., a palm growing 40 feet high, and of small diameter, is said to be very elastic, and fit for bows and rammers.

The smaller kinds are imported under the names of Partridge canes, (called also Chinese fishing canes,) Penang canes from the island of that name, together with some other small palms which are used for walking sticks, the roots serving to form the knobs or handles. The knots of these sticks exhibit irregular dots something like the scales of snakes; these arise from the small roots proceeding from the principal stem, which latter shows dotted fibres at each end of the stick and streaks along the side of the same.

The *twisted* palm sticks are the central stems or midribs of the leaves of the date palm; they are twisted when green, and stretched with heavy weights until they are thoroughly dry; they are imported from the Neapolitan coast, but are considered to be produced in Egypt.

The bamboos, which like the palms are endogens, are used in India and China for almost every purpose in the arts; amongst others, in working iron and steel, as the bamboo is preferred as fuel in this art: the large pieces serve as the blowing cylinders, the small as the blast-pipe, and also when combined with a cocoanut-shell constitutes the *hookah* of the artisan. The bamboos, and several of the solid canes, are used as walking-sticks, and for umbrella and parasol sticks.

The shells of the cocoanut and coquilla-nut, and the kernels of the areca or betle-nut, and those of the corosos or ivory-nut, have likewise their uses in our workshops.

Palisander, a name used in Europe for rosewood.

There is considerable irregularity in the employment of this name; in the work of Bergeron a kind of striped ebony is figured as *bois de Palixandre;* in other French works this name is considered a synonym of *bois violet,* and stated as a wood brought by the Dutch from their South American colonies, and much esteemed.

Partridge-wood is the produce of the Brazils and the West Indian Islands; it is sent in large planks, or in round and square logs, called from their tints red, brown, and black, and also sweet partridge; the wood is close, heavy, and generally straight in the grain. The colors are variously mingled, and most frequently disposed in fine hair-streaks of two or three shades, which in some of the curly specimens cut plankways resemble the feathers of the bird; other varieties are called pheasant-wood. The partridge-woods are very porous; cut horizontally the annual rings appear almost as two distinct layers, the one hard woody fibre, the other a much softer substance thickly interspersed with pores: this circumstance gives rise to its peculiar figure, which often resembles that of the palm-tree woods.

Partridge-wood was formerly employed in the Brazils for ship-building, and is also known as cabbage-wood: the red-colored variety is called *Angelim* and *Cangelim* in the Brazils, and *Yava* in Cuba.

It is now principally used for walking-sticks, umbrella and parasol sticks, and in cabinet-work and turning; the ladies have patronized it also for fans.

The partridge-wood imported from the West Indies is yielded by *Heisteria coccinea.* The wood of several trees is no doubt included under this name.

Peachwood. See *Nicaragua-wood.*

Pear-tree (*Pyrus communis*) is a native of Europe. The wild trees are principally used, and they may be obtained from 7 to 14 inches diameter. The color is a light brown, approaching that of pale mahogany or cedar, generally less red than the apple-tree; and it is esteemed a very good wood for carving, as it cuts with nearly equal facility in all directions of the grain, and many of the old works are cut in it. It is now much used for the engraved blocks for calico-printers, paper-stainers, and pastry-cooks; it does not stand very well, unless it is exceedingly well seasoned.

Some pieces of pear-tree much resemble lime-tree from being, in the language of the workmen, "without grain," but the pear-tree is harder and tougher, and has a few darker streaks: they are used, however, for similar purposes.

Pernambouca. See *Brazil-wood.*

Peruvian-wood, a fine sound wood so called, is of a rosewood character, and measures about 12 to 16 inches through; it is harder, closer, and lighter in color than rosewood, with a straighter distribution of its dark red-brown and black veins; it has no scent. Its true name and locality are unknown.

Pigeon-wood. See *Zebra-wood.*

Pines and Firs (*Pinus*) constitute a very numerous family of cone-bearing timber-trees, that thrive the best in cold countries. The woods differ somewhat in color, partly from the greater or less quantity of resinous matter or turpentine contained in their pores, which gives rise to their popular distinctions, red, yellow, and white firs or deals, and the red, yellow, and white spruce, or pitch pines, and larches. They are further distinguished by the countries in which they grow, or the parts from whence they are shipped, as Norway, Baltic, Memel, Riga, Dantzic, and American timber, &c.

The general characters of the wood, and its innumerable uses besides those of ship and house carpentry, are too generally known to call for any description in this place; but those who may require it will find abundant information in Tredgold's Carpentry, pages 208 to 218. The Swiss pine, imported under the name *Belly-boards,* are used for the sounding-boards of musical instruments The larch is particularly durable, from the quantity of turpentine it contains; it has of late been considerably employed for naval architecture, as likewise the Hackmetack larch: larch is considered the best wood for the sleepers of railways; its bark is also used for tanning. The American pitch-pine is likewise exceedingly durable, and is much used for flooring. The white hemlock contains very little turpentine, and is remarkably free from knots: it is sometimes from 2 to 3 feet square, and 60 to 70 feet long, and is suitable for piling, the staves of dry casks, &c.; it stands extremely well.

The Cowdie, Kaurie, or New Zealand Pine, or *Dammara australis,* is the most magnificent of the coniferous woods, although not a true pine. It is said to grow from 4 to 12 feet diameter; one that had been blown down by the wind was found to measure upwards of 170 feet. The Norfolk Island pine, *Araucaria excelsa,* has enormous knots.

In Norway, when they desire to procure a hard timber with an overdose of turpentine, they ring the bark of the branches just before the return of the sap; the next year they ring the upper part of the stem; the third year the central, and lastly, the lower part near the ground. By these means the sap or turpentine is progressively hindered from returning, and it very much increases the solidity and durability of the timber. The roots of some of the red deals so abound in turpentine, that the Scottish Highlanders, the natives of the West Indies, and of the Himalayas, use splinters of them as candles. The knots of deal, especially white deal, are particularly hard; they are altogether detached from the wood in the outer planks, and often fall out when exposed in thin boards.

The pines and firs being so numerous, and the timbers of many being known in commerce by such a variety of names, it is difficult to ascertain the trees which yield them.

The *Pinus sylvestris*, however, called the *wild pine*, or *Scotch fir*, yields the red deal of Riga, called yellow deal in London; *Abies excelsa*, or Norway spruce fir, yields white deal, *Abies picea*, or silver-fir, has whitish wood, much used for flooring; *Larix europea* is the larch common on the Alpine districts of Germany, Switzerland, and Italy. Several other pines, as *P. Pinaster*, *Pinea*, *Cembra*, *austriaca* and *pyrenaica*, are found in the south of Europe, but their timber is less known in commerce.

The North American pines, *P. strobus*, or Weymouth pine, called white pine in North America, and much used throughout the Northern States; *P. mitis* or *lutea*, the yellow pine, is chiefly employed in the Northern and Middle States for house and ship building; it is considered next in durability to *P. australis*, Southern pine, called also *P. palustris*, and yellow pine, pitch pine, and red pine in different districts: it is said to form four-fifths of the houses in the Southern States, and to be preferred for naval architecture. Its timber is exported to the West Indies and to Liverpool, where it is called Georgia pitch-pine. *Pinus tæda*, frankincense pine, called white pine in Virginia; *P. rigida*, Virginian or pitch-pine; *P. banksiana*, Hudson's Bay or Labrador pine; *P. inops*, Jersey or poor pine, and *P. resinosa*. The American pitch-pine or red pine, called Norway pine in Canada, and yellow pine in Nova Scotia, and many others, yield deals of various qualities, more or less used in different districts.

The American spruce firs are the *Abies alba*, *nigra*, and *rubra*, the white, black, and red spruce firs; the last is sometimes called Newfoundland red pine, and employed in ship-building; both it and the black pine are exported to England; *Abies canadensis*, hemlock spruce fir, and *A. balsamea*, balm of Gilead fir, are also employed, although less valued for their timber, but the American larch, *Larix americana*, is much esteemed. On the west coast of America some magnificent pines have been discovered, as *P. Douglasii* and *Lambertiana* and others in Mexico. In the southern hemisphere the Cowdie pine or New Zealand pitch-tree, *Dammara australis*, considered so valuable for masts, belongs to the same genus as the *Dammar*-tree, *D. Orientalis*. The Himalayas abound in true pines: a splendid species is the *Pinus Deodara* already mentioned under Cedar; so also are *Pinus excelsa*, *Khutrow longifolia*, with *Abies Webbiana*, *Pindrow*, and others.

Plane-tree, (the *Platanus occidentalis*,) a buttonwood-tree, is a native of North America; it is abundant on the banks of the Mississippi and Ohio. This, perhaps one of the largest of the American trees, is sometimes 12 ft. in diameter; it is much used in the Western States. The color of the wood resembles beech, but it is softer. The American variety is sometimes called water-beech and sycamore. Plane-tree is used for musical instruments and other works requiring a clean light-colored wood.

The *Platanus orientalis*, called also lacewood, is a native of the Levant, and other Eastern countries; it is smaller, softer, and more ornamental than the above; the beauty of its septa gives it the damasked appearance from which it is sometimes named. It is commonly used by the Persians for their doors, windows, and furniture, and is suitable to ornamental cabinet-work and various kinds of turnery. The first kind also has septa, but they are smaller.

The true lacewood-tree is the *Daphne Lagetta*.

Plum-tree, (*Prunus domestica* and *P. spinosa*,) Europe, similar in general character to pear-tree, is used principally in turning. This is a handsome wood: in the endway of the grain it resembles cherry-tree, but the old trees are of a more reddish-brown, with darker marks of the same color. It begins to rot in small holes more generally away from, rather than in the centre of the tree, and it is very wasteful on that account.

Poon-wood, or Peon-wood, of Singapore, is of a light porous texture, and light-grayish cedar color; it is used in ship-building for planks, and makes excellent spars. The Calcutta poon is preferred.

Calophyllum inophyllum is called Poona in the peninsula of India, and *C. angustifolium*, Dr. Roxburgh says, is a native of Penang and of countries eastward of the Bay of Bengal, and that it yields the straight spars commonly called Poon, and which in those countries are used for the masts of ships.

Princes-wood, from Jamaica, is generally sent in logs like cocoa-wood, from 4 to 7 in. diameter, and 4 to 5 ft. long; it is a light-veined wood, something like West India satin-wood, but of a browner cast; the sapwood resembles dark birchwood. It is principally used for turning.

The Princes-wood of Jamaica, called also Spanish elm, is *Cordia Gerascanthus*, but the above appears to be different.

Poplar, (*Populus*.) The woods are soft, light, easy to work, suited to carving, common turnery, and works not exposed to much wear. It is considered to be very durable when kept dry, and it does not readily take fire. The bark of white poplar is almost as light as cork.

The wooden polishing-wheels of the glass grinder are made out of horizontal slices of the entire stem, about one inch thick, as from its softness it readily imbibes the polishing materials.

The wood of the *Abele*, or white poplar, is also commonly known as Ars; it is extensively used in Europe for toys and common turnery, and is frequently of a uniform reddish color, like red deal, but with very small veins.

Populus alba is the white poplar or Abele, *P. canescens* the gray or common white, *P. Tremula* is the aspen, and *P. pyramidalis* or *fastigiata*, the Lombardy poplar. There are other species in North America and the Himalayas.

Prize-wood. A large ill defined wood, from the Brazils, apparently of the cocus wood kind, but lighter and generally of reddish color.

Purple heart is mentioned by Dr. Bancroft, (see *Greenheart*;) it is perhaps the more proper name for the wood next described.

Purple-wood, or Amaranthus, from the Brazils, is imported in logs from 8 to 12 in. square and 8 to 10 ft. long, or in planks: its color is dark gray when first cut, but it changes rapidly, and ultimately becomes a dark purple.

Varieties of Kingwood are sometimes called purple and violet woods: these are variegated: but the true purple-wood is plain, and principally used for ramrods, and occasionally for buhl-work, marquetry, and turning. A few logs of purple-wood are often found in importations of Kingwood; it is probable also that the purple-heart is thus named occasionally.

Quassia-wood. The quassia-tree is a beautiful tall tree, of North and South America and the West Indies. The wood is of a pale yellow, or light brown, and about as hard as beech; its taste is intensely bitter, but the smell is very agreeable; the wood, bark, and fruit are all medicinal.

"This wood is well known in the Isthmus of Darien, and is invariably carried by all the natives as a 'contra' against the bite of venomous snakes; it is chewed in small slices, and the juice is swallowed."—*Col. G. A. Lloyd.*

Quassia amara, is a small tree; *Simaruba amara* is the Mountain damson of the West Indies, and *Picræna excelsa*, the lofty Bitter-wood. All have a similarly colored wood, which is intensely bitter

Queenwood, from the Brazils, a term applied occasionally to woods of the Greenheart and Cocoa-wood character.

Quince-tree, (*Cydonia vulgaris.*) See *Apricot-tree.*

Red Gumwood. See *Gumwood.*

Red Saunders, or *Ruby-wood*, an East Indian wood, the produce of *Pterocarpus santalinus*, is principally shipped from Calcutta in logs from 2 to 10 in. diameter, generally without sap, and sometimes in roots and split pieces; it is very hard and heavy; it is very much used as a red dye-wood, and often for turning. The logs are often notched at both ends, or cut with a hole as for a rope, and much worn externally from being dragged along the ground; other woods, and also the ivory tusks, are sometimes perforated for the like purpose.

The wood of *Adenanthera pavonia* (see Coral-wood) is similar in nature, and sometimes confounded with the red saunders.

Rosetta-wood is a good sized East Indian wood, imported in logs 9 to 14 in. diameter; it is handsomely veined; the general color is a lively red-orange, (like the skin of a Malta orange,) with darker marks, which are sometimes nearly black; the wood is close, hard, and very beautiful when first cut, but soon gets darker.

Rosewood is produced in the Brazils, the Canary Isles, the East Indies, and Africa. It is imported in very large slabs, or the halves of trees which average 18 inches wide. The best is from Rio de Janeiro, the second quality from Bahia, and the commonest from the East Indies: the latter is called East India blackwood, although it happens to be the lightest and most red of the three; it is devoid of the powerful smell of the true rosewood, which latter Dr. Lindley considers to be a species of Mimosa. The pores of the East India rosewood appear to contain less or none of the resinous matter, in which the odor, like that of the flower *Acacia armata*, arises. Rosewood contains so much gum and oil, that small splinters make excellent matches.

The colors of rosewood are from light hazel to deep purple, or nearly black: the tints are sometimes abruptly contrasted, at other times striped or nearly uniform. The wood is very heavy; some specimens are close and fine in the grain, whereas others are as open as coarse mahogany, or rather are more abundant in veins: the black streaks are sometimes particularly hard, and very destructive to the tools.

Next to mahogany, it is the most abundant of the furniture woods; a large quantity is cut into veneers for upholstery and cabinet-work, and solid pieces are used for the same purposes, and for a great variety of turned articles of ordinary consumption.

In the Brazils, the ordinary rosewood is called *Jacaranda Cabuna;* there is a sort which is much more free from resinous pores that is called *Cabuna* only: and a third variety, *Jacaranda Tam*, is of a pale red, with a few darker veins; it is close, hard, and very free from resinous veins; its colors more resemble those of tulip-wood.

Mr. Edwards says, that "at the time when rosewood was first imported into England, there was on the scale of Custom-house duties, 'Lignum Rhodium, per ton, £40,' referring to the wood from which the 'oil of Rhodium' was extracted, which at that time realized a very high price. The officers claimed the like duty on the furniture rosewood; it was afterwards imported as Jacaranda, Palisander, and Palaxander-wood, by which names it is still called in Europe. The duty was first reduced to six guineas, then in 1842 to one pound, and in 1845 the duty was entirely removed; the consumption has proportionately increased. It is now only known as rosewood, some logs of which have produced as much as £150, when cut into veneers."

Rosewood is a term as generally applied as iron-wood, and to as great a variety of plants in different countries, sometimes from the color and sometimes from the smell of the woods. The rosewood which is imported in such large quantities from Bahia and Rio Janeiro, called also Jacaranda, is so named according to Prince Maximilian, as quoted by Dr. Lindley, because when fresh it has a faint but agreeable smell of roses, and is produced by a *Mimosa* in the forests of Brazil. Mr. D. Loddiges informs us it is the *Mimosa Jacaranda.*

The rosewood, or candle-wood, of the West Indies, is *Amyris balsamifera* according to Browne, and is also called Sweetwood, while *Amyris montana* is called Yellow candle-wood, or rosewood, and also yellow saunders. Other plants to which the name is also applied, are *Licaria guianensis* of Aublet, *Erythroxylum areolatum*, *Colliguaya odorifera*, Molina, &c.

The rosewood of New South Wales is *Trichilia glandulosa;* that of the East Indies, if the same as what is there called Blackwood, is *Dalbergia latifolia.*

The lignum rhodium of the ancients, from which the oil of the same name and having the odor of roses was prepared, has not yet been ascertained; it has been supposed to be the *Genista canariensis*, and by others, *Convolvulus scoparius*.

RUBY-WOOD. See *Red Saunders.*

SALLOW (*Salix caprea*) is white, with a pale-red cast, like red deal, but without the veins. The wood is soft, and only used for very common works, such as children's toys: like willow, of which it is a variety, it is planed into chips, and made into bonnets and baskets; it splits well. See *Willow*.

SANDAL-WOOD is the produce of *Santalum album*, a tree having somewhat the appearance of a large myrtle. The wood is extensively employed as a perfume in the funeral ceremonies of the Hindoos. The deeper the color, which is of a yellow brown, and the nearer the root, the better is the perfume. Malabar produces the finest sandal-wood; it is also found in Ceylon and the South Sea Islands. It is imported in trimmed logs from 3 to 8 and rarely 14 in. diameter; the wood is in general softer than boxwood, and easier to cut. It is used for parts of cabinets, necklaces, ornaments, and fans. The bark of the sandal-wood gives a most beautiful red or light claret-colored dye, but it fades almost immediately when used as a simple infusion; in the hands of the experienced dyer it might, it is supposed, be very useful.

There are woods described in the French works as red sandal-woods. See *Calembeg.*

The sandal-wood tree of the Malabar coast is the *Santalum album*; that of the South Sea Islands is considered to be a distinct species, and has been named *Santalum Freycinetianum*, there is a spurious sandal-wood in the Sandwich Isles, called by the natives *Naihio*, (*Myoporum tenuifolium.*)

SAPAN-WOOD, or Buckum-wood, (*Cæsalpinia Sapan,*) is obtained from a species of the same genus that yields the Brazil-wood. It is a middle-sized tree, indigenous to Siam, Pegu, the coast of Coromandel, the Eastern Islands, &c. It is imported in pieces like Brazil-wood, to which, for the purposes of dyeing, it is greatly inferior; it is generally too unsound to be useful for turning.

SATIN-WOOD. The best variety is the West Indian, imported from St. Domingo, in square logs and planks, from 9 to 20 in. wide; the next in quality is the East Indian, shipped from Singapore and Bombay in round logs from 9 to 30 in. diameter; and the most inferior is from New Providence, in sticks, from 3½ to 10 in. square; the wood is close, not so hard as boxwood, but somewhat like it in color, or rather more orange; some pieces are very beautifully mottled and curled. It was much in vogue a few years back for internal decoration and furniture; it is now principally used for brushes, and somewhat for turning; the finest kinds are cut into veneers, which are then expensive; the Nassau-wood is generally used for brushes. Satin-wood, of handsome figure, was formerly imported in large quantities from the island of Dominica. The wood has an agreeable scent, and is sometimes called yellow saunders. Bergeron mentions a "*bois satiné rouge*."

The satin-wood of Guiana is stated by Aublet to be yielded by his *Ferolia guianensis*, which has both white and reddish-colored wood, both satiny in appearance. The satin-wood of India and Ceylon is yielded by *Chloroxylon Swietenia.*

SASSAFRAS-WOOD is a species of laurel, (*Sassafras officinalis*;) the root is used in medicine. The small wood is of a light brown, the large is darker; both are plain, soft, and close. Sassafras-wood measures from 4 to 12 in. diameter; it is sometimes chosen for cabinet-work and turning, on account of its scent.

SAUL, or Sâl, an East Indian timber-tree, the *Shorea robusta*, (see 377, Dr. Wallich's Catalogue:) this wood is in very general use in India for beams, rafters, and various building purposes; Saul is close-grained and heavy, of a light brown color, not so durable, but stronger and tougher than teak, and is one of the best timber-trees of India. Captain Baker considers Saul to resist strains, howsoever applied, better than any other Indian timber; he says the Morung Saul is the best. The Sissoo appears to be the next in esteem, and then the teak, in respect to strength. See *Baker's Papers.*

SAUNDERS. See *Red Saunders.*

SERVICE-TREE. This is a kind of thorn, and bears the service-berry, which is eaten; it is very much like English sycamore in every character as regards the wood.

Bergeron describes the service-tree as a very hard, heavy, and useful wood, of a red-brown color, and well adapted to the construction of all kinds of carpenters' tools. He says they will glue slips of the service-tree upon moulding planes, the bulk of which are of *oak*, on account of its hardness and endurance. He also speaks of a foreign service tree, (*Cormier des Isles*,) which is harder, but more gray in color, and more veined: these appear to be totally different woods.

SISSOO (*Dalbergia Sissoo*) is one of the most valuable timber-trees of India, and, with the Saul, is more extensively employed than any other in Northwest India. The ship builders in Bengal select it for their crooked timbers and knees, it is remarkably strong; its color is a light grayish-brown, with darker-colored veins. "In structure it somewhat resembles the finer species of teak, but it is tougher and more elastic." There are two kinds used respectively in Bengal and Bombay; the latter is much darker in color. The Indian black rose wood (*Dalbergia latifolia* is a superior species of Sissoo from the Malabar coast.

SNAKEWOOD, Letter or Speckled wood, is used at Demerara, Surinam, and along the banks of the Oronoko, for the bows of the Indians. The color of the wood is red hazel, with numerous black spots and marks, which have been tortured into the resemblance of letters, or the scales of the reptile; when fine, it is very beautiful, but it is scarce in England and chiefly used for walking-sticks, which are expensive; the pieces, that are from 2 to 8 in. diameter, are said to be the produce of large trees, from three to four times those diameters, the remainder being sap.

Dr. Bancroft says, "*Bourra courra*, as it is called by the Indians, by the French *bois du lettre* and by the Dutch *Letter hout*, is the heart of a tree growing 30 feet in height with many branches," &c.

"The above must not be confounded with the Snakewood of the West Indies and South America, the *Cecropia*, of which there are three species, all furnishing trees of straight and tall growth, and a wood of very light structure, presenting sometimes distinct and hollow cells. The *Balsas*, or floats, used by the Indians of South America for fishing, &c., are very commonly constructed of this wood."

It is thought by some to be the *Tapura guianensis*, of Aublet.

Speckled-wood. See *Snakewood.*

Spanish Chestnut. See *Chestnut.*

Spindle-tree (*Euonymus europa*) is a shrubby tree, with a yellow wood, similar to the English boxwood, but straighter and softer: it is turned into bobbins and common articles. Bergeron says the wood is used in France for inferior carpenters' rules, and that its charcoal, prepared in a gun-barrel or any closed vessel, is very suitable to the artist, as its mark may be readily effaced.

Sycamore, the *Acer pseudo-platanus*, is called in Europe the great maple, and in Scotland and the north of England, plane-tree; its mean size is 32 ft. high. Sycamore is a very clean wood, with a figure like the plane-tree, but much smaller; it is softer than beech, but rather disposed to brittleness. The color of young sycamore is silky white, and of the old brownish white; the wood of middle age is intermediate in color, and the strongest; some of the pieces are very handsomely mottled. It is used in furniture, piano-fortes, and harps. Sycamore may be cut into very good screws, and it is used for presses, dairy utensils, &c. See *Maple.*

Teakwood is the produce of the *Tectona grandis*, a native of the mountainous parts of the Malabar coast, and of the Rajahmundry Circars, as well as of Java, Ceylon, and the Moulmein and Tenasserim coasts.

It grows quickly, straight, and lofty; the wood is light and porous, and easily worked, but it is nevertheless strong and durable; it is soon seasoned, and being oily, does not injure iron, and shrinks but little in width. Its color is light brown, and it is esteemed most valuable timber in India for ship-building and house-carpentry; it has many localities. The Malabar teak grown on the western side of the Ghaut mountains is esteemed the best. Teak is considered a more brittle wood than the Saul or the Sissoo.

In 25 years the teak attains the size of two feet diameter, and is considered serviceable timber, but it requires 100 years to arrive at maturity. There is a variety, says Dr. Roxburgh, which grows on the banks of the Godavery in the Deccan, of which the wood is beautifully veined, closer grained and heavier than the common teak-tree, and which is well adapted for furniture.

Some of the old trees have beautiful burrs, resembling the Amboyna, which are much esteemed.

The woods in general do not very perceptibly alter in respect to length; Teak, says Colonel Lloyd, is a remarkable exception. He found the contraction in length, in the beams of a large room he erected in the Mauritius, to be three-quarters of an inch in 38 feet.

The teakwood when fresh has an agreeable odor, something like rosewood, and an oil is obtained from it. He adds, "The finest teak now produced comes from Moulmein and other parts of Burmah; some of this timber is usually heavy and close-grained, but in purchasing large quantities care must be taken that the wood has not been tapped for its oil, which is a frequent custom of the natives, and renders the wood less durable."

"At Moulmein, so much straight timber is taken and the crooked left, that thousands of pieces called 'shin logs,' and admirably adapted for ship-timbers, are left. Teak contains a large quantity of silicious matter, which is very destructive to the tools."

African teak does not belong to the same genus as the Indian teak; by some it is thought to be a *Euphorbiaceous* plant, and by Mr. Don to be a *Vitex.*

Toonwood has already been mentioned under the head of Cedar, as being similar to the so-called Havana cedar, the *Cedrela odorata*. The toon-tree is *C. Toona;* its wood is of a reddish-brown color, rather coarse-grained, but much used all over India for furniture and cabinet-work.

Tulip-wood is the growth of the Brazils. The wood is trimmed and cut like Kingwood, but it is in general very unsound in the centre, its color is flesh-red, with dark red streaks; it is very handsome, but it fades. The wood, which is very wasteful and splintery, is used in turnery, Tunbridge-ware manufactures, and brushes.

A wood sometimes called French tulip-wood, from its estimation in that country, appears to resemble a variegated cedar: it is much straighter and softer in the grain than the above, the streaks are well contrasted, the light being of an orange red; it appears to be a very excellent furniture and turnery-wood, but has no smell; it contains abundance of gum, and is considered to come from Madras, but which peninsula has no pines.

Vinhatico. The Portuguese name for several yellow and yellow-brown woods. See *Canary-wood.*

Violet-wood. See *Kingwood.*

Vinewood. See *Apricot-tree.*

Walnut. The Royal or Common Walnut (*Juglans regia*) is a native of Persia and the north of China. Walnut was formerly much used in England before the introduction of mahogany. The heart-wood is of a grayish brown, with black-brown pores, and often much veined with darker shades of the same color; the sap-wood is grayish white. Some of the handsome veneers are now used for furniture, but the principal consumption is for gun-stocks, the prices of which in the rough vary from a few pence to one and two guineas each, according to quality. An inferior kind of walnut is very much used in France for furniture, frames of machines, &c.; it is less brown than the fine sort.

The Black Virginian Walnut (*Juglans nigra*) is found from Pennsylvania to Florida. It is a large tree, has a fine grain, is beautifully veined, and is the most valuable of the American kinds for furniture.

The White Walnut is the Hickory, which see.

Willow. There are many varieties of the willow, (*Salix.*) It is perhaps the softest and lightest of our woods. Its color is tolerably white, inclining to yellowish-gray; it is planed into chips for hat-boxes, baskets, and wove bonnets; it has been attempted to be used in the manufacture of paper. The small branches of willow are used for hoops for tubs, the large wood for cricket-bats. From the facility with which it is turned, it is in demand for boxes for druggists and perfumers, which are otherwise made of small birchwood.

The wood of the willow is described by Mr. Loudon as soft, smooth, and light; the wood of the larger species, as *Salix alaba* and *Russelliana*, is sawn into boards for flooring. The red-wood willow, *S. fragilis*, is said to produce timber superior to any other species: it is used for building light and swift-sailing vessels; *S. Russelliana*, being closely allied to *S. fragilis*, is probably allied to it in properties. The wood of *S. caprea* is heavier than that of any other species. Hats are manufactured in France from strips of the wood *S. alba*.

Yacca-wood, or Yacher, from Jamaica, is sent in short crooked pieces like roots, from 4 to 12 in. thick. The wood is pale grown, with streaks of hazel brown; it is principally used for ornamental cabinet and marquetry work, and turning; some pieces are very handsome.

Yellow-wood. There is a fine East India wood thus called; it appears to be larger and straighter than boxwood, but not so close-grained.

This is probably a *Nauclea*. The wood of *Nauclea cordifolia*, according to Dr. Roxburgh, is exceedingly beautiful in color, like boxwood, but much lighter, and at the same time very close-grained. It is used by the inhabitants of Northern India to make combs of.

Yew. The yew-tree is common in Spain, Italy, and England. The tree is not large, and the wood is of a pale yellow-red color, handsomely striped, and often dotted like Amboyna. It has been long famed for the construction of bows, and is still so employed, although the undivided sway it held in the days of Robin Hood has ceased. The English species (*Taxus baccata*) is esteemed a hard, tough, and durable wood: it is a common saying amongst the inhabitants of the New Forest in Hampshire, that a post of yew will outlive a post of iron; it would appear the yew-tree lives to a great age, as some of those in Norbury Park are said to have been recorded in Domesday Book. The yew-tree is used for making chairs, handles, archery-bows and walking-sticks. Some of the older wood is of a darker color, more resembling pale walnut-tree, and very beautifully marked; the finer pieces are reserved for cabinet-work, and it is a clean wood for turning. The Irish yew is preferred for bows.

The burrs of the yew-trees are exceedingly beautiful, and although larger in figure, they sometimes almost equal the Kiabooca.

The American yew, *Taxus canadensis*, is supposed to be only a variety of *T. baccata*; the Himalayan species are closely allied to this and to *T. nucifera*.

Zante, or Young Fustic, from the Mediterranean, is a species of sumach, (*Rhus Cotinus.*) It is small, and of a golden yellow, with two-thirds sap; it is only used for dyeing, and is quite distinct from the *Morus tinctoria*, or old fustic.

Speaking of this tree, Dr. Bancroft says: "A distinction was improperly created at least 130 years ago, (now 180,) calling that of the *Venice sumach Young* Fustic, (as being manifestly the wood of a small shrub,) and that of *Morus tinctoria*, (which is always imported in the form of large logs or blocks,) *Old* Fustic."—*Bancroft's Phil. of Colors*, v. i. p. 413.

The Zante is also called *Chloroxylon*; its modern Greek name is *Imppore*.

Zebra-wood is the produce of the Brazils and Rio Janeiro; it is sent in logs and planks, as large as twenty-four inches. The color is orange-brown, and dark-brown variously mixed, generally in straight stripes; it is suitable to cabinet-work and turnery, as it is very handsome. A wood from New South Wales bearing some resemblance to the above is sometimes called by the same name, as are also some other woods in which the stripes are of a distinct and decided character.

The zebra-wood is considered by upholsterers to be intermediate in general appearance between mahogany and rosewood, so as to form a pleasing contrast with either of them. The Portuguese name for the zebra-wood appears from Mr. G. Loddiges' collection to be *Burapinima*, and from Mr. ——'s *Goncalo do para*: No. 53, of the last group, *Casco do tartarua*, is like Zebra, but heavier, more handsome, and of a rich hazel brown, with black wavy streaks. The pigeon-woods are usually lighter, and of more yellow-browns.

Zebra wood is also called Pigeon wood; one kind of Pigeon-wood in Jamaica is *Guettarda speciosa*.

Memoir on the preservation of woods.—A paper bearing this title was lately read before the French Academy of Sciences, by its author, Dr. Boucherie, and as an appropriate sequel to the foregoing pages upon the woods, we append a synopsis of the numerous experiments referred to.

He contrasts the increasing consumption and the rapid decay of timber, with its slow rate of production, which make it necessary to economize its employment. He adverts to the many projects for its preservation, enumerated by Mr. John Knowles, and the methods subsequently proposed, to many of which he objects from their uselessness; to others from the slow and superficial manner in which timbers part with their contained fluids, or absorb new ones by simple immersion, (circumstances long since proved by Duhamel;) and to all from their *expense*, which is of course the ultimate test of general application.

Dr. Boucherie argues, that all the changes in woods are attributable to the soluble parts they contain, which either give rise to fermentation or decay, or serve as food for the worms that so rapidly penetrate even the hardest woods. As the results of analyses, he says that sound timbers contain from three to seven per cent. of soluble matters, and the decayed and worm-eaten rarely two, commonly less than one, per cent.; he therefore concludes that "since the soluble matters of the wood were the causes of the changes it undergoes, it is necessary to its preservation, either to abstract the soluble parts in any way, or to render them insoluble by introducing substances which should render them infermentable or inalimentary;" which he considers may be done by many of the metallic salts and earthy chlorides.

Dr. Boucherie shows, by parallel experiments upon "vegetable matters very susceptible of decomposition, as flour, the pulps of carrot and beet-root, the melon, &c., (which only differ from wood, of which they possess the origin and constitution, by the greater proportion of soluble matter which they contain,") that in the natural states they rapidly alter, but are preserved by the pyrolignite of iron, (pyrolignite *brut* de fer,) a cheaper material than the corrosive sublimate commonly used, and one very desirable in several respects. He presumed that by immersing the end of a tree *immediately after it was felled* into a liquid, the vital energies not having ceased, the tree would then absorb such fluid through all its pores, by a process which he calls aspiration; and in this fortunate surmise he was entirely successful. This led step by step to numerous practical results, which their inventor enumerates as follows, and describes in separate chapters.

1st. "For protecting the woods from the dry or wet rot."

2d. "For augmenting their hardness."

3d. "For preserving and developing their flexibility and their elasticity."

4th. "For rendering impossible the changes of form (*jeu*) they undergo, and the splits (*disjonctions*) which take place when they are brought into use, or are submitted to atmospheric changes."

5th. "For greatly reducing their inflammability and combustibility."

6th. "For giving them various and lasting colors and odors."

We shall endeavor to convey a general notion of the methods in the same order.

1. Durability. He took a poplar tree measuring 28 *mètres* in height and 40 *centimètres* diameter, simply divided from its root with its branches and leaves undisturbed, and immersed it erect to the depth of 20 *centimètres* in a vessel containing pyrolignite of iron; in six days it was entirely impregnated even to the leaves, and had absorbed the large quantity of three *hectolitres*. This method required powerful lifting apparatus, and a support for the tree to lean against, and hence was objectionable.

He repeatedly operated upon trees lying on the ground, by attaching to their bases water-proof bags containing the liquid: the experiments were varied in many ways; sometimes portions of the branches were lopped off, but the crown or tuft was always left upon the principal stem; at other times the aspiration was effected by boring detached holes near the earth supplied with different fluids, which gave rise to all kinds of diversities in the result; and other trees were pierced entirely through, and a horizontal cut extending to within an inch or so of each side was made with a thick saw, leaving only sufficient wood for the support of the trees.

For fear of losing the trees upon which he had the opportunity of experimenting, the process was not deferred beyond 24, 36, or 48 hours after they were felled, as the vigor of the absorption was found to abate rapidly after the first day, and that at about the tenth day it was scarcely perceptible: it was also found the aspiration entirely failed in *dead* wood, whether occurring at the heart of old trees, or at parts of others from any accidental interruption of the flow of the sap during the growth; and also that resinous trees absorbed the fluids less rapidly than others.

Observations were also made of the quantities of the liquids taken up; these fluids, when of a neutral kind, as the chloride of soda, often equalled in bulk that of the wood itself, without causing any addition to its weight; the acid and alkaline fluids were less abundantly absorbed, apparently from contracting the vessels by their astringent action. It is stated that the pyrolignite of iron effected the preservation of the substance when equal to less than a fiftieth of the weight of the green wood. These points are all separately treated in the original paper.

2. The hardness of the wood was considered by various workmen to be more than doubled by the action of the pyrolignite.

3. The flexibility (due to a certain presence of moisture) was increased in a remarkable manner by the chloride of lime and other deliquescent salts, the degree of elasticity depending upon their greater or less concentration. As a cheap substitute for the above, the stagnant water of salt marshes was adopted, with a fifth of the pyrolignite, for the greater certainty of preservation. Pieces of prepared deal, 3 *millimètres* thick and 60 *centimètres* long, were capable of being twisted and bent in all directions, as into screws, also into three circular coils; the wood immediately regained its figure when released; this condition lasted eighteen months, that is, until the time his paper was read.

4. The warping and splitting, principally due to the continual effect of the atmosphere in abstracting and restoring the moisture, was stayed by impregnating the wood with a weak infusion of the chloride, so as always to retain it to a certain degree moist; one-fifth of pyrolignite was also added in this case. The seasoning of the wood was also considered to be expedited by the process, and which was not found to interfere with the ordinary use of oil-paint, &c. Large boards of the prepared wood, some of which were painted on one or both sides, and similar boards of unprepared wood, were compared; at the end of twelve months, the former were perfect as to form, the latter were warped and twisted as usual.

5. The inflammability and combustibility of the woods were also prevented by the earthy chlorides, which fuse on their surfaces by the application of heat, and render them difficult of ignition. Two similar cabins were built of prepared and of ordinary wood respectively, and similar fires were lighted in each; the latter was entirely burned, the other was barely blackened.

6. In respect to colors infused by the aspiratory process, the vegetable colors were found to answer less perfectly than the mineral, and the latter succeeded best when the color was introduced at two processes, so that the chemical change (that of ordinary dyeing) occurred in the pores of the wood

itself. Odorous matters, required to be infused in weak alcoholic solutions, or essential oils, they were considered to be equally durable with those supplied by the hand of nature; and resins similarly introduced were found to increase amazingly the inflammability of the woods, and to render them impervious to water.

On the whole, the method is considered to promise the means of working almost any desired change in the constitution and properties of woods, when the fluids are presented to them before the vitality of the tree has ceased. It is true we have as yet only two years' trial of these experiments, but they have been scientifically deduced, and their inventor is still engaged in prosecuting them. It is to be hoped, and also expected, that these interesting and flattering promises of success will be realized, and even extended, when tried by that most severe of all tests, time.*

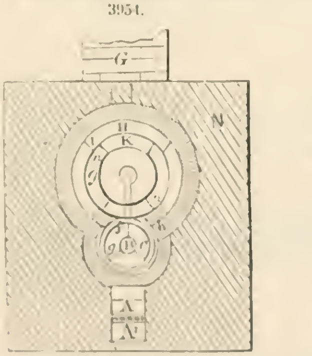
For the preceding article on Woods, we acknowledge our indebtedness to Holtzapffel's Turning and Mechanical Manipulation, a work we conceive of great merit.

WOOD STEAM CARBONIZING MACHINE. Description of an apparatus for carbonizing wood by means of heated steam. By M. Violette. It is well known that the nature of the product of the carbonization of wood, in a close vessel, varies according to the temperature: for instance, a very great heat produces a black charcoal, deprived of the greater part of its volatile hydrogenated parts; whilst a more moderate heat gives a red charcoal, retaining more of the properties of wood, and still charged with volatile principles. It is this latter quality of charcoal which produces the best gunpowder; and it is therefore important to discover the best means of preparing it. With this object in view, M. Violette has, by experiment, determined the limits within which a red charcoal may be obtained: that is to say, a product which is not wood, and yet is not perfect charcoal. To effect this object he employs a bath of metal, fusible at 160°, composed of one part bismuth, 4 parts of lead, and 3½ parts of tin. This metal he keeps in fusion in a deep glass vessel, suspended over a Carcel lamp. A thermometer, graduated at 350°, is immersed in this bath to show the temperature. The pieces of wood to be experimented upon are fastened to the ends of platina wires, and put into glass tubes, closed at one end, and immersed in the metallic bath. By this arrangement the wood is maintained at the temperature indicated by the thermometer, and sufficiently protected from contact with the atmosphere. The wood may be withdrawn for inspection, when required, by means of the platina wires. A suitable and unvaried temperature may be maintained by raising or lowering the wick of the lamp at the beginning of the operation. The wood exposed in this apparatus during an hour to a temperature of from 200° to 250°, does not become converted into charcoal; at the end of two hours, at the same temperature, it is converted into red charcoal, its surface being properly carbonized, but its interior being still wood; at the end of three hours it is converted into a hard red charcoal, brittle, and burning with flame, but incapable of extending its combustion; if submitted for an hour to a heat of 300° a very good red charcoal is obtained, of sufficient hardness, but easily pulverizable; on the prolongation of the experiment to two hours a more perfect charcoal is obtained, which burns with flame; and lastly, at a temperature of 350°, and at the end of half an hour, a charcoal is obtained which is black, friable, and easily pounded.

The first experiments were made with a small apparatus, capable of containing about 2 lbs. of wood; and, independently of the superior quality of the powder manufactured with the charcoal thus obtained, it was found that the product was augmented to as much as 42 per cent. of the weight of the wood.

The apparatus now employed for this purpose is shown below, Fig. 3953 being a longitudinal vertical section, and Fig. 3954 a transverse section in the line *a b* of Fig. 3953. It consists of two hollow con-

3954.



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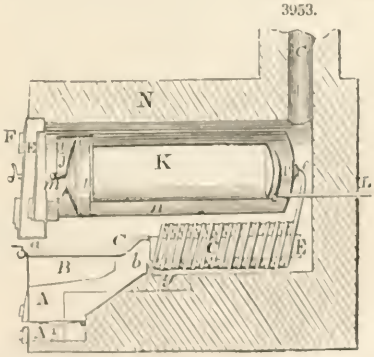


centric iron cylinders, H and K; in the inner one (K) of which the wood to be carbonized is placed. C is a coil of steam pipe, communicating at one end with a steam-boiler, and at the other with the outer cylinder H. A is the fire place, (which may be fed with wood or coke, or some other suitable fuel,) wherein the steam pipe is heated to any required degree of temperature. The cylinder H is closed by a wrought iron cover I, and the apparatus is provided with two outside cast-iron doors F F, by which it is protected from the cooling action of the atmosphere. L is a pipe for letting off the steam and the products of the distillation of the wood from the cylinder K. G is the flue, for the escape of the smoke from the fireplace A. The whole apparatus is surrounded by brickwork or masonry, N.

* In France, Dr. Boucherie has relinquished his *brevet*, and thrown the process open to the public in consideration of a national reward; and immense preparations are being there made, by the Minister of Marine, for the employment of the preservative process for the French navy. In England Dr. Boucherie and Company have obtained two patents, and Mr. Puddock, their agent, has specimens of pine, plane tree, &c., variously prepared and colored, with the pyrolignite of iron, the prussiate of iron, the prussiate of copper, and various other metallic salts, &c.

The wood to be carbonized is first placed in a cylinder, made either of wirework or perforated metal, which is introduced into the cylinder K; by this arrangement, should the charcoal become ignited on being taken out, the flame will be prevented from spreading. The charge in this apparatus weighs from 30 to 40 lbs.

Mode of operation.—The first thing to be done is to get up the steam, until the manometer indicates one atmosphere; the fireplace for heating the steam-pipe is then to be lighted, and in about a quarter of an hour the doors may be opened, and the perforated cylinder containing the wood introduced into the cylinder K, which is then closed by means of the cover I; a luting of clay being made round the edge thereof, and a screw *m* applied to fasten the cover in its place, the outer doors may then be closed. After the lapse of ten minutes, when the luting has become sufficiently dried, the induction steam-cock is opened, and the steam rushes into the steam-pipe C, where it becomes heated; from thence it passes into the outer cylinder H, and into the inner cylinder K at its open end, where it gradually insinuates itself into the pores of the wood, acting, by its great heat, in such a manner as to carbonize it, and finally makes its escape through the pipe L, carrying with it the gases evolved from the wood. In order to keep the fire at a certain temperature, there is a small glazed opening at *a*, through which the workman can see that the flame acts properly upon the steam-pipe. After some time, a thermometer, (specially constructed for the purpose,) on being introduced into the cylinder K, shows that the temperature has reached such a height as to melt tin; and the steam which escapes shows, by its color and odor, that it is mixed with the first products of distillation of the wood, and that the carbonization has commenced. The smoke or vapor thickens, and takes successively various aspects, which are certain signs of the progress of the operation. After about two hours from the time the distillation was first apparent, the smoke shows that the operation is finished. The attendant then proceeds to discharge the charcoal; and for this purpose two other attendants are ready with what is called the *extinguisher*, a large iron cylinder, about three feet in diameter, and about six feet in length, to receive the charcoal. The chief attendant then shuts off the steam, opens the doors F, turns the screw *m*, lays hold, by means of wooden handles, of the respective ends of the cross-bar J, which keeps the disk in its place, detaches it, and plunges it into a vessel full of water close by; then, by means of the same wooden handles, he takes hold of the disk, and twisting it round, so as to break the luting, detaches it, and plunges it also into the vessel of water. The attendants holding the extinguisher put it in a horizontal position in front of the cylinder K, so as to close the orifice. The chief attendant then pushes a long rod through the pipe L, so as to push the cylinder containing the charcoal into the extinguishing cylinder, which is then quickly placed on the ground, and the hydraulic joint with which it is provided is filled with water. The operation is then completed.

The inventor has observed that there are no traces of tar in the apparatus, as it is all driven off by the steam. The charcoal obtained is of very fine quality, and varies according to the temperature: that is to say, is *red* or *black*, according to the degree of heat and the length of time during which it has been maintained. The former is suitable for manufacturing the finer sorts of powder for sporting purposes, and the latter, inferior powder, for blasting mines, &c.

The apparatus above described has been in operation more than a year, and has produced 5000 lbs. of superior charcoal, and is now in very good condition.

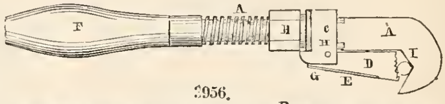
Various modifications may be made in this apparatus without in any manner altering the main feature of the invention; for instance, the inventor proposes, in some cases, to use an apparatus containing three carbonizing cylinders, one of which shall not be supplied with steam, but merely serve to dry the wood, and prepare it for either of the other cylinders, on either side of the steam-pipe; this arrangement has the effect of rendering the operation continuous.

WRENCH, CYLINDER. Invented by S. Merrick, of Springfield, Massachusetts, and patented January 2, 1849.

This wrench is designed for grasping and turning round bolts, nuts, gas and water pipes, and other cylindrical substances.

By reference to the accompanying drawings, its construction and operation will be readily understood.

3955.



3956.

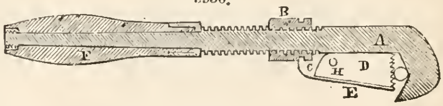
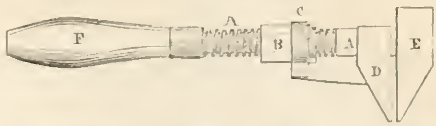


Fig. 3955 is a side elevation; Fig. 3956 a central vertical section. The same letters refer to like parts in each figure. A, *main bar*; B, *nut*, fitted to a screw, cut on the two opposite edges of the main bar; C, *slide*, made to move easily upon the main bar, and connected with the nut by a collar on the end of the nut and a groove underneath the end of the slide; D, *tightening lever*, attached to slide C by a joint, as seen at H; E, *spring* for the purpose of pressing the lever D upon the main bar; F, *handle*. The end of the lever D is made circular, the centre of which circle is shown at G, for the purpose of pressing more firmly against the cylinder I, as the end of the lever is forced down towards the main bar. The circular end of the lever is also indented or roughened that it may not slip on the cylinder I. H, joint of the lever D and slide C; I, the cylindrical substance to be turned.

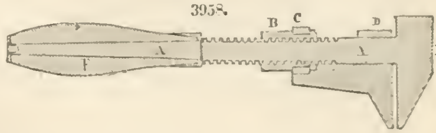
To operate the wrench, it is placed upon the cylinder to be turned, as seen in Fig. 3955, and the indented end of the lever D is brought in contact with it by means of the nut B. The handle is then moved backwards, and the lever advanced at the same time, until the end of the lever is somewhat raised from the main bar; the handle is then carried forward in the direction shown by the arrow, which causes the lever to take firm hold of the cylinder and carry it around in the same direction; and by reversing the motion of the handle, the cylinder is instantly released for a new hold. It will be obvious that the wrench can be readily adapted to any size of cylinder within its compass, and will thus supply the place of a pair of tongs (the only tool in use for the same purpose previous to this invention) for each particular size of cylinder. It also possesses the advantage of being worked with one hand after being set to the particular size required.

WRENCH, SCREW. Invented by S. Merrick, of Springfield, Massachusetts, and patented August 17, 1835; patent extended May 14, 1849.

3957.



3958.



In the drawings, Fig. 3957 denotes a side elevation; Fig. 3958, a vertical central section. The same letters refer to like parts in each figure.

A is the *main bar;* B, the *nut* fitted to a screw, cut on the two opposite edges of the main bar; C, a *strap,* which passes around in a groove formed in the nut B, and is riveted to the end of the slide-jaw D. The collar on the end of the nut B takes into a corresponding groove in the slide D; E, the end of the main bar, which forms the stationary jaw of the wrench; F, the handle. The nut is made to move freely in the strap C, and, by turning it to the right or left, the slide D is moved to any desired point on the main bar.

The principal advantages possessed by this wrench are, its *simplicity* of construction and consequent *cheapness*—its *compactness, durability,* and *strength;* the size of the main bar being duly proportioned to the power applied, as will be seen in the figure.

ZINC, *composition and use of.* Zinc or Spelter has a crystalline texture, is brittle at ordinary temperatures, and of a bluish-white color: at 300°, it is both malleable and ductile, and at a white heat it is converted into vapor. When pure zinc is exposed to air and moisture, it acquires a dull color from partial oxydizement; and great electric action takes place when it is in contact with copper, and the zinc decays in consequence. Its specific gravity is 7, and it has a great attraction for oxygen; the weight of a cubic foot is 439¼ pounds.

Oxide of zinc is obtained by intensely heating the metal exposed to air; it takes fire at a red heat, if the air is freely admitted, burning with a very bright flame.

Zinc	1	32	80
Oxygen	1	8	20
	1	40	100

Sulphuret of zinc (*blende*) is found native, and is a brittle, soft metal, of a brown and black color; its primitive form is a rhomboidal dodecahedron, and it is a most abundant mineral. The pure metal is obtained from it by roasting the oar, and afterwards distilling it when mixed with charcoal.

Zinc	1	32	66·5
Sulphur	1	16	33·5
	1	48	100·0

Carbonate of zinc, (*calamine:*) when found crystallized, its primitive form is an obtuse rhomboid.

Oxide of zinc	1	40	64·5
Carbonic acid	1	22	35·5
	1	62	100·0

Zinc is obtained from the sulphuret and carbonate; the ore when broken is submitted to a dull red heat in a reverberatory furnace, when the carbonic acid is driven off from the calamine, and the sulphur from the blende: it is then mixed with one-eighth of its weight of powdered charcoal, being first ground and thoroughly washed, and distilled by the application of a red heat; the metal being put into earthen pots with iron tubes cemented into the lower parts, dipping into water, where it is collected, and afterwards cast into cakes. A bar of zinc 12 inches long and 1 inch square, weighing 3·05 pounds, expands in length at one degree of heat $\frac{1}{81265}$, and melts at 648°; it will bear, without permanent alteration, a pressure on a square inch of 5700 pounds.

Zinc is used for the preservation of iron, by electro-deposition. The iron is first rendered perfectly clean and free from oxide, by placing it in a bath of heated sulphuric acid and water; then in a cold solution of sulphate of zinc. The positive pole of a galvanic battery is attached to a zinc plate, and the negative to the iron to be covered; the pure metal is deposited, and the zinc and iron are amalgamated. Wooden troughs are employed for the process, and iron plates so covered are extensively used for roofing, and do not after many months exhibit any signs of decay. The iron being coated with zinc in a cold solution does not in any way change its condition; but when the zincing of iron is performed by steeping it in a bath of melted zinc, a combination takes place between the two metals, and a brittle alloy is the consequence, the iron losing all its tenacity.

Tin is usually prepared from the native oxide its oxygen being removed by charcoal: the purer kinds are called grain tin, and the others block tin. The common ores are known under the name of mine tin, and furnish a less pure metal than the stream tin. Tin has a silvery-white color; its specific gravity is 7·3, and the air and moisture have little effect upon it: it melts at 442°, and is converted into a white oxide by exposure to heat and air.

The specific gravity of the native peroxide of tin is 7, and its primitive crystal an obtuse octohedron

Protoxide of tin: specific gravity 6·6:

Tin	1	58	87·8
Oxygen	1	8	12·2
	1	66	100·0

Bisulphuret of tin (*Aurum musivum, Mosaic gold*) is a mixture formed by heating peroxide of tin which contains two of oxygen and one of tin, with its weight of sulphur. Bisulphuret of tin is also formed by decomposing perchloride of tin by sulphuretted hydrogen; it is quite insoluble in the acids, except nitro-muriatic; it forms the bronze powder used by paper-stainers.

Tin	1	58	64·4
Sulphur	2	32	35·6
	1	90	100·0

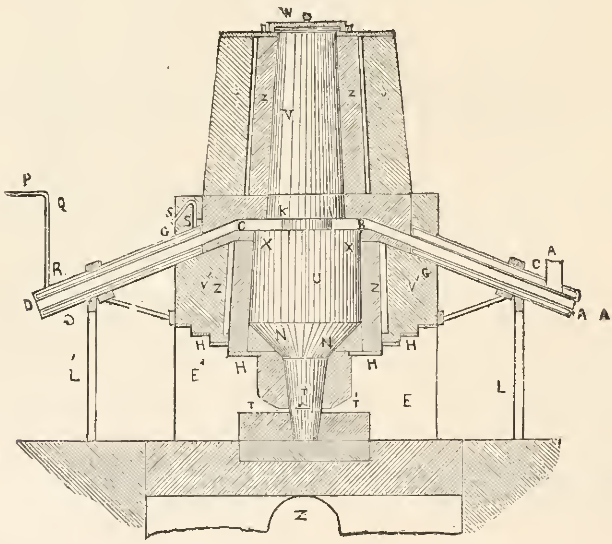
The weight of a cubic foot of cast tin is 455·7 pounds, and the weight of a bar 12 inches long and an inch square is 3·165 pounds; it expands, according to Smeaton, at one degree of heat $\frac{1}{72510}$, and melts at 442°. It will bear on a square inch 2880 pounds without any permanent alteration, and an extension of length of $\frac{1}{1600}$. Compared with cast-iron, its strength is 0·182 times, and its extensibility 0·75 times, and its stiffness 0·25 times, cast-iron being considered as unity.

Zinc white, a carbonate of zinc, which is destined to supersede the white-lead as a paint. It is equally durable with lead as a color, and does not turn yellow as does lead. It is also free from the poisonous qualities possessed by preparations of lead which render its effects upon the workmen who use it so disastrous.

Brooman's improvements in the manufacture of zinc.—The general object of this invention is to do away with the troublesome and expensive processes of assorting, pounding, and crushing, now ordinarily followed in order to the extraction of zinc from its ores; and this is effected by a method of direct reduction. We extract the following description of the apparatus employed, and of the peculiar processes followed in connection therewith, from the patentee's specification:

Fig. 3959 is a vertical section of the apparatus on the line A D of Fig. 3960, which is a horizontal section on the (dotted) line A, B, C, D of Fig. 3959. C is the hearth of the furnace; F, F, F are the tuyères, which are three in number; N is the shoot; U the chamber of the furnace. So far the parts of the structure are very similar to those of a small blast-furnace. At I K the upper part of the chamber U is suddenly contracted, so as to form a neck V, or narrow passage, between the upper and lower parts of the furnace. The charge, as it falls through this neck, leaves, necessarily, a vacant annular space at x x, between it and the sides of the furnace, where the volatilizable matters may collect. F F are four rectangular passages, formed of cast or sheet iron, which lead off at right angles, and in an

3959



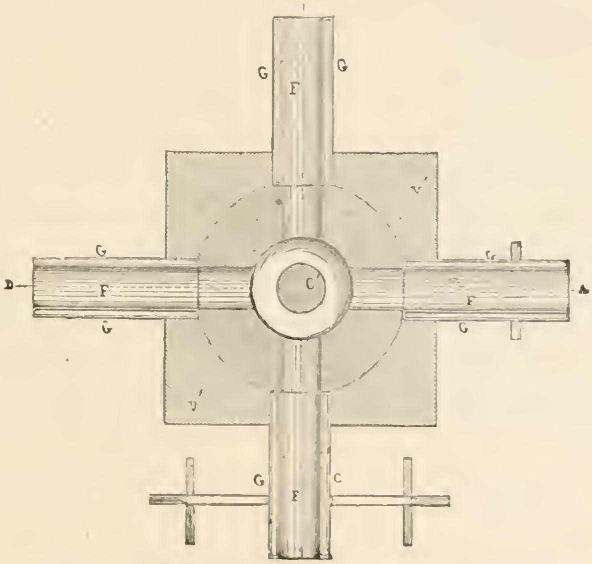
inclined direction, from the annular space x x, and each passage is encased for a certain distance within a chamber G, through which cold water is kept continually circulating, flowing in from the tube P, Q, R, and escaping through the pipe S S. At the lower end of each of the rectangular passages there is a tubular passage A^1, by which the uncondensed gases of the furnace are carried off to different points, to be employed for heating purposes, as hereafter explained; and each passage is provided at its lower end with a sliding door A^2 which may be closed or opened as required. W is a lid or cover by which the furnace is closed at top, and which fits into a groove made for it, so that there may be no escape of the gases at that part. All the interior parts of the furnace are formed of fire-brick, with an outer wall or casing V^1, which may be made of ordinary brick; and between the outer and inner walls there is left a space Z Z, which is filled with some substance which is a bad conductor of heat. H H are strengthening plates of cast-iron, which are inserted into the lower brick-work V^1, immediately over the tuyère openings E^1 E^1. L^1 are cast-iron frames, which carry the passages F F and cold-water chamber G.

The mode of operating with the apparatus is as follows:—After the furnace has been built, it is left to dry; then a fire is kindled on the hearth, and kept up for about three weeks by supplies of fuel (by preference coke) introduced through the throat. The furnace being in this manner filled with incandescent fuel, a small charge of quicklime is thrown in. As soon as this charge has descended as far down as the tuyères, a mixture of ore, flux, and fuel is fed into the furnace, the top of the furnace closed, and a moderate blast of atmospheric air applied by means of a blowing machine.

The fuel, the flux, and the ore are in such proportions to one another that the whole of the zinc contained in the ore shall be reduced, and then volatilized, while all the foreign matters shall form with the flux a residual slag of more or less fluidity when in the heated state. The fuel employed may be either charcoal, or coke, or common coal, or anthracite, or turf, taking care always that it is of a sufficiently hard nature to resist the incumbent pressure of the charge in the furnace.

The quantity of fuel employed should be greater at the commencement than during the subsequent stages, and should in all cases be sufficient not only for the complete reduction of the zinc, but also to leave so considerable an excess that when it arrives directly before the tuyeres, the combustion of the fuel shall not give rise to any gaseous oxidating product; such, for example, as carbonic acid. The flux (the selection of which, as well as that of the fuel, depends on the quality of the ore) must be used in such a state as not to produce any oxidating matter during the formation of the slag. For this reason, when the nature of the ore requires the employment of lime as a flux, the lime should be used in a caustic state, and not as a carbonate; and for the same reason it is advisable to use a blast of dry air, that is to say, air deprived of aqueous vapor. The products of the furnace are, in the first place, the gases arising from the combustion of the fuel; secondly, the vapors of zinc; thirdly, the non-volatilizable matters, consisting of scoriæ or slag, and of reduced metallic substances of greater density than the zinc. The throat of the furnace being closed, "the gases arising from the combustion of the fuel" pass

3960.



off through the passages A[1], and are made use of either for the purpose of heating the boiler of the steam-engine which drives the blowing machine, or to burn lime when used for a flux, or to melt the zinc which is carried over in a state of vapor, or to dry and roast the ores. The "vapors of zinc" are condensed in the passages F F, and may be easily withdrawn therefrom by means of a rake, (the rectangular form of the passages F F affording great facilities for this purpose,) after which they are reduced and formed into ingots or bars. The "non volatilized" or residual matters, which collect on the sole or hearth of the furnace, are run off from time to time according as they accumulate.

The ores containing zinc may be divided into two classes: firstly, those in a state of oxide, either free or combined with carbonic or silicic acid; secondly, those containing sulphuret of zinc, (blende.) When the ores are of the first class, (oxides,) they are first dried, and if they contain a carbonate, they are subjected to a roasting process. The flux employed for the treatment of ores of this class is quicklime, the quantity of which varies according to the quantity of earthy matters contained in the ore, but should be sufficient for the formation of a bisilicate, or, as it is commonly called, a good slag. When the ores contain any other metals, such as iron or lead, these metals are reduced to the metallic state, when they collect on the sole of the furnace, where they arrange themselves in different strata according to their respective densities, and may be drawn off separately. When the ores are of the second class, (blende,) they are treated in one of two ways; either by roasting, which brings them into the state of oxide, which oxide is then mixed with a little damp clay and formed into blocks, which, after being dried, are treated in the manner before described; or (which is considered the preferable way) these sulphurous ores are mixed with a quantity of iron ore, so that when the metals are fused the iron shall combine with the sulphur, and set the zinc at liberty.

The flux employed in this case is quicklime; and if the ore contain a portion of baryta or gypsum, then fluorine is added. The quantity of quicklime employed depends on the quantity of earthy matters contained both in the zinc and iron ores. The iron ore best suited for this purpose is that containing zinc, but in too small a quantity to be treated separately as a zinc ore. When, however, the iron ore contains water or carbonic acid, it is necessary that these should be expelled by roasting, in order that no substance susceptible of oxidizing the zinc may be introduced into the furnace. If the iron ore contain too great a quantity of oxidating matter, then it is preferable to expel the sulphur from the zinc ore by means of cast-iron or malleable iron. This plan presents the advantage of driving off the whole of the substances capable of reoxidizing the zinc which has been reduced. When a sulphuret of zinc in which there are several other metals, such as iron, copper, lead, silver, &c., is treated in the furnace, there collects on the sole, besides the slag, a stratum of argentiferous lead, on which is superimposed a stratum of cast-iron arising from the excess of iron ore used in the process. Again above the stratum of iron there collects a mass composed principally of sulphuret of iron, sulphuret of copper, and portions of the sulphurets of other metals.

If white, gray, or yellowish oxide of zinc should be formed accidentally in the passages F F, it can be made use of directly as a coloring matter, and sold as such; or else it can be mixed with damp clay, made up into blocks, dried, and again passed through the furnace; in which case a sufficient quantity of quicklime should be added, to convert all the clay into a fusible slag.

When ores containing zinc in a state of oxide have to be treated, they should be previously assayed, in order to effect an analysis, and to ascertain the quantity of earthy matters contained therein capable of being converted into scoria, and which will determine the proper proportion of quicklime to be added. The lime and magnesia contained in the ore are also taken into account.

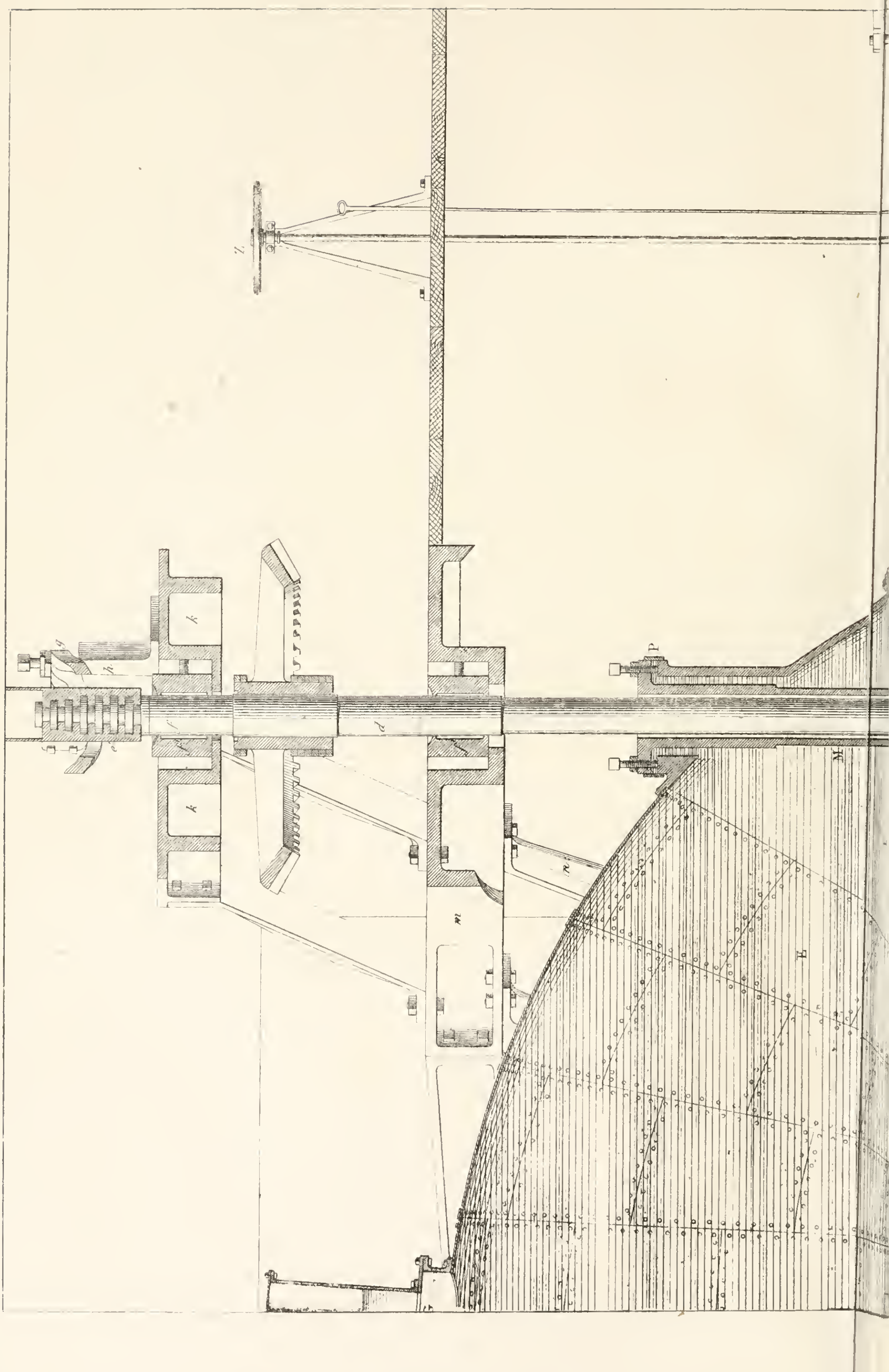
When ores containing zinc in the state of sulphurets have to be treated, the quantities of sulphur, earthy matters, and metallic substances contained therein should also be ascertained by preliminary assay, so that the quantity of iron ore used in the charge shall be sufficient to produce the cast-iron requisite for combining with all the sulphur that may be in the zinc. In order that the combination of the sulphur and iron may be the more completely effected, it is advisable to employ a slight excess of iron ore. But if there should be reason to apprehend that the iron ores might produce too great a quantity of oxidating matter, and thereby create too great a quantity of oxide of zinc, then cast or malleable iron may be directly used for the purpose of combining with the sulphur, in which case the proportion of cast-iron or malleable iron is to be determined by the quantity of sulphur contained in the ore, always employing a slight excess of the iron. The proportion of quicklime or of fluorine used for making a fusible slag will depend on the quantity of earthy matters contained in the ore to be treated, as well as in the iron ore when used for combining with the sulphur. The quantity of fuel employed in this case will depend not only on what has been already stated, but also on the richness and fusibility of the iron ores, and in all cases should be so regulated that the working of the furnace shall in all respects resemble that of a blast-furnace for casting purposes.

As sulphuretted ores contain generally other metallic substances besides zinc, a great quantity of reduced metals, and of crude metals, composed principally of sulphuret of iron, will collect on the hearth of the furnace, and combine with the sulphuret of copper and a portion of the sulphurets of the other metals. In this case, therefore, it is better to run off the metal more frequently than in the preceding cases. The lead thereby obtained can be recast into pigs ready for sale, or submitted to the process of cupellation, if it should contain silver; and any other masses of crude metal may be treated by any of the well-known processes, in order to extract the copper therefrom. As in the preceding cases, the whole of the zinc will be volatilized, and collected condensed in the passages F F, and chamber G.

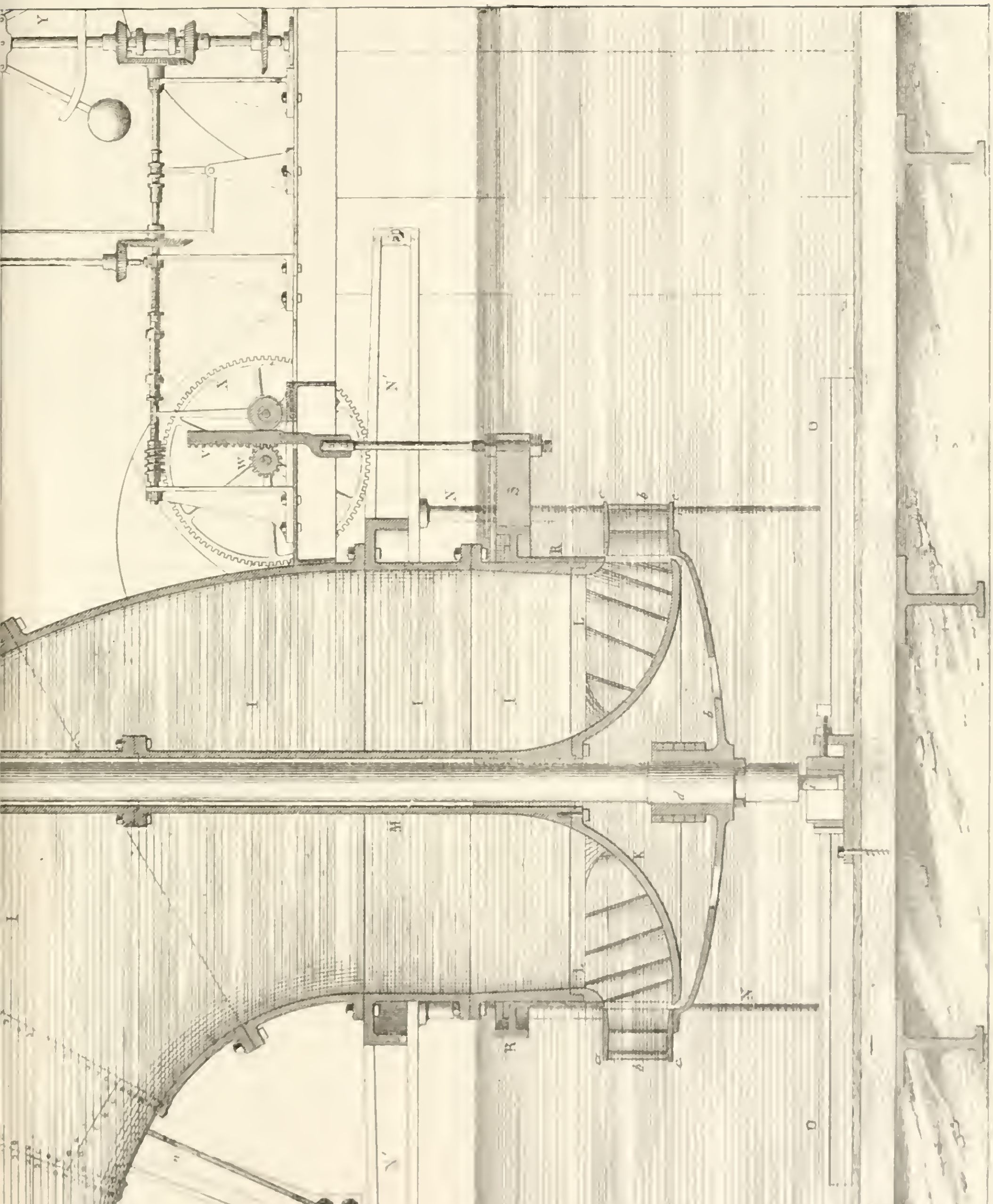
END OF VOL. II.

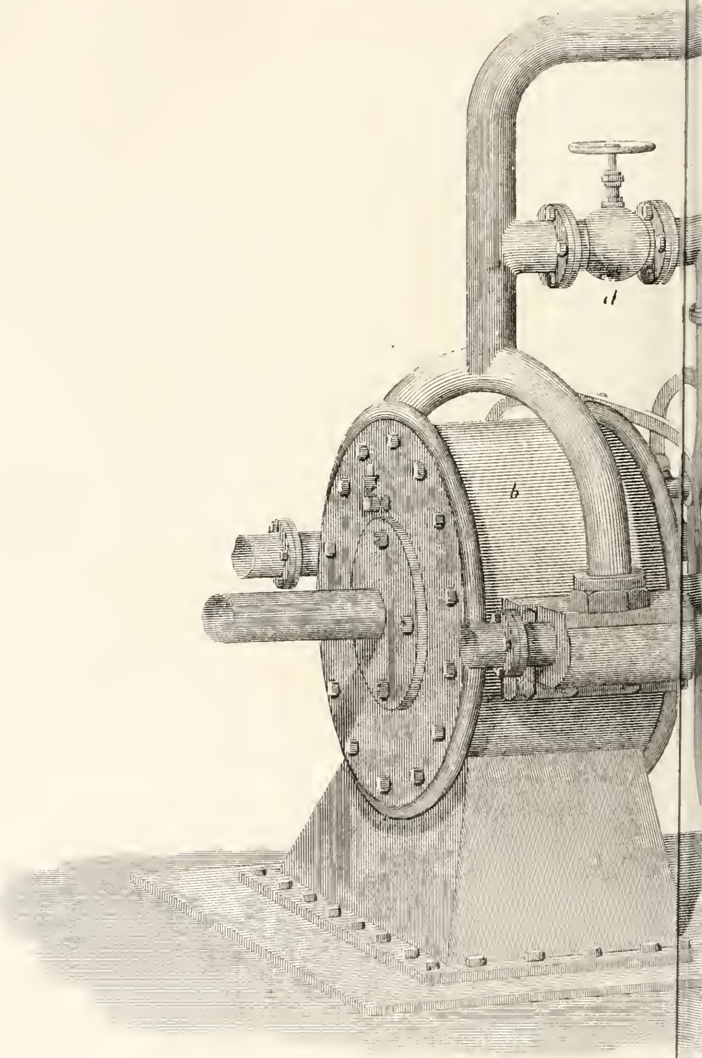
INDEX.

APPENDIX.



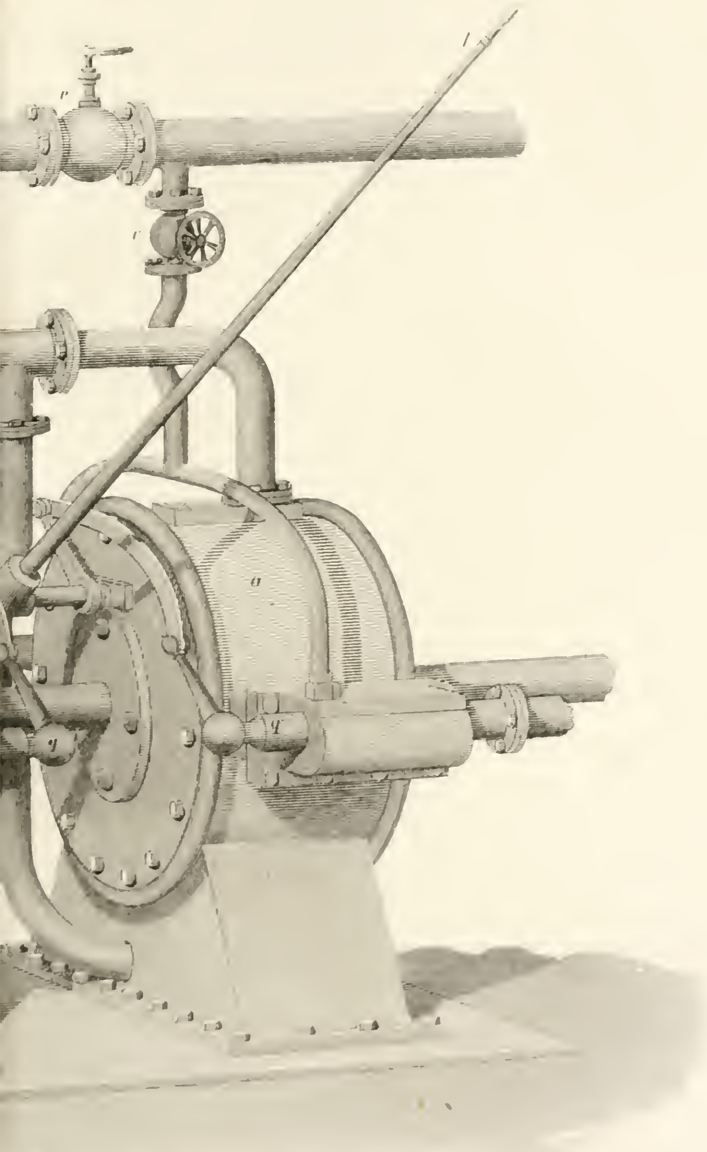
Pl. III





DOUBLE ROTA

E. BARROW NEW



RY ENGINE.

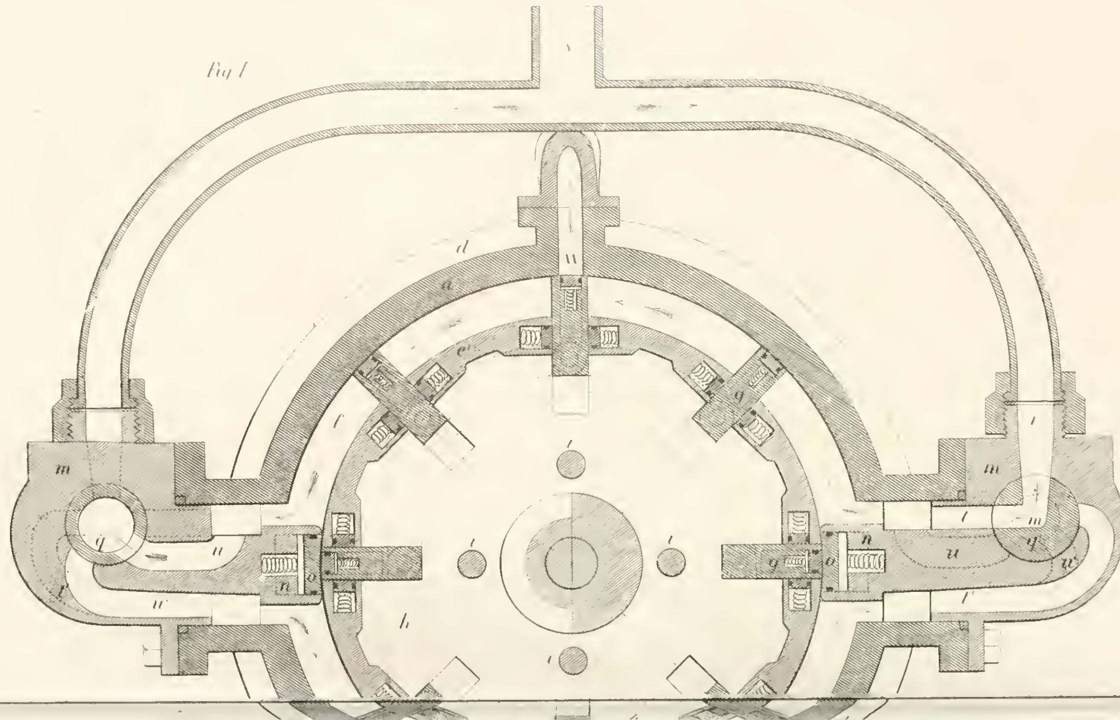
EW YORK

Appleton's Dictionary of Mechanics

BARROW'S DOUBLE ACTING REVERSIBLE

ROTARY STEAM ENGINE.

Fig 1



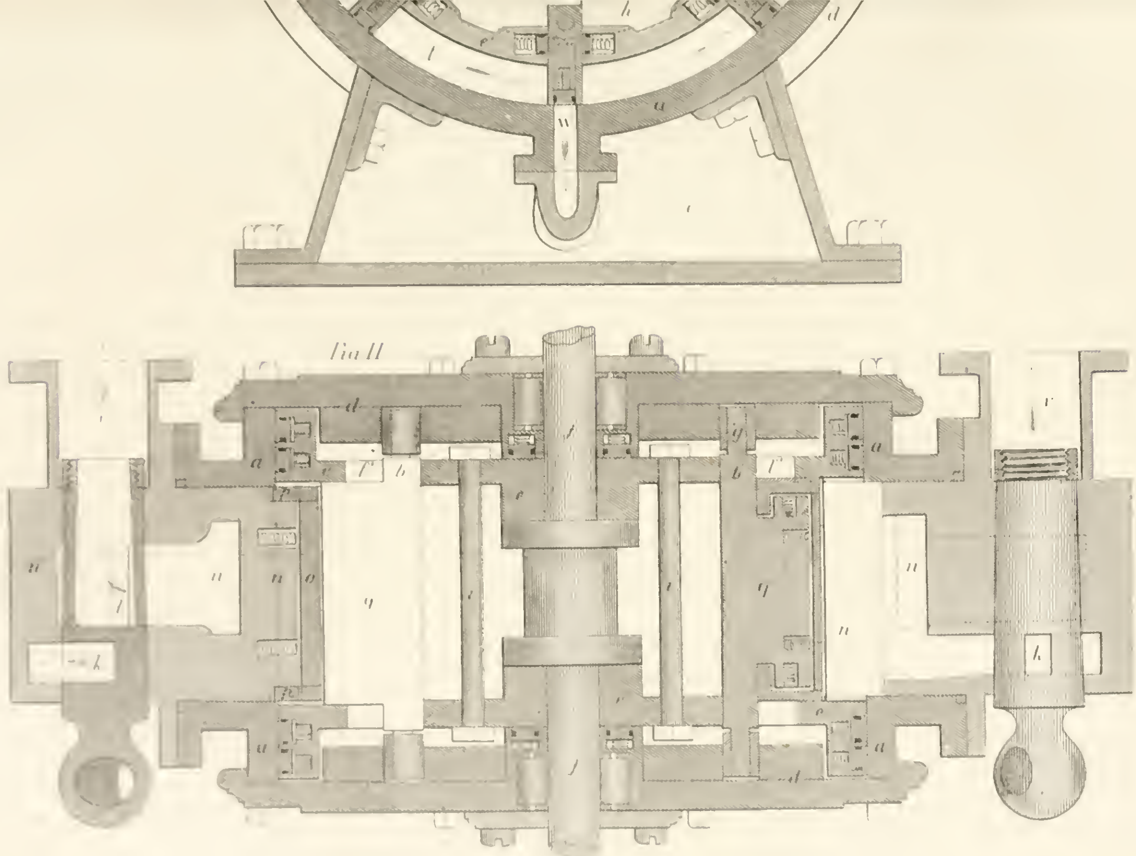


Fig. 11

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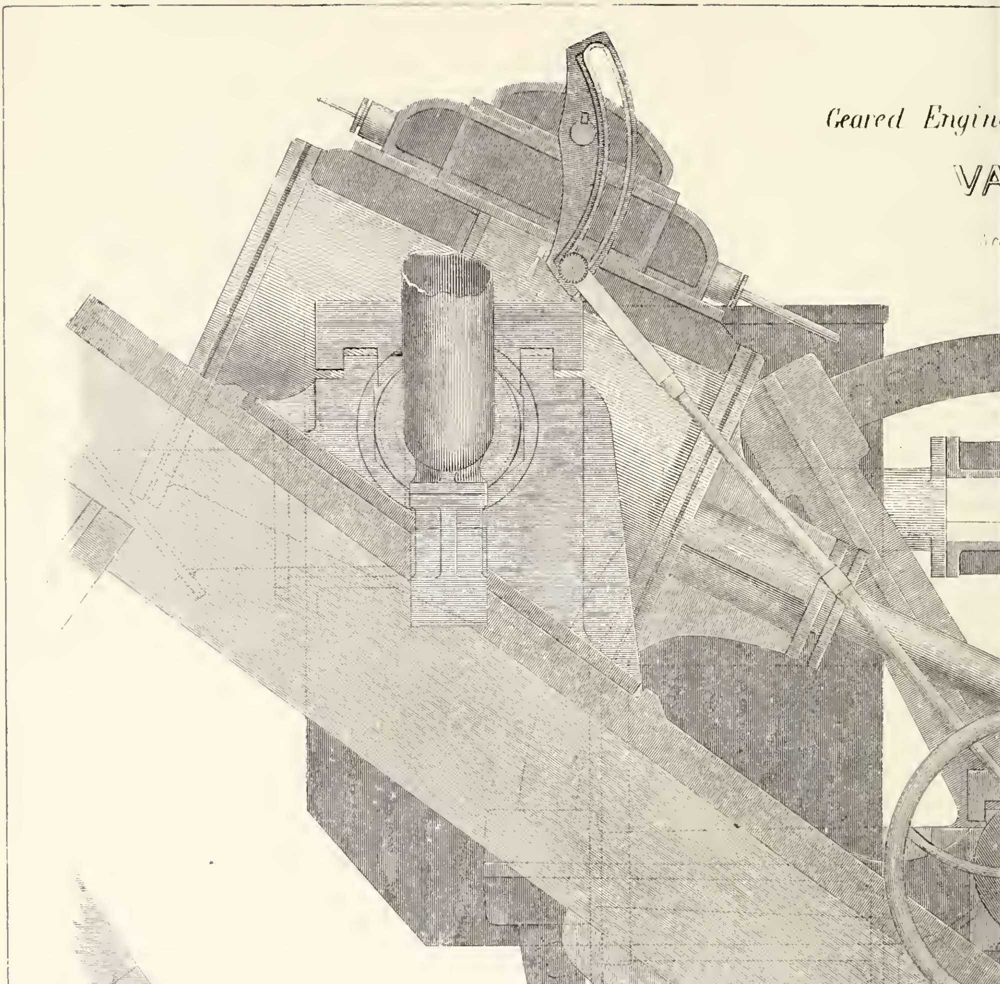
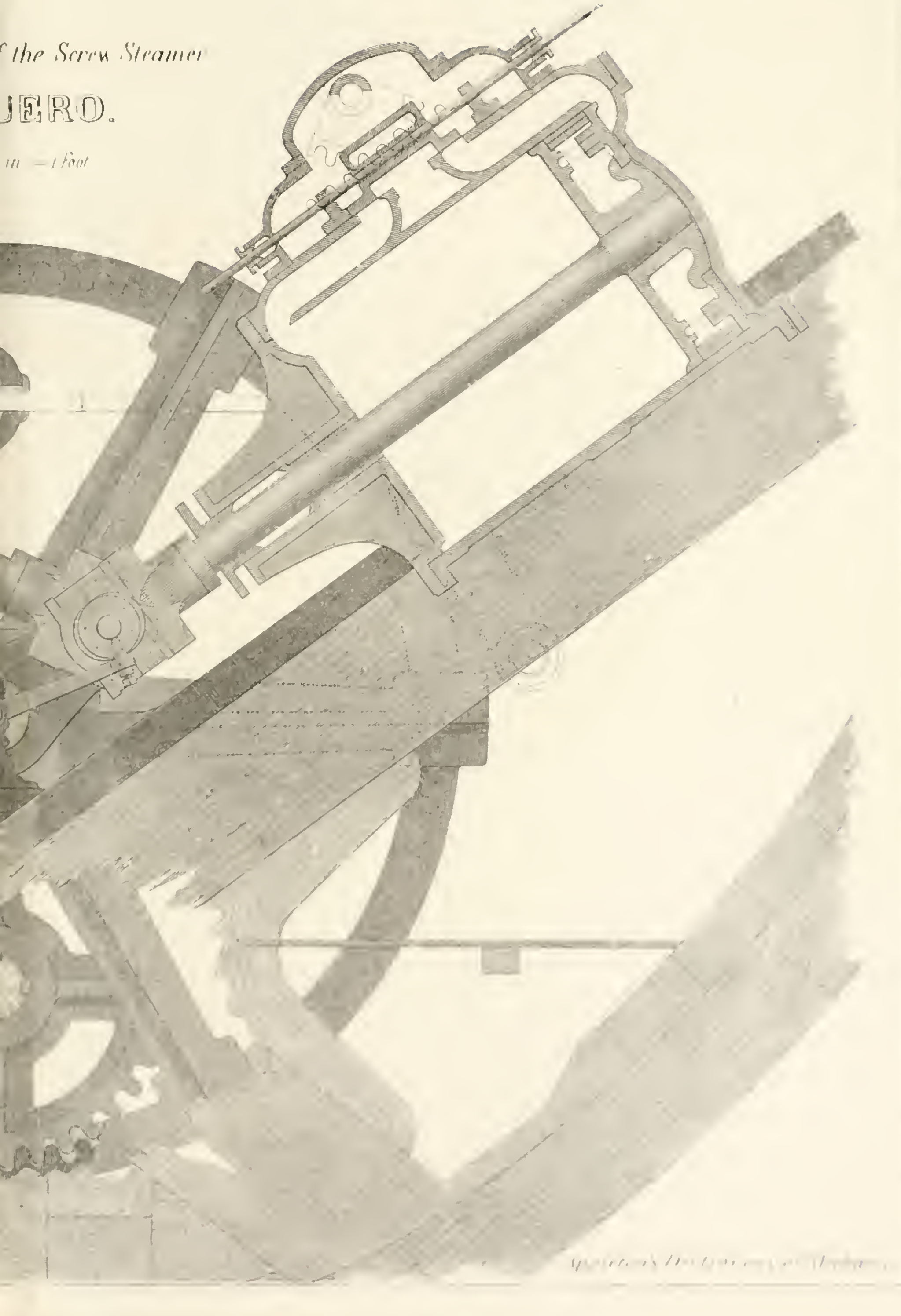

Geared Engine
VA

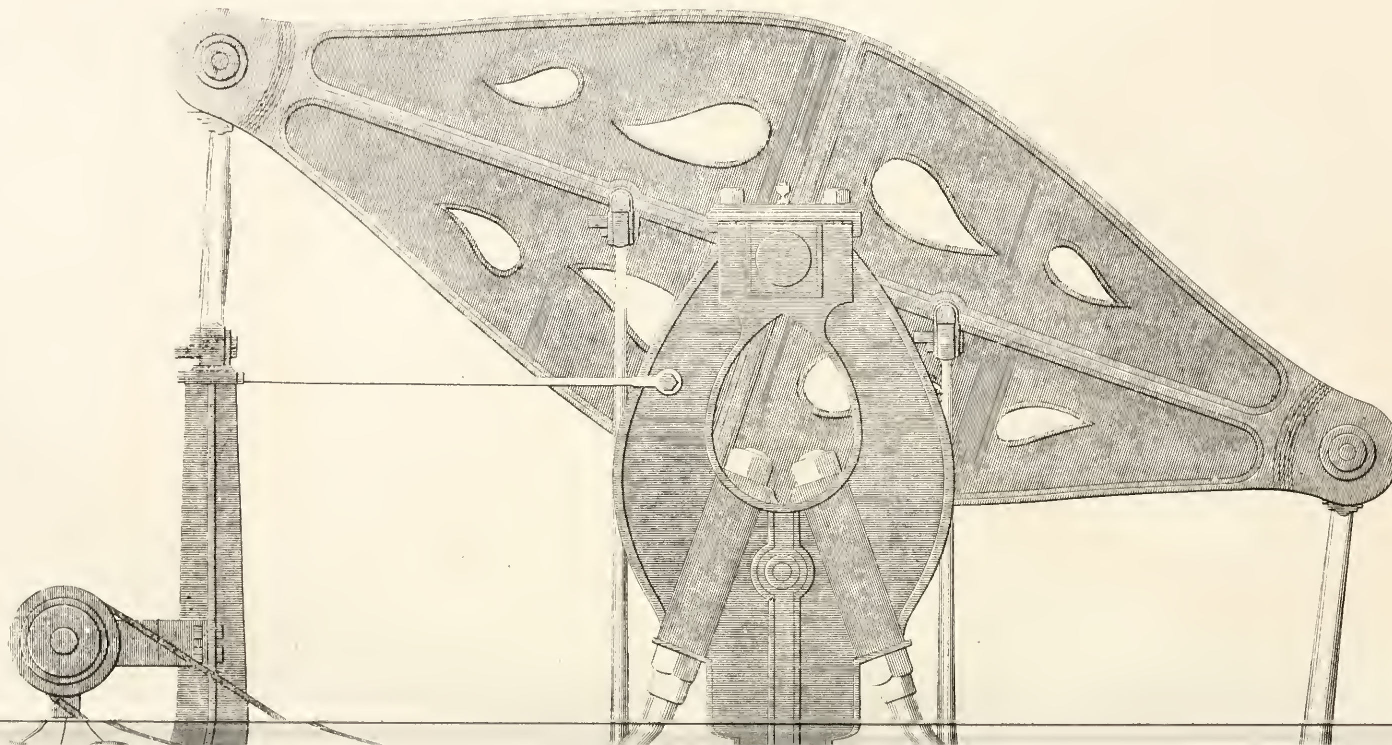
f the Screw Steamer

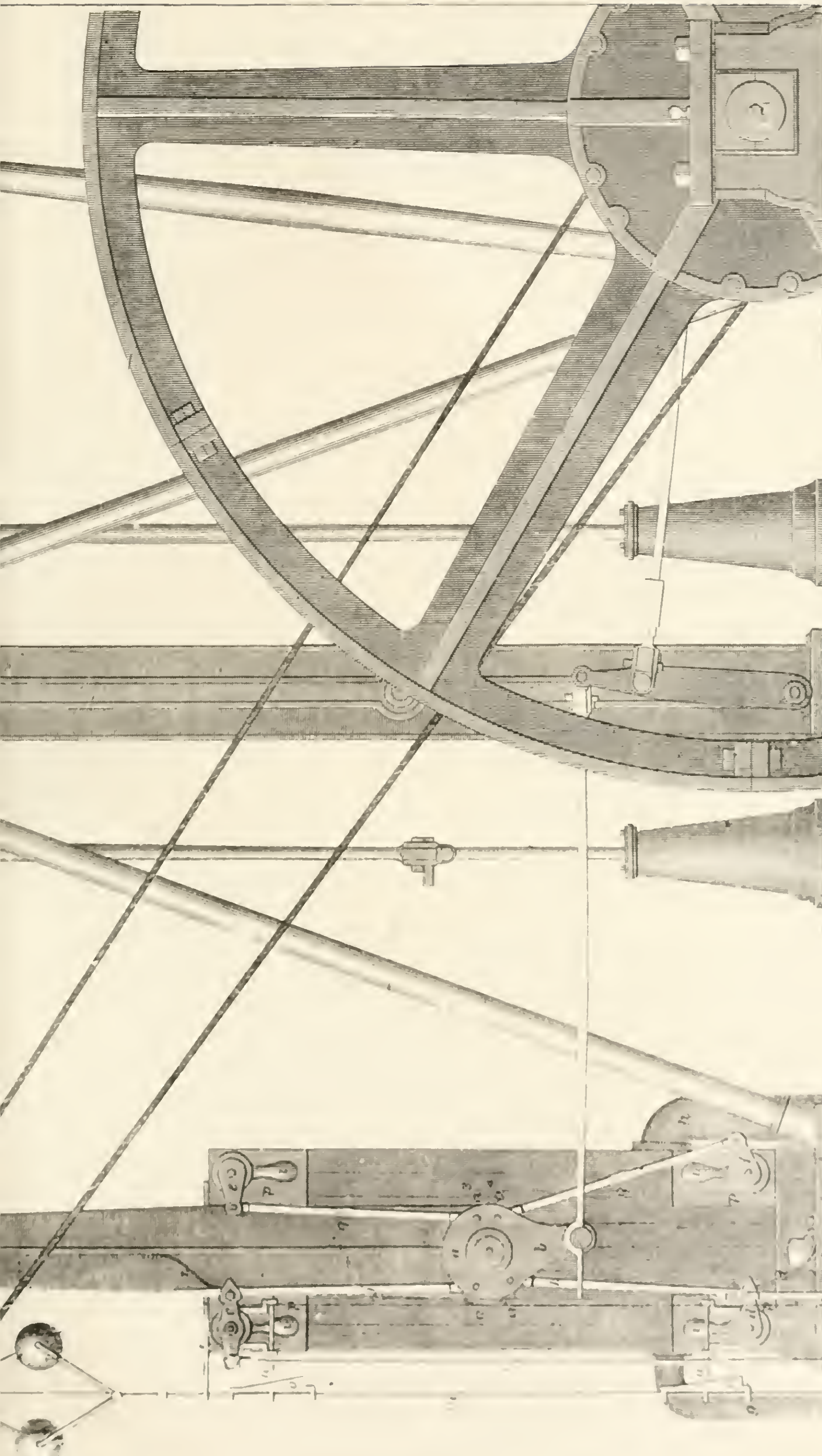
JERO.

in = 1 Foot



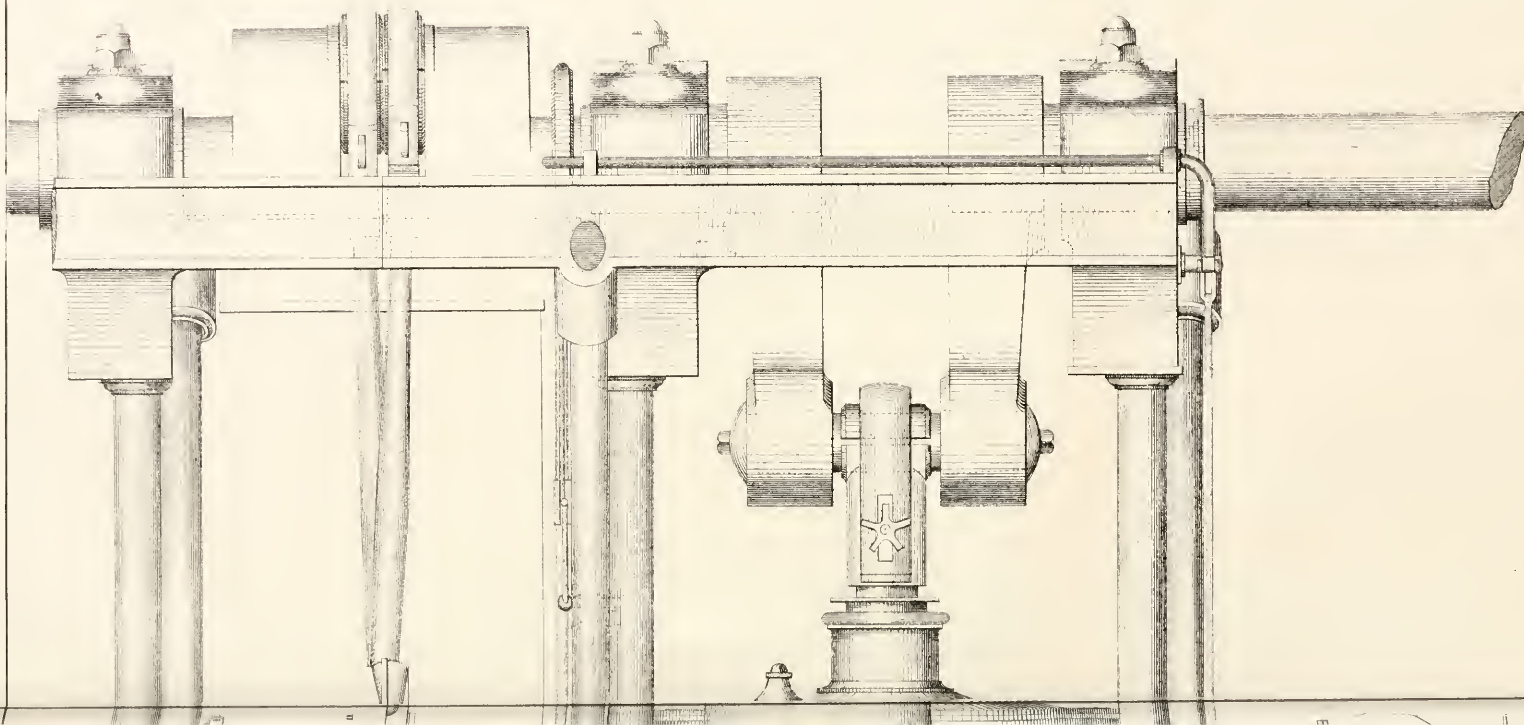
CORLISS' STEAM ENGINE.

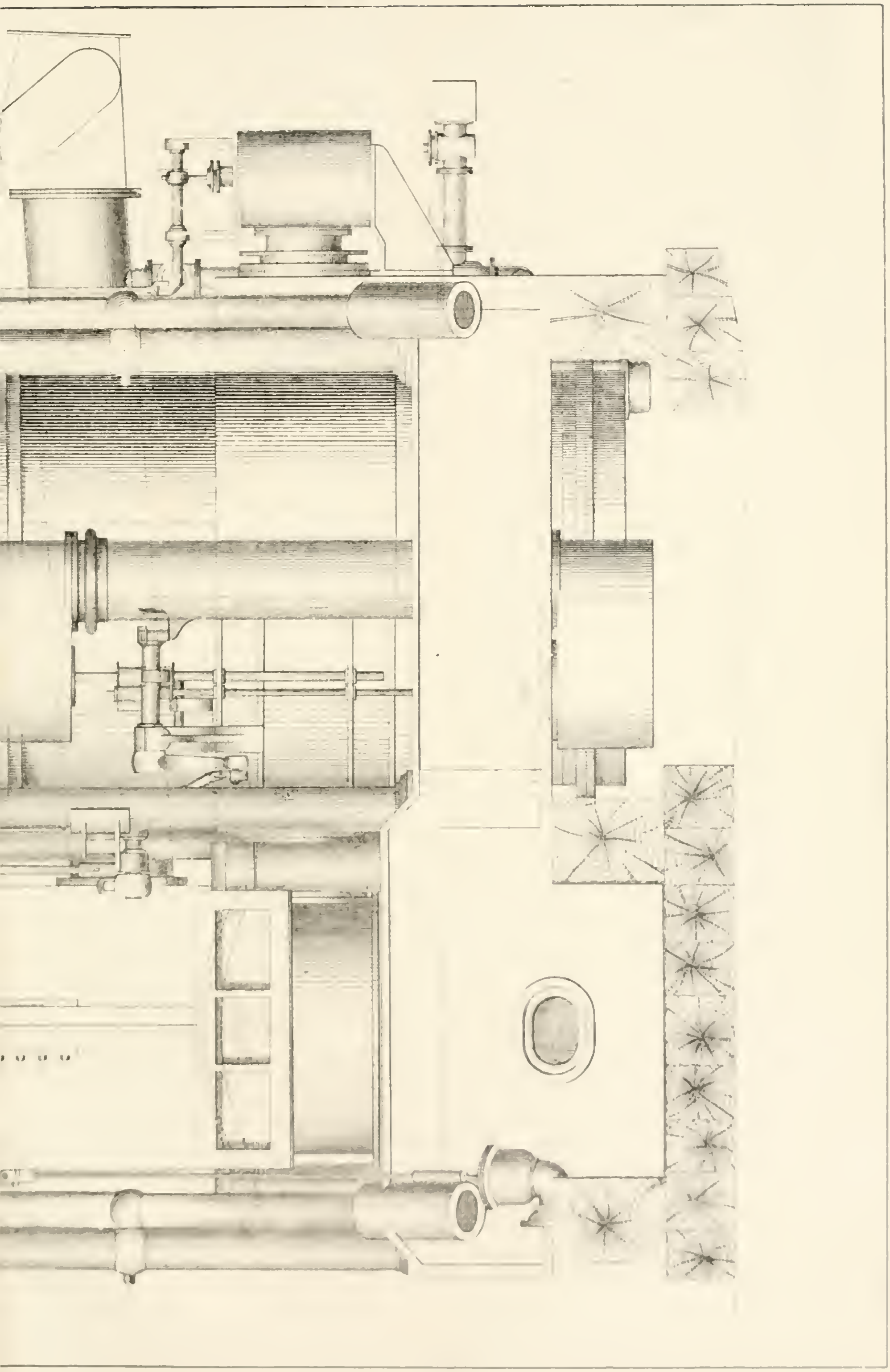




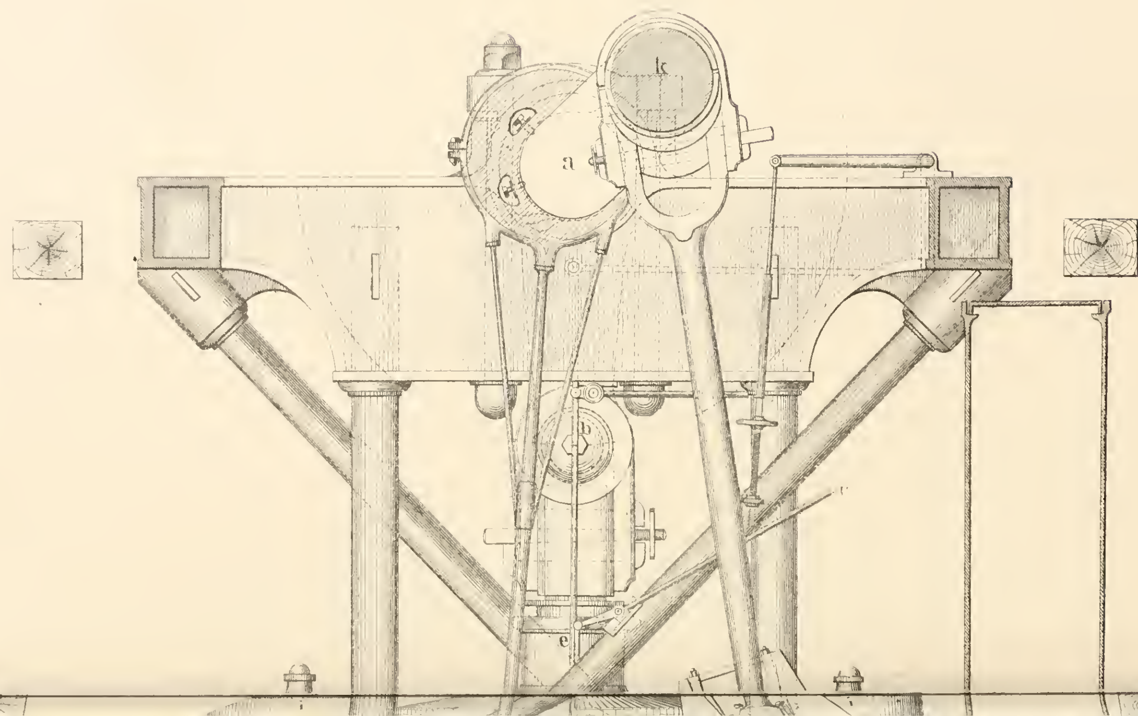
Appleton's Dictionary of Mechanics.

FRONT ELEVATION.

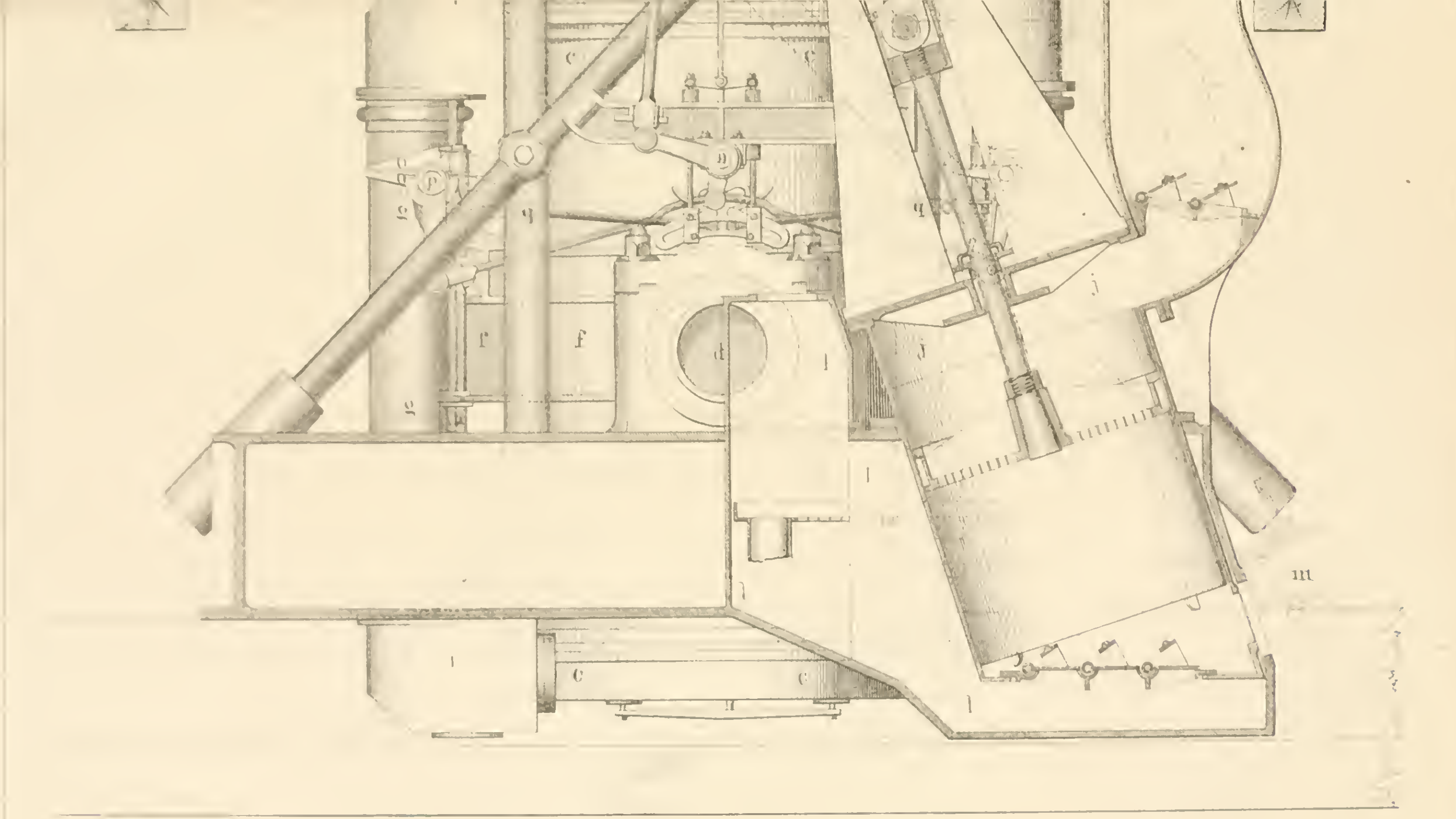




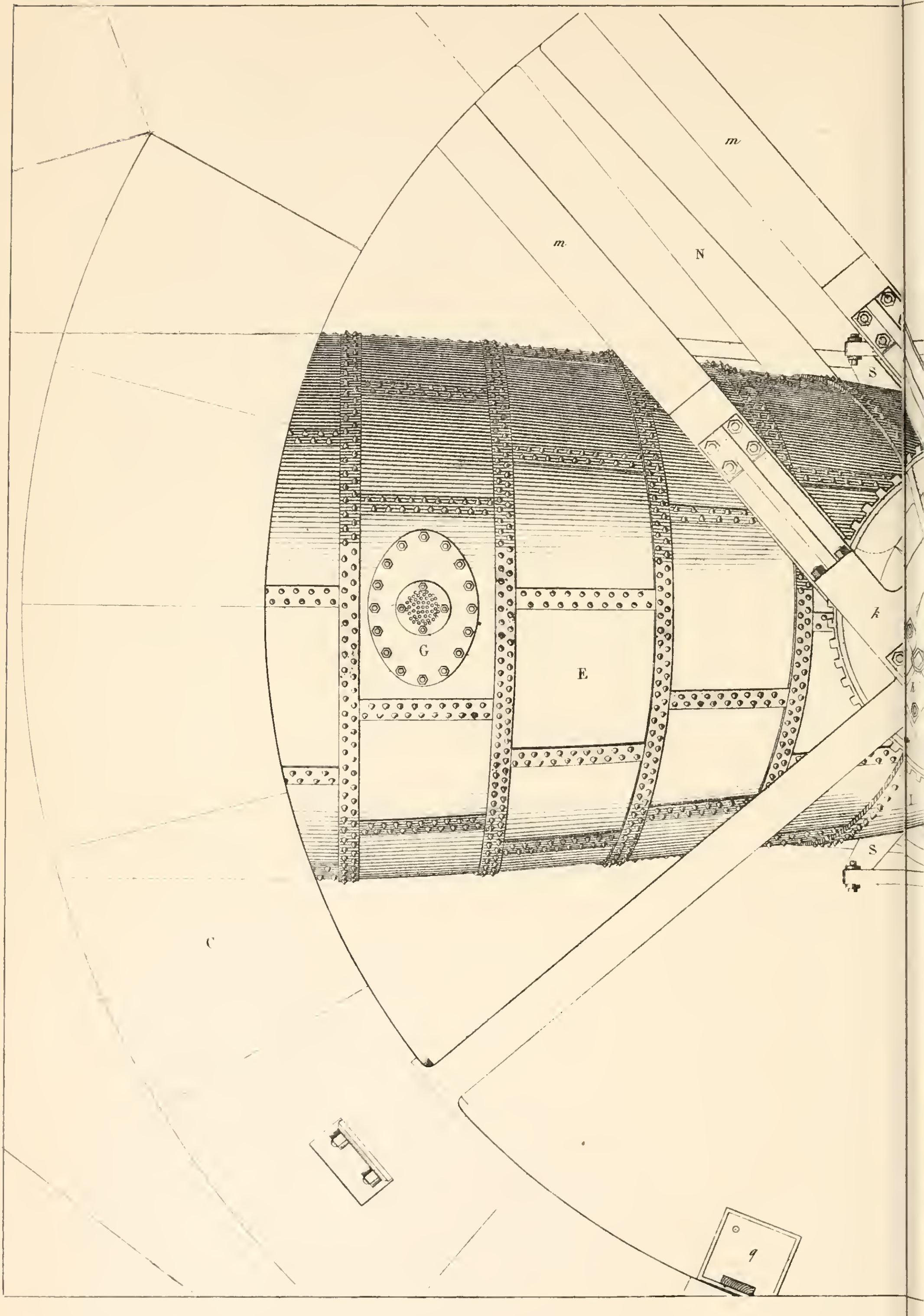
SIDE ELEVATION & SECTION *thro' air pump.*



Pl. XLII



Scale of feet



m
m
N
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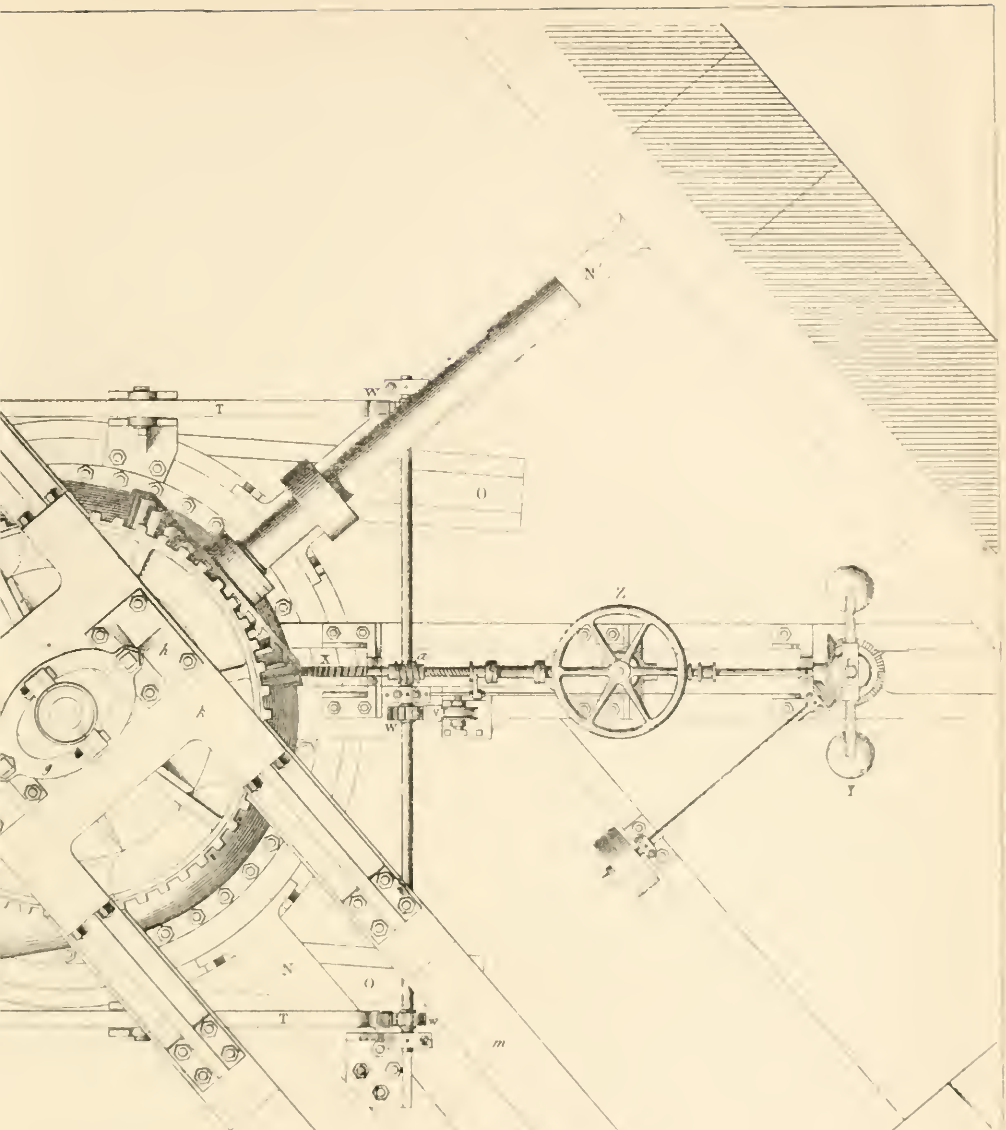
C
q


N
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