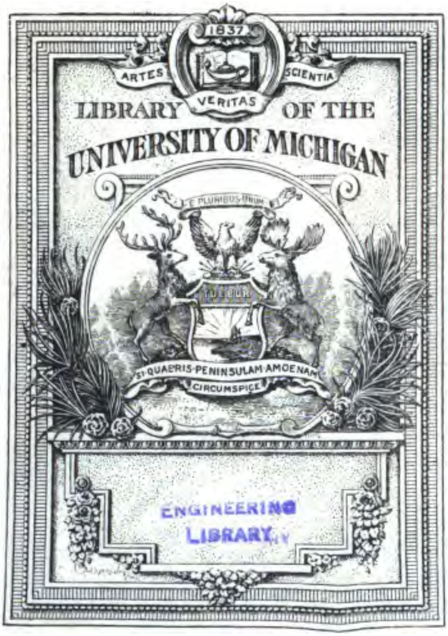

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ENGINEERING
FACTS AND FIGURES FOR 1868.

AN

ANNUAL REGISTER

OF PROGRESS IN

MECHANICAL ENGINEERING AND CONSTRUCTION.

WITH NOTES

FROM THE PARIS AND HAVRE EXHIBITIONS.

ILLUSTRATED BY NUMEROUS PLATES AND WOODCUTS.

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PREFACE

IN presenting this, the sixth volume of a work of which he is glad to say the highest opinions as to its practical utility reach him from numerous sources both at home and abroad, the Editor begs to point out as a feature of it, notes of the International Maritime Exhibition held at Havre in 1868. A visit was paid to this, and the notes were, in the majority of instances, prepared specially during it. In some departments a few additional notes on the still greater and more important Exhibition held at Paris in 1867 are given, which tend to complete the subjects which were pretty fully described in last year's volume, and to which the Reader's attention is again drawn. The present volume, therefore, will, it is believed, not be behind in practical value those which have preceded it.

In this, as in the case of the other volumes, the Editor has to acknowledge having received much of the matter which constitutes its pages from the following periodicals:—'Engineering;' 'The Engineer;' 'The Mechanics' Magazine;' 'The English Mechanic;' 'The Practical Mechanics' Journal;' 'The Civil Engineer and Architects Journal;' 'The Scientific Review;' 'The Journal of the Society of Arts;' and 'The Scientific American.' To these, as well as to 'The Building News' and the 'Builder,' the reader is referred for various important papers, space for even the briefest of epitomes of which could not be had in the present volume

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ENGINEERING

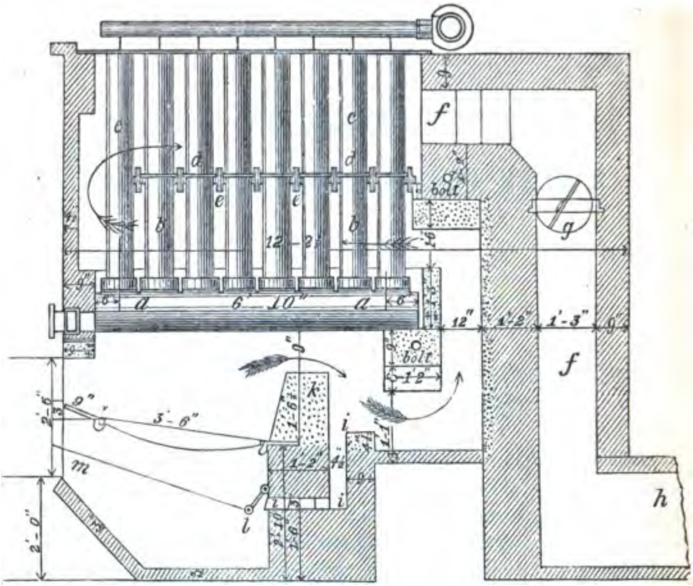
FACTS AND FIGURES FOR 1868.

DIVISION FIRST.

BOILERS AND VESSELS FOR CONTAINING STEAM AND OTHER FLUIDS UNDER PRESSURE.

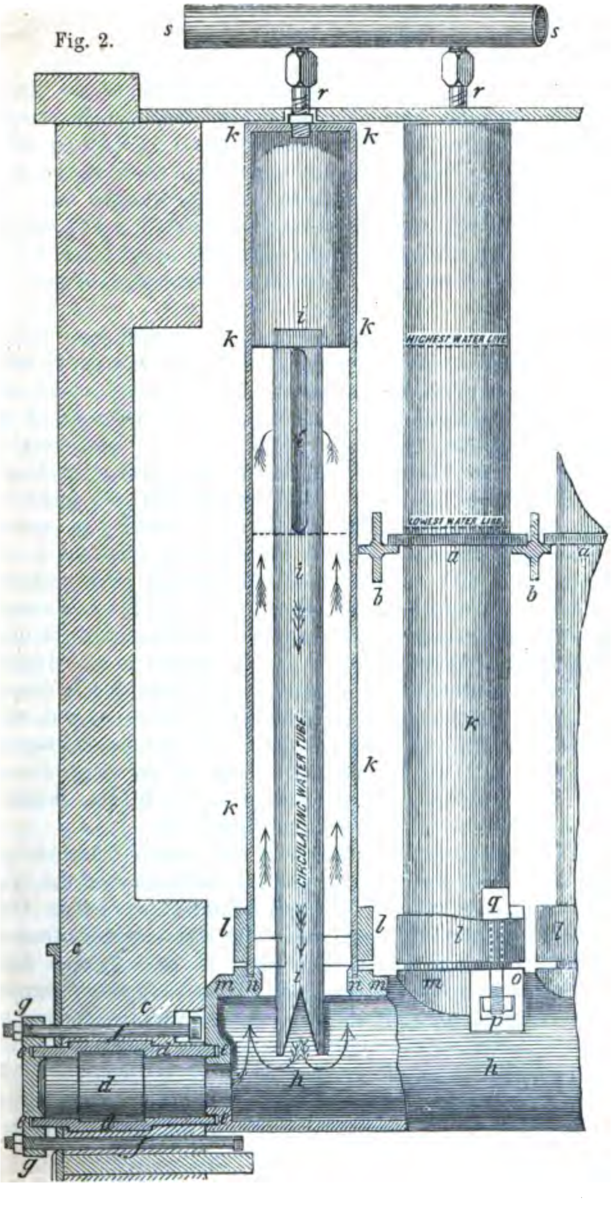
1. *Recent Improvements in Howard's Patent Safety Boiler.*—In last volume we described the Boiler patented and manufactured by the Messrs. J. and F. Howard of Bedford. Since then important improvements have been made in it, to which we beg to ask the notice of the Reader. As originally introduced and illustrated in last volume, the horizontal tubes were placed transversely, or across the furnace, now they are placed longitudinally, and the ends passed through the front of the furnace; by which arrangement special means for facilitating the cleaning of the tubes are now available in the manner illustrated in fig. 2. We shall describe the whole arrangement of the Boiler as now introduced. As will be seen from the drawings in figs. 1, 2, and 3, here given, the boiler proper consists of three "elements" of construction—first, a series of tubes *a a* placed horizontally in the furnace *k*; second, a series placed vertically, as *b b*; and third, the internal or circulating tubes, placed within the vertical tubes, as *i i*, fig. 2. The horizontal tubes are closed at the ends, and run longitudinally from end to end of the furnace, being supported at some distance above the fire-grate. On the upper side of each tube projecting parts *o m m* are cast flat at the top, and with circular apertures in each leading to the interior. In the

Fig. 1.



upper face of the projecting part, which serves as a base for the vertical tubes to rest upon, an annular groove is formed thereon, of the same, or a little more width, than the thickness of the vertical tube. On the sides of the base, and at the opposite corners, recesses are made, which act as chambers to receive a gun-metal nut, "tapped," and which is easily slipped in laterally into the chamber; but they are held down when in action, or *in situ*, by the metal of the sides of the chambers. The whole of the cast-iron tubes are so supported by the brickwork of the furnace that they are free to expand or contract in any direction; they are supplied with water by longitudinal tubes, which run along the whole length of the boiler at each side of the furnace, and which are connected by branch tubes to the horizontal tubes.

Fig. 2.


s
s
r
r
k
k
i
k
k
HIGHEST WATER LINE
LOWEST WATER LINE
a
a
b
b
i
k
CIRCULATING WATER TUBE
k
k
q
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In the first stages of experience of this boiler the deposit formed in the tubes was "blown off" by means of the longitudinal supply tube; but the necessity for the "blowing off" is now avoided, and "caps" are now supplied to the cast-iron tubes, by taking off which at intervals they can be cleaned out. The caps are made tight, and capable of withstanding any pressure by perfect joints, the whole being tightened up with screw bolts. As these "caps" are placed outside the furnace, they are very easily got at.

We now come to the second element of construction—namely, the vertical tubes which are supported by the horizontal tubes. These, which are 4 feet 6 inches or 5 feet in length, and 7 or 9 inches in diameter, are of wrought-iron. The lower end of each tube, as *k k* (fig. 2), is provided with a metal ring *l l* (fig. 2), this ring being provided with two projecting lugs or ears, which have apertures made in them, and the position of which corresponds, when the tube is *in situ*, with the centre of the gun-metal nut *p* situated in the recess of the base *o m* of the horizontal tube. The end of the vertical tube projects a little below the under side of the ring, *l l* (fig. 2), as shown at *n n*. This end passes into the annular groove made in the upper face of the base of the cast-iron tube, as shown in the drawing. Previous to inserting it, an indestructible elastic ring is dropped into the annular groove in which the end of the tube *n n*, which is turned fair in the lathe, butts. The whole are secured together by inserting bolts (*q*, fig. 2) in the holes of the rings *l l*, and which take in to the gun-metal nuts *p* placed in the chambers, in the base *o m m* of the horizontal tubes *h h*.

With reference to the strength of the rings *l l* formed upon the vertical tubes *k k*, we have it on the authority of the editor of the "Engineer," that he has seen a force of more than *thirty-four tons* applied to draw off one of the cast-iron rings from the foot of the wrought-iron tube, without in the slightest degree affecting the integrity of the joint. Dismissing the description of the modes of affecting the lower junction of the vertical and horizontal tubes, we refer the reader to fig. 2, where the method of finishing the tops of the vertical tubes is illustrated. The upper end has a solid top of wrought-iron, with reference to the ring, half-inch thick, carefully welded to the end of the tube.

This welding is one of the nicest operations carried on in the Messrs. Howard's factory, and requires the exercise of the utmost degree of manipulative skill and watchful care on the part of the men employed in carrying it out. Tapped into each end, is a small wrought-iron tube, *r r*, 1 inch in diameter, connected at its upper end to a wrought-iron tube, *s s*. 2 inches diameter, running along the tops of the tubes, and which conveys the steam to the main pipe, in which the "stop valve" branch or pipe is cast, and which also carries at another point the safety valve. Covering in the tops of all the vertical tubes is a plate—shown at *t t* in fig. 2. The effect of the arrangement of tubes as now explained is such, that almost any contingency is provided for, so far as the expansion or contraction of the whole system or any part of it is concerned. Indeed, as a "flexible system," so to call it, the various members of which have very wide or comparatively wide limits of expansive or contractile movements allowed them, without disturbing the integrity, in the slightest possible degree, of any one of its parts; a high position is claimed for it, a position which the inventors believe is taken by no boiler as yet introduced. The great stumbling-block in the way of the success which other inventors have encountered, in constructing a tubulous boiler, has been the want of a system which allowed of an independent expansion and contraction of the various parts. Unless adequate provision be made for the action of expansion and contraction, it is impossible to keep the joints tight. In the Safety Boiler, this being, as above stated, fully provided for, absolute tightness of the joints is required.

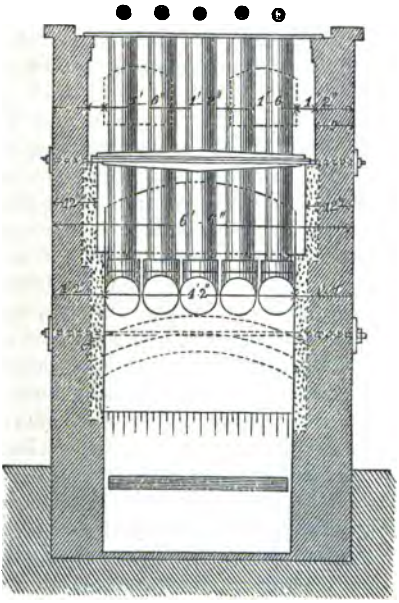
We now come to the third element in the construction of the boiler—namely, the circulating tubes, *i i* (fig. 2), with which the vertical tubes *k k* (fig. 2) are provided, and which perform highly-important offices in the economy of its operation. In the first boiler made, the system comprehended the arrangements only so far as we have above described; but, although the heat was readily absorbed in the system of tubes when filled up to the normal level with water, still an amount of deposit was observed which it was deemed advisable to get rid of; and further, a loss of heat arising from the tendency of the steam to "cling in layers" to the interior of the tubes. Hence the addition of the internal tubes. Each tube is of such diameter that when in position there is an annular ring formed between its external diameter and the inside diameter of the vertical tube *k k*, while there is, of course, an internal column of water in the inside of the circulating tube, as at *i i* (fig. 2). To admit of the free circulation of the water between the annular ring, and column of water, the lower end of the internal circulating tube, which is inside the horizontal tube, is provided with vandyked or triangular openings, and at its upper end with narrow slots. These slots admit of the water entering freely at the top, no matter what may be the variations of the water level, within certain wide limits. The effect of the arrangement is such, that there is a perfect and complete circulation established between the inner column of water in the circulating tubes *i i*, and the external or annular ring of water surrounding them, as illustrated in fig. 2.

We have already alluded to the mode by which the horizontal tubes are cleaned out, by the addition of "caps" to their outer ends. One of these is illustrated in fig. 2, at *g g*. On the inner face of this an annular groove is made, into which an elastic joint is placed; this butts against the end *e e* of the collar or short tube *d d*, the other end of which goes into a groove *e e*, in the face *m m*, of the end of the horizontal tube *h h*. The "caps" *g g*, tube *d d*, are secured to the tube *m m*, and perfect joints made by the bolts *f f*.

2. As a *superheater* Howard's Boiler is also favourably known, and possesses features of great value. On this subject generally, and with special reference to this boiler, we take from a pamphlet recently issued by the Messrs. Howard the following remarks:—" If the reader will turn to the drawing in fig. 1, he will see that the upper part *c c* of the vertical tubes which contain steam alone are subjected to the radiated heat of the upper chamber, formed by the plate *d d* resting upon the bearers *e e*—see also *a a*, *b b*, fig. 2—and also to the heat of the currents of gases as they pass through this chamber to the chimney flue; the heat which is thus passed to the steam effectually dries and superheats it, and thus, amongst other advantages, obviates the evil of *priming*, which is such a source of loss and trouble in the ordinary form of boilers. Some still maintain that no advantages are derivable from the use of superheated steam, affording an instance of how long it sometimes takes for a correct

principle to be universally received and acknowledged. Much of the prejudice that exists has, doubtless, arisen from sanguine experimenters having carried the principle of superheating much further than it was either desirable or economical. True it is, that we know comparatively little as to how superheated steam, when used in a steam engine, brings about the economy, which it assuredly does, in its working; but because we do not know all, or much, or, indeed, anything, as to the why of the success of its use, we should no more decide that this success does not exist than we should decide that because we know nothing as to what electricity, for example, is, we should decide that it is of no value. Superheated steam, and the value of it, is by no means a new thing, as will be seen from the following brief historical notes respecting it, which may not be out of place here.

Fig. 3.



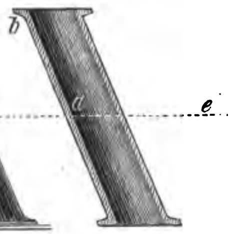
So early as the year 1802, a Mr. Thomas Saint took out a patent for a self-acting valve, which, when the steam from the boiler fell below the atmospheric pressure, opened and admitted the heated gases from the furnace to rise with the steam and raise its pressure. It is necessary here to explain that this was in the early history of steam boilers, when they were worked at pressures below, or but slightly above, that of the atmosphere. Although scarcely a superheating apparatus, still it may be looked upon as the pioneer of all those patents—and they are very numerous—which have been taken out since. In 1809, a Mr. English patented an apparatus, consisting of tubes which were heated, and through which the steam passed, the object he aimed at being to expend the steam so as to be used with increased effect in the cylinder. In 1830, the well-known engineer Trevithick, to obtain the same advantage, heated the cylinder by means of a separate fire, which not only prevented condensation within and radiation from the cylinder, but superheated the steam. But it was about or at the same period that the principle received the greatest attention, if not the most decided impulse, by the researches and resulting patented arrangements of a Dr. Haycroft, which, although embodying some erroneous ideas or statements, nevertheless were of great value; so much so, that many subsequent patents showed how much those who took them out had been indebted to, or influenced by, the researches of the doctor. One great advantage which is now thoroughly acknowledged by competent modern authorities, pointed out by Dr. Haycroft, was the prevention of condensation of the steam in the cylinder, 'which, by subsequent evaporation, occasions an abstraction of heat and a consequent waste of steam.' We may here note in illustration of this, that from every unit of heat thus condensed, there are lost no fewer than one thousand units of heat which have been derived from the fuel. If superheated steam was placed under the same circumstances it might be made to lose all its added or extra heat, and yet not be condensed, that is, it would still retain the form of steam. Various attempts were made after this period to introduce superheating apparatus, which were more or less successful, but only so far successful, after all, that they served little practical purpose than merely to keep the subject alive and prevent it from fairly dying out. In 1847 the subject received again a fresh impulse, and in that year Mr. Moses Poole took out a patent, by which he proposed to remedy one of the defects of previous plans, in which superheated steam of a very high temperature was used, and which was found to burn the packing with which it came in contact. This he proposed to do by a method of mixing highly superheated steam with a small portion of ordinary saturated steam. This, some years afterwards, was re-patented, and caused no small excitement in the engineering world. The above disadvantage of superheated steam is got rid of in ordinary working by only using steam not heated to a great degree, and yet sufficiently to realize a great economy in working. Thus, if to steam at 50 lb. in the inch, and possessing a temperature of 301 deg. Fah., heat be added to raise the temperature to 400 deg., this temperature will not be so high as to injure packing or the cylinder with which it comes in contact; yet it will be so far beneficial as to increase its volume or pressure 20 per cent. This economy was soon noticed by observant engineers, and the value of superheating of steam was pretty universally acknowledged. But, as we have already said, that there are those who, because all the phenomena attendant upon its use are not easily, or at all, explainable, come to the decision that there is no practical advantage obtained by its use. To such, should any be amongst our readers, the following considerations may be of some value. Apart altogether from other considerations, and to some of which we have already alluded, it is obvious that by using even a smaller degree of heat we can change steam from the saturated condition in which we know positively that it often exists, and in which it acts as the vehicle to carry over to the engine a certain portion of water, to that in which at all events, it may be *dry*, and thus be used in the steam engine as steam only, and not as partly steam and partly water, as in the other case it is. Every practical man knows the evils attendant upon 'priming,' which are brought into existence by using steam in its saturated condition. Now, in all cases where the steam does carry over water to the engine, which, even in the best constructed ordinary boilers, is done to a much larger extent than is generally supposed or may be admitted, it must be obvious that although the water thus carried over takes away with it so much heat, which heat is expensive, it cannot be used as a source of power; it must lower the force. The advantages, then, of drying this steam—in other words, of superheating it—must be obvious; we get rid, on the one hand, of the water heated at an expense which is not in any way returned in useful effect, and we, on the other, convert it into an elastic vapour, and raise it in temperature, so that it will not be condensed in the working parts of the engine. In this direction, and in this alone, if alone used, the superheating of steam is of great value. But another advantage flows from the use of superheated steam, and this where an engine is worked on the expansion principle, for it is obvious that the highest degree of economy arising from the use of this principle cannot be realized, where saturated steam is employed, for every degree of condensation is just a loss of expansion. This is not the place to enter further into the discussion of this important department of steam economy; suffice it to say, that according to the most distinguished authorities, a saving of fuel results from the use of superheated steam to the extent of from 20 to 30 per cent.; but if a less saving even than this be effected by its use, the principle will still be worthy of general adoption, and this when the steam is superheated only to that degree which will bring it up to the temperature of the steam employed in locomotives working at 120 lb. to the inch, and which introduces no objectionable feature in working. Hitherto the great objection to the plans proposed, by which the superheating was effected, arose from the circumstance that special and separate forms of apparatus were required, involving extra cost and much labour in keeping them in repair; but in the Safety Boiler all these objections are obviated from the peculiar construction of the boiler, in which the means are present of superheating the steam, and this without involving any cost either in making or in working. We do not deem it necessary to say more upon the other advantages possessed by the Safety Boiler, namely, the *entire absence of seams and rivetted joints, the absence of leaky joints, or the economy of its cost,* for on these we have already given what we deem essential, and the consideration of what was given in describing the construction will make them all sufficiently obvious to the practical reader."

3. *Wood's Improved Method of Fitting Boiler Tubes.*—"In

affixing," says the 'Mechanics' Magazine,' "cross or diagonal tubes in the flues of steam boilers, great difficulty is experienced in getting them to their places, more particularly when the flues are finished and fixed in their places in the boilers, and it is often found absolutely impossible to take them out whole or to put new ones in a boiler which is completed or has been working without taking out the flues or using packing to make up the length of the cross or diagonal tubes, which latter method is obviously very objectionable, and entails difficulty in making the ends of the cross or diagonal tubes properly tight. By the adoption of the system we are about to describe, all these difficulties may be obviated, as the cross or diagonal tubes may be readily fixed in the flue or fire-box of any boiler, whether vertical or otherwise, after such boiler be completed, or even when fixed on its seat ready for working without altering any part of its present construction or taking any part of it to pieces. This system has been patented by Messrs. Wood, of the Don Boiler Works, Sheffield, and is illustrated in the annexed engraving, in which fig. 4 shows a side elevation, and fig. 5 a longitudinal section of a flue

Fig. 4.

Fig. 5.

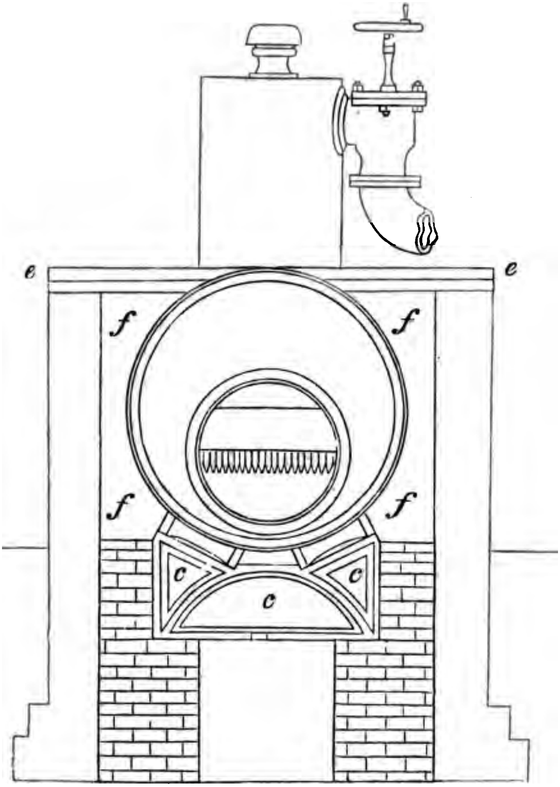


tube. *a a* is the water flue tube, having a flange *b b* at either end, serving to connect the same to the boiler flue or fire-box. The ends *c c* of the tube, instead of being at right angles thereto, are made at an oblique angle to the centre line of the tube. In this manner the tube, when placed in the flue, will be in such position that a line *d d*, drawn through its centre from the edge of one flange to the opposite edge of the other flange, will be at about a right angle to the centre line *e e* of the boiler flue *f*, or slightly inclining thereto, in the same direction as the cross or diagonal tube. Tubes fitted in this manner possess the advantage of being readily passed into the flue, and of being fixed or removed at any time for the insertion of new tubes, without interfering with the flues in which they are placed whatever the kind of boiler in which they are applied. We hear that these tubes have been applied to several boilers now at work, and which are giving every satisfaction. All the Cornish boilers now made by Messrs. Wood are fitted with them, three large boilers with thirty-four tubes having just been completed for one firm. Within the last three months they have been applied to five-and-twenty new boilers. The boilers fitted with the patent tubes and at work are reported to be effecting a saving of from 25 to 40 per cent. on the amount of coal required for the boilers they have replaced. In fact, this appears to be a most successful invention, and is one well worthy the attention of all steam power users."

4. *Parson's Steam Boiler Cradle Setting.*—We are indebted to the patentee for the following communication:—The revelations brought to light by the Manchester Association for the prevention of boiler explosions, and the frequent reports in our journals, have led me to devise a plan for the better inspection of boilers of the 'Cornish' and 'Egg-end' types. From my experience with a large number of boilers, I have found it almost impossible from internal inspection to detect leakages arising from cracks in angle iron, plates, and seams, and I have frequently been surprised to discover, on removing the brickwork, that parts of the boiler plates have been in the last stage of corrosion, and their resisting power reduced to the minimum, and this arising from the seams leaking, and being in contact with bricks and lime, defying detection without incurring the serious loss of removing the boiler.

At the first instance, could these have been detected, a few blows from the boiler-maker's caulking tools would have been an effectual remedy. We find, from the able work published by Mr. Fairbairn of Manchester, and the reports of Messrs. Longridge & Fowler, that boilers at present in use are ever likely to become a source of danger without a frequent and thorough examination of all their parts exposed to the action of the fire. From this it is clear that to lessen the source of danger arising from boilers continually undergoing alternations of temperature, that a principle of setting boilers that would give unrestricted freedom of inspection of all the parts without incurring the expense of pulling down the brickwork, so that within a few hours' notice engineers, masters, or inspectors, could avail themselves of such a facility, would be a boon widely recognized.

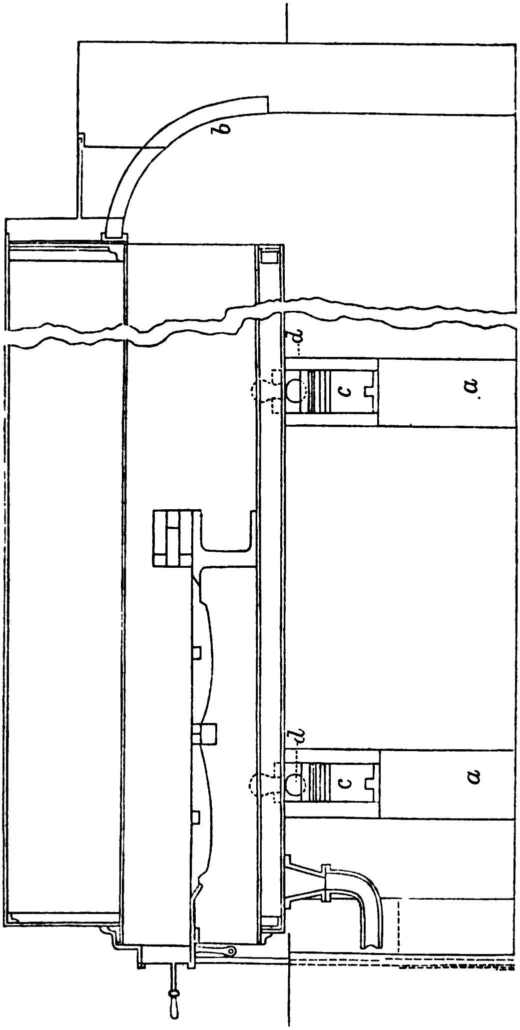
Fig. 6.



It has been generally understood that in boiler setting the capacity of the flues around the heating surface of the boiler is restricted to the most contracted limits, and to such an extent has this been carried to keep the products in close contact with the tubes and shells of boilers, that the sectional area of such flues has prevented the chimney from displacing anything like the product of the area of the fire-grate. Now, as there are such able treatises written by some of our most eminent engineers and chemists upon combustion, it would be out of place for me to enter into the chemistry of the combustion of coals, but I will content myself by stating it as my belief—from the results I have obtained—that the contracted flue system must have been, and is, a wasteful source of heat as obtained from boiler fires.

Referring to the sketch in figs. 6 and 7, it will be seen that a Cornish boiler is placed in a rectangular chamber, consisting of three walls, forming two along the sides, and a back wall, sunk below the surface of the ground to the depth of five feet, having a width larger than the diameter of the boiler from 6 to 9 inches each side, near the back part 2 feet 6 inches longer than the boiler, or in some instances 3 feet. A cast-iron girder spans the opening, and is securely built in the side walls, forming a key to an arch which springs from the back wall, and forming a quadrant *b* to the cast-iron girder of fire-bricks. At intervals along these walls, rising from the foundation, are brick piers *a a*, suitable in division for the length of the boiler to be set, and rising to the level of the surface. On these pillars are placed cast-iron frames *c c*, with inverted tops curved to the shape or diameter of the boiler, and made suitable to receive cast-iron rolls *d d*. These are built on the side walls at equal distances, and upon these cradles and rollers the boiler is rolled on, and brought within half-an-inch or so from the cast-iron girder spanning the wall at the back, to allow for any expansion that may take place in the boiler. The front end, then, is brought level, and is the same length as the side walls, leaving a space, as before said, of 6 or 9 inches of its diameter on each side. The sides of the furnace continue upwards to the level of the top of the boiler, and a space is thus left from the centre of the boiler, gradually increasing to the circle of the boiler, and is covered, as shown, at

Fig. 7.



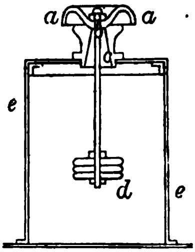
the end elevation of sketch, with fire bricks, or slabs, *e e*, fig. 6.

Thus, the boiler lies virtually in a hot-air chamber, or oven, *f f*, fig. 6, and only in contact with the brick-work of the covering of bricks of the side flues, and the filling in of the space at the front of the boiler with 4½ inches of brick. Now, at the first view taken of such a mode of setting boilers, it seems highly objectionable and dangerous. The objection seems to arise from the 3-feet space receiving the fire as it passes from the tube at the back of the boiler, and then having a large square recess, 5 feet deep, under the whole length of the boiler, and continuing up on both sides nearly to its whole diameter. And here another objectionable feature seems to amount even to a danger, from the fact of the side flues being carried up so high above the water level, and in some instances enveloping by an arch the whole top of the boiler. But a careful consideration of what takes place when the products of the fire issue from the internal tube, and are directed by coming in contact with the quadrant arch, *b*, fig. 7, at the back of the boiler, to sweep along the bottom of the boiler occupying the large space, will show that the arrangement allows the heated air and flame to be absorbed by the boiler and brickwork forming the oven, and then, in a subdued state, to radiate up each side of the boiler to the top part of the flue along each side of the boiler. Now, from this explanation of the action of the flame and heated gases, this mode of setting prevents the impinging action from taking place upon any particular part of the boiler, and the large expanding chamber permits the heat to be gradually diffused by a properly regulated exit through the damper immediately at the front of the boiler. And as in the old 'wheel draught' principle, the fireman can increase the make of steam by partially closing the damper, after having obtained a clear, bright fire; and by simply attending to this a saving of fuel is now being obtained of 30 per cent. Now, as to the advantages of this mode of setting the boiler, there is no one part of the shell of the boiler acted upon by the fire in one place more than another, this giving great facility for a regular expansion, the want of which is more injurious than is generally admitted. This freedom to expand and contract is an advantage well worthy of attention. The rollers and cradles form also such a rigid seat to preserve the boiler in a true horizontal position without the possibility of being strained by the giving way of the brickwork, which is a frequent source of started rivets. Should these occur, which is often the case with large boilers, by a manhole left in the back arch, the engineer, fireman, or inspector, can enter the chamber beneath, where the seams can be examined and caulked, or new rivets put in, and repairs done to the extent of an entire new plate, without causing one brick to be removed. This has been accomplished in several instances.

Now, with regard to the collapsing of tubes, I have also endeavoured to place at the disposal of persons using this class of boilers an additional security. From the experiments published by William Fairbairn, C.E., F.R.S., on the resistance of tubes to collapse, arose his recommendation to place round the tube a strong, or T iron, at intervals, to divide it into three or four parts, as the case may be; now, acting upon this, and knowing its efficiency when properly done, I have discovered that by placing cast-iron rings whose section is 5 to 6 inches square at equal distances along the inside of tube, with projecting ribs to keep them from bearing direct upon the shell, to allow the fire to pass between them and the plate with a space of 1½ or 2 inches, the tube will be preserved in its cylindric form, and its resistance to collapse will be increased equal to the shell of a boiler with a tube in proportion to its diameter. This gives great strength with economy. The ready mode by which it can be applied to all boilers by simply removing the fire bars, and admitting the rings direct into the tube, is also another advantage at least. The good results obtained by applying this principle to over 50 boilers, seem to indicate a great step in advance, and if not preventing altogether, considerably lessening the accidents to boilers from collapsing of tubes. There is, moreover, a slight advantage in having three or four cast-iron rings at a red heat in contact with the boiler plates.

Now the next source of danger that is universally acknowledged by all our eminent men is, the inability of many safety-valves to perform their functions. Safety-valves have too frequently to perform the office of discharging a volume of steam under certain circumstances which are really denied to them. They are constructed so that they have not a sufficient opening or outlet for the steam brought into existence by the sudden stopping of the engine. Now from witnessing year after year the hundred occurrences under my immediate notice of the safety-valves failing to perform their office (unaided) in a safe and proper manner, without increasing the pressure (in some instances a surplus load of 8 to 9 lbs.), I was led to look for some means where this could be efficiently prevented, by making a safety-valve that should be capable, without the least liability of derangement, to discharge with unfailing accuracy the whole capacity of steam, as fast as it is generated by the boiler fire, even when urged to its greatest capacity, and that the only outlet should be through the opening provided by the safety-valve. Fig. 8 illustrates the improvement that I have effected in safety-valves, which I think accomplishes much that has long been sought after. The valve *a*, fig. 8, covers the orifice by a spherical face *b*, and is confined in a scroll-like form in section *c c*, extending over the flanges projecting from the body of the valve, leaving a vaulted-like recess from 2 to 3 inches encircling the whole of the valve and outwards to the angle of 60°, which, meeting, would form a cone above the centre of the valve. It will be seen from the annexed sketch in fig. 8 that this valve is kept in contact with a very small surface of the seating, by weights, *d*, hanging in the interior part of the dome *e*, on a spindle passing through the valve to a brass nut on the top *c*; any additional weighting is quite impossible by the person in charge of the boiler, and the valve cannot stick or be impeded from lifting by

Fig. 8.



becoming jammed, as it simply sits on a knife-like edge. The next advantage arising from the vaulted formation of the valve is, that the steam, in issuing between the points of the seating, is directed downward, and by the shape of the outer edge of the valve being at the angle of 60°, the steam issues forth in the shape of a large cone whose base is the dome, and the frustrum is the centre of the valve. Now the recoil caused by the volume of atmospheric air being displaced by the steam pressing downwards, will efficiently lift the safety-valve to the requirement of the production of steam in the boiler. And so well has this system proved its efficiency, that, in every instance where a safety-valve has been erected, it has been found invariably to relieve itself accurately to the gauge under trying circumstances where, in the old valve, explosions must have undoubtedly followed.

The accurate action of this valve must be seen to be believed. Now, acting under the law that causes the sky rocket to ascend, it would almost appear at first sight that the valve, having once left its seat, and being opened for the outlet of steam, and the additional area caused by the extension of the bent flanges of the valve, it would be impossible for it to return in contact with its seat without a serious diminution of the pressure of steam; and were it so, it would render the valve useless; but, to the surprise of all parties who have seen its operation, it invariably returns in contact with its seat in every instance within a lb. of loss of pressure from its commencement to blow off. Now this is a feature which enables the engineer or inspector to avail himself of a recommended course, that is, to cut down the pressure of steam when the boiler has been discovered to be too weak to continue to work at a pressure. This has been done in most instances with safety-valves which have been at the option of people by altering the pressure on the valve from ignorance or design, and the consequence has been in many instances fatal. After recommending the immediate reducing of pressure, the question by the proprietor of a steam boiler has been how am I to obtain this? when I find the steam blowing off from the safety-valve at a pressure varying from 30 to 50 lbs., and when I have asked, says the proprietor, my stoker why the steam is blowing off at 30 lbs. instead of 40 or 50 lbs. as the case may be, he tells me that the valve has stuck, and it does not come down on its seat properly, or it is leaking through the seat being imperfect. Now these causes and questions have led me, after many trials, to produce this valve, that will not stick, that will not leak in its seat, nor admit surplus of steam, which cannot be overweighted or reduced in weight either by ignorance or design, and be continually under the control of whoever is in charge, and which can revolve on its seat without the least escape of steam; and so perfect is the action of the cup and ball principle of seating on a very thin edge to preserve a steam tight joint, that it has been the remark made by persons in different works where this has been applied, that the valve must have stuck, for they have not seen for a week an appearance of steam escaping from the valve. As an instance of this, Mr. Petrie, superintending Engineer of the Swansea Vale Railway, in sending me his testimonial of the two valves he has got in use, observes that the men say, that we never have any steam in our boilers, only at meal times; this meaning that the perfection of the valve will not allow the steam to escape until the pressure is accurately attained, and then never permits it to get above. As he observes in his testimonials to me, I am continually showing parties this valve by stopping the machinery suddenly, and I have failed as yet, by urging the boiler to its fullest extent, to get the valve to vary at the point of discharging the steam, and in no instances have I found it possible to get a half-pound more, so exactly does it relieve the pressure.

5. *Dunn's Boiler for Marine Engines.*—In 'Engineering' for February 14th, 1868, there is an article descriptive of this; from which we take the following; the article contains many illustrations, for which we refer the reader to the number as above stated:—"The firegrate is situated at about the middle of the height of the boiler, and the roof of the firebox is formed of semi-elliptical plates rivetted together at their edges, so as to produce a corrugated surface against which the products of combustion impinge. These corrugations are intended to give a larger heating surface to the firebox, and increase its strength; they also prevent the adhesion of sediment, as the expansion and contraction of the plates loosen the scale and allow the water to have free access to them. Beyond the firegrate is the bridge, over which the products of combustion pass to the down flue,

and then through the tubes, forming the multitubular part of the boiler, and then into a chamber which communicates by means of a flue with the chimney or funnel. Under the bridge are inserted a few short tubes, which admit air into the down flue for the purpose of igniting the inflammable gases passing over the bridge, or a regulating damper is employed instead of the tubes. The flue near the bridge is only opened when the fires are just ignited, but if owing to the leaking of the vessel the water should come in and close the lower flue, the upper flue may be opened so as to keep the engines going until the water rises in the vessel sufficiently to extinguish the fires. In another form the roof of the firebox is made of corrugated plates, stayed longitudinally and vertically, and the water partitions are placed in the down flue to absorb a portion of the heat from the products of combustion in passing to the up and down flues, which are formed by the water partitions projecting downwards from the central portion of the boiler, and the other partitions projecting upwards from the lower part of the boiler. The chamber and the flues are similar to those above described. In this boiler the outer side of the chamber is formed by the water partition, and consequently all the flues and lower portions of the boiler are perfectly water-tight, so that in case of the leaking of the vessel the boiler may be kept in full work until the water rises to the level of the fire-grate. In both these marine boilers the fire is applied near to the surface of the water; the ashes and cinders are or may be collected in buckets, and the direction of the products of combustion is indicated by the arrows."

6. From the same Journal we take the description of the "Galloway-Field" Boiler at Saltaire, as constructed by Messrs. Galloway of Manchester. "This boiler has been designed by Mr. George Salt, and, besides including a combination of the 'Galloway' and 'Field' tubes, it embraces several new features both of arrangement and details. The boiler is of a cylindrical form, and it is 8 ft. in diameter by 11 ft. high. It contains a cylindrical fire-box 7 ft. high by 7 ft. 3 in. in diameter at the bottom, and from the crown of this fire-box to the crown of the external casing there extend nineteen 'Galloway' tubes 10 in. in diameter at their upper, and 6 in. in diameter at their lower ends. From the crown of the fire-box, also, there hang

273 'Field' tubes, each 3 ft. 6 in. long by 2¼ in. in diameter, and amongst these there are disposed nineteen 'ball bafflers.' These 'ball bafflers' are of cast-iron, and they are each 9 in. in diameter. Each sphere is connected with the water space at the sides of the fire-box, and with that above the crown, by a pair of pipes, these pipes being of wrought-iron, and being fixed with screwed ferrules. The thicknesses of the plates of which the boiler is composed are as follows:—Smoke-box tube plate, ⅝ in.; fire-box tube plate, ¾ in.; shell of boiler, ½ in.; shell of fire-box, ½ in. All the rivet holes in the boiler are drilled, and the longitudinal seams are double riveted. The fire-box stays are of iron, and are screwed in and riveted over. The fire-box tube plate was rolled in one, but the top plate of the boiler had to be made in two pieces and welded together, it being impossible to obtain a single plate of the required size. The fire-grate surface is 41·27 square ft., and the fuel is supplied through two fire-hole doors, 20 in. wide, placed opposite each other. Sixteen tubes, 2½ in. in diameter, through which air can be injected by steam jets, are provided for the consumption of smoke, and besides the safety-valves and usual fittings, the boiler is provided with six blow-off cocks. The boiler is mounted on three cast-iron standards, and is completely free from all brickwork, being merely connected with the chimney by a short wrought-iron flue. The boiler is intended to work at a pressure of 80 lb. per square in., and it has been tested up to a pressure of 150 lb. We have no doubt that the arrangement adopted in this boiler will be found a thoroughly efficient one." (For a description of the "Field Tubes" see the vol. of 'Engineering Facts and Figures for 1865,' p. 2, and for 1867, p. 21).

7. *Langlois' Moveable Boiler Tubes.*—These tubes were exhibited at the Havre International Exhibition—held this year—and attracted great attention. We take from 'The Engineer' of September 4th, 1868, the following description of them:—"The object of the invention is to allow of the removal of tubes from time to time in order to cleanse them from the calcareous deposit. This is accomplished by means of collars screwed on to the end of the tube, and removable with little difficulty by means of a special key.

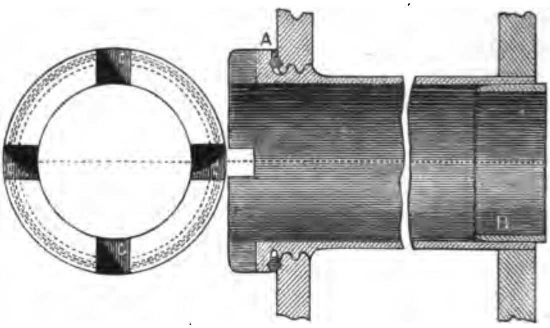
The loss of efficiency caused by incrustation in ordinary steam boilers is said to be from 20 to 25 per cent., and the following results of experiments made on board ships of the Imperial navy are given in support of the statement :—

	Periods of Working.		No. of turns of screw.	Coal per 100 turns.	Augmentation in consumption of coal.		
					Per 100 turns.	In each period.	In the whole.
				kilos.	kilos.	kilos.	kilos.
Magenta: plated frigate, 1,000 H.P.	1st 500 hours,	2700 hours	1,376,588	103			
	2d ,,		1,020,879	115	12·00	122,500	
	3d ,,		1,037,927	122	19·00	197,220	
	4th ,,		1,056,000	125	22·00	232,320	
	5th 700 hours,		1,585,200	130	27·00	428,000	980,040
Duplex: corvette, 400-H. P.	1st 500 hours,	3274	1,478,020	51·80			
	2847 hs. folg.		7,671,700	64·33	12·53	618,468	618,468
Nievre: transport, 160-H. P.	1st 500 hours,	2896	1,571,232	26			
	2396 hs. folg.		7,200,920	32	6·00	432,054	432,054
							2,030,562

The inference from this table is that an economy of more than two thousand tons of coal, or 25 per cent. of the whole consumption of the voyages of the three vessels, would have been saved if the apparatus could have been maintained from the first in perfect condition, and to this must be added the cost of replacement of tubes and plates, and of minor repairs rendered due to incrustation. It must be observed also that the number of turns of the screw having diminished relatively to the quantity of coal consumed, there resulted an increased expense for crew and material due to the augmentation of the time occupied. Experiments made with the boilers of fixed engines are said to have yielded like results, and therefore the inventor infers that there is a general loss of 25 per cent. by the fouling of boilers and tubes.

The accompanying engraving, fig. 9, shows the ends of a tube, either of iron, brass, or copper, fixed in the two plates of a boiler, with the rounded screw-thread and all the details of adjustment as now adopted by the inventor after a long course of practical experiments. A leaden washer A is interposed between the plate of the smoke-box and the adjusting collar of the tube, a small gutter being cut in both collar and plate, into which the lead is squeezed by means of a powerful key taking into the four notches C of the gun metal head brazed on to the tube. In order to pre-

Fig. 9.



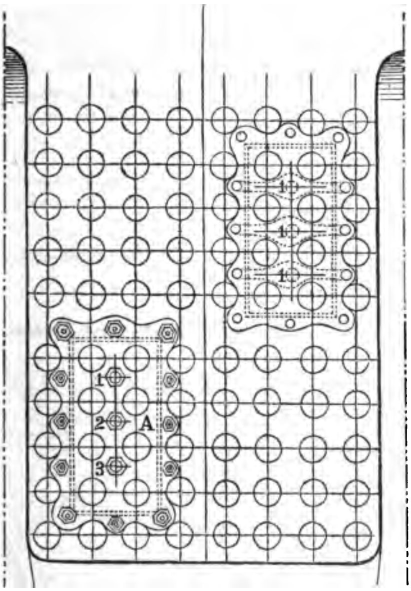
vent the adhesion of the tubes by oxidation, the threads are smeared with zinc mastic, and it has been found that the tubes can be taken out without much difficulty after having been in use for two years. The end of the tube by the fire-box is fixed by means of a slightly conical ring of steel or iron, which is tightened up by means of a circular split wedge, acted upon by a conical mandril driven into the central opening. The difference between the outer diameter of the tube and the diameter of the threaded hole in the plate of the smoke-box is about a quarter of an inch, so that a tube covered with incrustation the eighth of an inch thick all round can easily be removed, and of course when all the tubes are taken out the cleaning of the interior of the boiler is a comparatively easy matter.

As cost is a very important question in such a practical matter as this, we may say that the expense of fitting the tubes according to M. Langlois' system—including the gun metal caps and everything else, with the exception of the tubes themselves—is stated to vary from 8s. 4d. for a 1½in. tube to £1 5s. 8d. for one of 4¾in., the expense being the same whether the boiler be new or old, and whether the work be done in a construction shop, on board ship, or elsewhere.

The inventor furnishes a host of testimonials from officers and engineers of the Imperial navy, declaring that tubes thus fixed are perfectly staunch, and that the time occupied in removing a tube does not average more than five minutes. The general adoption of Langlois' tubes in the Imperial navy was preceded by the favourable report of a special commission appointed to examine and experiment upon the boilers of the steam despatch boat Faon, after the moveable tubes had been in use for fourteen months."

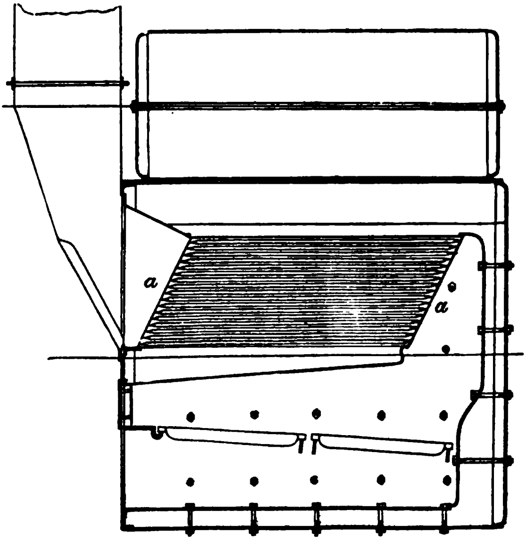
8. *Keesen's Marine Boilers.*—M. Keesen also exhibited at Havre his patented arrangement for enabling the tubes of marine boilers to be cleaned from the deposits, or saline incrustations, which gather upon them. In place of having the end plates of the boiler of one piece, or rather solid, M. Keesen makes in each end rectangular openings, shown by the dotted lines; these are placed diagonally, as shown in fig. 10, and of size sufficient to allow a man to enter easily. These openings are covered with plates, made with curved edges, which admit of the ends of the tubes being embraced, as shown in fig. 10. The tubes are fixed upon a plate which

Fig. 10.



lies flat on the face of the boiler plate at the smoke-box, and is secured by twelve screw-bolts and nuts, as shown at *a*, in fig. 9. The orifice in the smoke-box, and of the boiler, is made sufficiently large to admit of the plate which closes the rectangular opening made in the fire-box end of the boiler to pass easily in. This second plate is fixed upon the other end of the tubes, and rests upon the interior of the boiler-plate at the fire-box end; the two plates are secured together by three long bolts, which pass through the interior of the boiler, the ends of which are shown at 1 2 3 in fig. 10, and which pass through holes in the centre of the fire-box end plate, and are carried by transverse bars I I I, fig. 9, bolted to the outside of the boiler-plate at the fire-box end; the ends of the bolts pass through holes in these bars, and are tightly screwed. By unscrewing the twelve nuts in the plate A, fig. 9, and the three nuts outside the transverse bars I I I, at the fire-box end, the tubes—eight in number in the drawing—carried by the plate A A, can be moved forward sufficiently

Fig. 11.



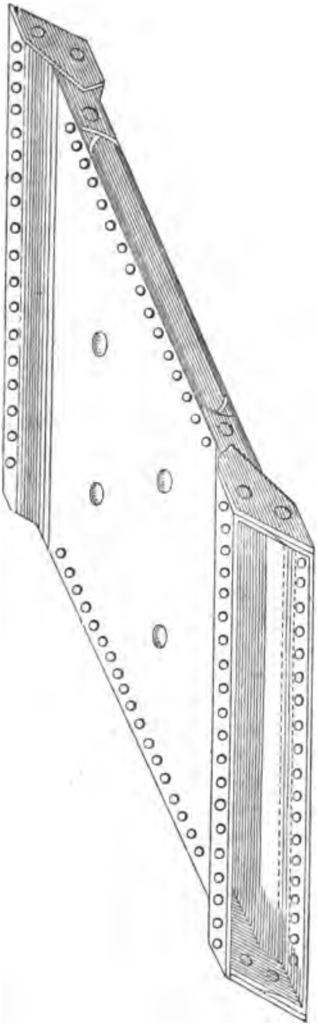


Fig. 12.

to allow the opening in the fire-box end to be opened for the entrance of the men to clean the tubes in the interior. As the plate A at the smoke-box end is outside the boiler plate, and the plate I I I in the inside of the fire-box boiler plate, the pressure is equalized.

9. *Holt's Marine Boiler.*—This boiler—which was also exhibited at Havre—we illustrate in fig. 10. It is the invention of Mr. Holt, engineer, of Trieste, Austria, and the peculiarity consists in the way in which a very extended heating surface is obtained by means of the part *a a*, an enlarged view of which is shown in fig. 12. The inventor claims for this arrangement of flat heating tubes a saving of space or size equal to one-third as compared with ordinary boilers, a perfect and rapid circulation, and a consequent freedom from incrustation and deposit in the boiler, and a much larger amount of heating surface; as, for example, in two boilers, each ten feet in length, in one made on the ordinary Cornish system, there are only 720 square feet of heating surface as against 5,720 feet obtained in the boiler made on the improved system; an ordinary vertical boiler has 200 square feet of heating surface, and on the improved system 800 feet.

10. *Cast-steel Boilers.*—"The use of steel," says the 'Scientific American,' "in the manufacture of steam boilers is of comparatively recent date, and the relative advantages, if any, over ordinary iron boilers, except on the score of their less weight, has hardly yet been satisfactorily determined. We have before us perhaps the latest information bearing on this subject, being the results of an important series of experiments made recently at the rolling mills of Messrs. Funk & Elbers, of Hagan, Prussia, for the purpose of ascertaining the respective evaporating power of the new compared with the old style of boiler.

The two boilers experimented with were each five feet in diameter, and thirty-four feet long, constructed to stand five atmospheres 'over' pressure. One was made of wrought iron, and the other of soft cast-steel. The thickness of the sides in the cylindrical portions of the iron boiler was 0·50 of an inch, and of the cast-steel boiler 0·33 of an inch. Each boiler had a heating surface of 293 square feet, and twelve square feet of surface. Both were new, and had never been before heated.

They were set alike in brickwork, one above the other, but entirely separated by masonry; the gaseous products of combustion passed through a single flue underneath each boiler, and passed directly into the same chimney. At first both boilers were filled, and fires were kept under them for several days in order to dry the brickwork, after which the fires were extinguished and the boilers emptied and cleaned. Each boiler then received exactly 712 cubic feet of water at 95° Fah. temperature; the man-holes were closed, and the water was heated to the boiling point; again the fires were put out, and all the ashes and coals taken away. From this point the boilers were fired afresh, and fed with weighed fuel; the man-holes, hitherto kept closed, were now opened to let the steam escape; and the firing was so well regulated, by means of dampers, that the velocity of the escaping steam—measured by List's Velocimeter—was the same in each boiler. The temperature of the gases from the fire was measured, at a point six feet from the rear end of each boiler, by Gauntlett's Pyrometer, and found to vary from 644° to 734° Fah.

After consuming on each grate 3,150 pounds of coal of the same quality, the cinders of which were burned over and over again, the fires were put out, and the man-holes closed. On the following day the remaining water of the boilers, showing a temperature of 95°, was let out through the emptying tube, situated at the lowest part of the boiler, and measured by means of a hydrometer adapted to the tube. The iron boiler showed 387 cubic feet, and the steel boiler 331 cubic feet of the remaining feed water. Therefore the water evaporated in the iron boiler was 712—387—325 cubic feet, or 20,065 pounds; and that evaporated in the steel boiler was 712—331—381 cubic feet, or 23,523 pounds. Hence the evaporating capacity was proved to be 17·20 per cent. in favour of the steel boiler. One pound of coal evaporated in the iron boiler 6,350 pounds of water, and the steel boiler 7,467 pounds of water at 212° Fah.

At the next trial the whole operation was performed in the same manner, only the velocity of the escaping steam was less. It resulted in showing 19·62 per cent. in favour of the steel boiler. One pound of coal evaporated in the iron boiler 5,809 pounds, and in the steel boiler 7,008 pounds of water.

These two experiments were verified in the following manner:

To an equal quantity of feed water in each boiler an equal volume of a strong solution of salt was added. After stirring the water for some time, by means of long poles, and boiling it with closed man-holes, samples were taken out for future analysis. In completing this experiment in which equal quantities of fuel and water were used, further samples were taken out. The analysis of the samples by Dr. List, of Hagan, showed that in the iron boiler one quart of water contained before evaporation 4,629 grammes of chloride of sodium, and after, 5,985; in the steel boiler one quart contained 4,371 grammes before, and 7,385 grammes of salt after evaporation; the iron boiler lost 33·76 quarts, and the steel boiler 40·81 quarts of water, showing 20·85 per cent. in favour of the latter. The average percentage of these three experiments is 19·24 per cent. in favour of the steel boiler, which it will be noted had a shell 33 per cent. thinner than that of the wrought-iron boiler."

11. *Double-Flued Cornish Boiler, Constructed by Messrs. Hick, Hargreaves and Co., Bolton, of Steel Plates Manufactured by the Bolton Steel and Iron Co.*—From 'Engineering' of May 29th, 1868, we take the following description of this:—"We give above a perspective view (not here inserted) of one of a set of double-flued Cornish boilers, 30 ft. long by 7 ft. in diameter, now being made by Messrs. Hick, Hargreave, and Co., of Bolton. These boilers are being constructed entirely of mild carbonized steel plates, manufactured by the Bolton Iron and Steel Company, and there are many points about them worthy of the attention of those interested in the application of steel to boiler-making. In the first place, notwithstanding the size of the boilers, each ring is formed of one plate only, there being but one joint, and that being placed above the water-line, and also above the brick setting, so as to be always open to inspection. The longitudinal seams of the rings are disposed alternately on opposite sides of the centre line, as shown in the engraving, so that they break joint. The shell plates are ⅜ in., and the end plates, ½ in. thick, the boilers being intended to be worked at a pressure of 60 lb. per square inch. The rivets used are all made of a specially prepared steel, and the rivet holes are punched, the plates being annealed after punching. In punching the plates, punches are used with plenty of clearance in the die, the result

being that the holes are considerably coned, or of a deep countersunk form. The rivets are of a taper form, so that they fit the coned holes properly, their diameter being $\frac{5}{8}$ in. at the smallest part, and they being disposed in double rows at a pitch of $1\frac{3}{4}$ in., in all directions. Mr. Henry Sharp, of the Bolton Iron and Steel Company, has experimented upon the effects produced by punching steel-plates with punches having different amounts of clearance in the die, and he has found that considerable benefit results from making this clearance large. In the course of the paper lately read by him before the Institution of Naval Architects, he referred to these experiments, and, although we give this paper in full in our number for April 3 last, we may repeat the principal results here. A $\frac{1}{2}$ in. steel plate was taken and cut in two. One piece was then punched across the middle with $\frac{11}{16}$ in. holes, the punch and die used being of the usual proportions, and the clearance barely $\frac{1}{16}$ in.; the other piece was punched with the same punch, but the die had a clearance of $\frac{3}{16}$ in., the holes formed in this latter instance tapering from $\frac{11}{16}$ in. to $\frac{7}{8}$ in. in diameter. The plates were then cut into strips and tested, when the pieces of plate punched in the ordinary way bore a tensile strain of but 26·004 tons per square inch, and those punched with the tapered holes a strain of 32·527 tons per square inch—a most important difference. Mr. Sharp also found, during his experiments, that the tensile strength of steel plates, $\frac{5}{16}$ in. thick, was deteriorated to the average extent of 38 per cent. by the ordinary process of punching, as compared with drilling; but that by annealing the plates after punching, the original strength was entirely or almost entirely restored. Mr. Sharp, however, does not advocate punching and subsequent annealing as being better than drilling, but he considers that the former processes may frequenly be conveniently substituted for the latter without there being any fear of bad results.

"In the boilers which form the special subject of this notice, there is a peculiarity about the construction of the flues which we must mention here. As in the case of the outer shell, each ring of the flues is formed of a single plate, and these rings are united by weldless steel hoops of a section somewhat resembling a Barlow rail. Two of these hoops are shown leaning against the flue in the foreground of our engraving. They are but $\frac{1}{4}$ in.

thick throughout, and from their form they give a certain amount of longitudinal elasticity to the flues. The prejudice against the employment of steel plates for boilers is rapidly dying out, and it will probably not be long before it disappears altogether. There are now large numbers of steel boilers at work in almost all parts of the kingdom, and many of them have now been at work some years. The great thing is to select plates of a proper quality, and the next is to treat these plates in a proper manner in making them up into a boiler. Steel plates undoubtedly to a certain extent require different treatment to iron; but it is now pretty well known what this treatment should be, and it is the fault of the boiler-maker if he does not avail himself of the experience already acquired."

12. *Rules for the Strength of Boilers* we take from the work entitled 'Useful Information for Railway Men,' written by Mr. W. G. Hamilton, for the Ramapo Wheel and Foundry Company, U. S. " For the cylindrical parts :—

To Find the Working Steam Pressure Due to a given Diameter, Thickness of Plate, and Quality of Joint:—Rule—Multiply thickness of plate in inches by two, and by the working strength of the longitudinal joint in pounds, per square inch, and divide by the diameter in inches; quotient is working steam pressure in pounds, per square inch.

To Find Thickness of Plate, Due to a given Diameter, Quality of Joint, and Working Pressure:—Multiply the working pressure in pounds, per square inch, by the diameter in inches, and divide the product by the working strength of the longitudinal joint in pounds, and by 2. The final quotient is the required thickness of plate in inches.

The ultimate or bursting pressure is five times the working pressure.

To Find Working Steam Pressure, Due to a given Diameter of Tie-rod, and Area of Segment to be guarded by it:—Divide the working strength of the tie-rod in pounds, by the area of the segment in square inches; quotient is working steam pressure in pounds, per square inch.

To Find Thickness of Plates of Stayed Surfaces:—Multiply the square root of the pressure in pounds, per square inch, by the greatest distance between the stays in inches, and by ·008; product equals thickness of plate in inches.

To Find area of Segment, Due to a given Diameter of Tie-rod and Working Pressure:—Divide the working strength of the tie-rod in pounds, by the working pressure in pounds, per square inch; quotient is area of segment in square inches. Working tensile strength of best iron rods is seven-eighths inch diameter, 8,000 pounds; one inch diameter, 10,000 pounds; one and one-eighth inches diameter, 13,000 pounds. Deduct ten per cent. if the rod is reduced by screwing.

To Find Dimensions of Stay Bolts:—Multiply area supported by stay in square inches, by pressure of steam in pounds per square inch; the sum divided by 9,000 equals area of stay bolts in square inches, if the stay is thickened out where the screw is cut. If the screw is cut out of the body of the stay, divide by 6,000. Where stays are secured by keys, the stay at the end should be one and a quarter diameter of the body of the stay. Depth of cutter, 1·6 diameter of stay; thickness of cutter, 0·3 diameter of stay.

To Find Working Strength of a Roof-stay (or Crown bar) of given Dimensions, fixed in its place:—Multiply thickness of stay at the centre in inches, by the square of its depths at the centre in inches, and by 30; divide the product by the length of the span in inches; quotient is working load in tons equally distributed, when stay is fixed in its place.

Staying Locomotive Boilers.—Fire-Box Water Spaces:—Working pressure in pounds, per square inch, being one-sixth of bursting pressure; stays, three-quarters inch diameter; copper plates, one-half inch thick; iron do., three-eighths inch thick.

STAY.	PLATE.		STAYS 5 IN. APART.	STAYS 4 IN. APART.
Copper	Copper	Screwed and riveted	107	185
Iron	Copper	Screwed and riveted	160	250
Iron	Copper	Screwed only	120	190
Iron	Iron	Screwed and riveted	185	290

For low pressure boilers, at twenty pounds per square inch, flat portions should be stayed at intervals of twelve inches apart.

To Find the Pressure borne by the Roof-stays (or Crown-Bars) of a Fire-box:—Multiply the span of the roof in inches, by the pitch of the stays in inches, and by the pressure in pounds per square inch, and divide by 2,240; the product is the pressure uniformly distributed, borne by each roof-stay, in tons.

Strength of Boiler Plates and Joints:—Working strength of best boiler plates are:

Yorkshire plates per square inch of entire section,	11,000	pounds.
Staffordshire, ...	9,000	,,
American, ...	14,000	,,
American, ordinary, ...	12,000	,,
Cast steel plates, ...	18,000	,,

Working Strength of Joint per Square Inch of Entire Section:

	BEST YORKSHIRE.	BEST STAFFORDSHIRE.	BEST AMERICAN.
Scarf welded, joint, .	11,000	9,000	14,500
Double riveted, double welt,	9,000	7,000	10,500
,, ,, lap joint,	8,000	6,500	9,750
Lap, welded joint, . .	7,400	6,000	9,000
Double riveted, single welt,	7,300	6,000	9,000
Single riveted lap, . .	6,700	5,400	7,800

The strain per unit of length upon transverse circular joints is only half of that on longitudinal joints; longitudinal seams should therefore be the strongest, and the double riveted double welt joints should be used for longitudinal joints, and the single-riveted lap joints for circular seams.

Riveting for Boilers.—Table of Dimensions of Rivets, etc., for Steam Boilers:

Thickness of Plate.	Diameter of Rivet.	Length of Rivet from head.	Distance apart of Rivets, Centre to Centre.	Breadth of lap, single riveting.
In.	In.	In.	In.	In.
3·16	⅜	⅝	1¼	1¼
¼	½	1⅛	1½	1½
5·16	⅝	1⅜	1⅝	1⅞
⅜	¾	1⅝	1¾	2
½	13·16	2¼	2	2¼
⅝	15·16	2¾	2½	2¾
¾	1⅛	3¼	3	3¼

For double-riveted joints, add two-thirds of the breadth of lap."

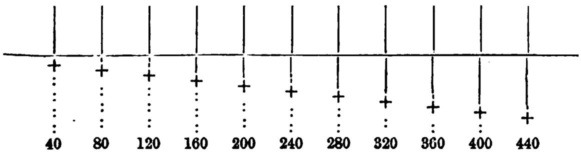
13. *On the Strength of Boilers.*—(From the 'Scientific American'). "The capacity of boilers to resist rupture by the pressure of the steam, and the unequal expansion of the material of boilers from unequal heating, is a subject of very great importance, and not generally understood. Some illustrations and remarks relative thereto will be found below. Any tube closed at the ends and subjected to an elastic pressure from within, will rupture longitudinally with about one-half the force per square inch required to break it transversely.

For example, a cylindrical boiler, without tubes or flues, made of a single piece of homogeneous iron, one quarter inch thick, without seams, may be conceived, twenty feet long, and thirty-six inches in diameter. For convenience, we will assume that each square inch of the iron of the cross section, and of the longitudinal section, on the horizontal plane, has the ability to restrain a force having a tendency to rupture it, equal to fifty thousand pounds. The circumference of the boiler is about one hundred and thirteen inches, consequently the area of the cross section of the iron has about twenty-eight square inches; it would therefore require one million four hundred thousand pounds pressure against the heads to pull it apart with a transverse rupture. The whole number of pounds representing the transverse strength, divided by one thousand and seventeen, which is the number of square inches area of the heads, against which the steam would press to cause the transverse rupture, gives thirteen hundred and seventy-six pounds as the pressure per square inch against the head required to break such a boiler in two transversely. The longitudinal section contains one hundred and thirty-eight square inches of iron; consequently, it requires six millions nine hundred thousand pounds pressure to break it in two in the longitudinal direction. The area of the surface against which the steam would press—the boiler being two hundred and forty inches long and thirty-six inches wide—is eight thousand six hundred and forty square inches; which, used as a divisor for the sum of pounds, representing the strength to resist longitudinal rupture, and we have seven hundred and ninety-eight pounds per square inch, as the pressure necessary to pull it apart with a longitudinal rupture. Whether such a boiler could resist transverse rupture until the pressure of the steam reached 1,376 lbs. to the inch, and longitudinal rupture up to 797 lbs. to the square inch, is not material to this particular inquiry. It is important for engineers and others to know, that a boiler is nearly twice as strong to resist transverse rupture as the longitudinal, because it will be then possible to determine that some other force than the direct pressure of the steam has been the cause, when a boiler is found broken transversely, and not longitudinally, all other conditions being equal, as contemplated herein. If a boiler of the cylindrical form has flues, or tubes, it would increase the ability to resist transverse ruptures, for two reasons, which should be considered: 1st. The part of the area of the head covered by the area of cross section of the flues, or tubes, would have to be deducted in determining the sum of the pressure of the steam against the heads acting to pull the boiler apart transversely; and 2d. The strength of the tubes, or flues, should be added to the strength of the shell, as if they were stays between the heads, increasing the ability of the boiler to resist rupture transversely. Yet, notwithstanding these important considerations, I do not think there has ever been a single example noticed of the longitudinal rupture of an upright boiler.

If the force with which the tubes would expand, if made hotter than the shell, should be considered, or the increased circumference of that part of the shell above the water from the same cause, should be taken into account, in addition to the pressure of the steam, the explosion may be accounted for.

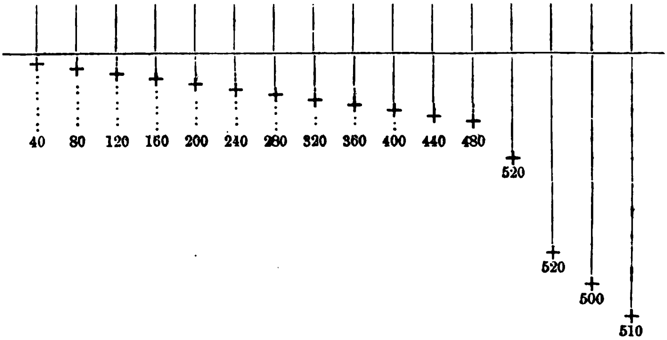
No class of explosion is more common than the rupture of steam chimneys on the kind of boilers almost universally used on river and sound boats along the Atlantic coast. I do not believe a single case can be remembered in which a steam chimney has been ruptured longitudinally. I have known of a large number which have burst transversely, and leaks in the transverse seams are so common that scarcely one can be found which does not leak. It is not the pressure of the steam which is the cause of either the leaks, rupture, or explosion, in this part of the boiler. But if the force with which the uptake flue expands upward when it is heated to a higher temperature than the outside shell, is taken into account, in addition to, or even without the pressure of the steam, it can be understood why such parts of the boiler give way when subject to only twenty-five pounds pressure of steam, after the water test has shown them capable of withstanding fifty pounds.

It has been found by actual experiment that single riveted seams have but fifty-seven hundreds of the strength of the iron elsewhere than through the rivet holes. The ratio of weakness is greater than the proportion of the iron, cut out in punching the holes. This is probably due in part to the distortion of the iron by the punch, immediately about the hole, putting the material in a state of tension, or strain. The caulking tool also buckles the iron and thereby adds to the tension; and the lap of the sheet throws it out of the line of the tension exerted by the pressure of the steam, the tendency being to bend the sheet. As all structures are only as strong as their weakest part, it would seem to be a reprehensible error in boiler-makers to continue to construct boilers with invariable lines of weakness, like the seams, having but little more than half the strength of other parts. But it has been almost invariably noticed, when examples of exploded boilers were being examined, that the rupture did not either begin with, or follow the rivet holes, or any weak part of the iron with flaws, which is also an indication that some other force than the elastic pressure of the steam caused the initiatory rupture. Any piece of iron subjected to a tensile strain will be stretched to the extent which will give it a permanent set by about one half the force which will break it. This curious fact was discovered and demonstrated by Professor Daniel Treadwell, whose essays on some of the qualities of metals are extremely valuable.



The experiment was constructed by stretching a piece of wire along a table, about fourteen feet in length, and by means of a lever, after marking its length, subjecting it to a tension of forty pounds. The extension for that weight, and for each weight applied is shown full size on the cut. The weight was removed after each application, and it was found that two hundred and eighty pounds gave the first permanent set; that is, the iron did not recover its original length after the application of that weight. The continued additions to the weights shown, increased the permanent extension until four hundred and forty pounds were sustained, without breaking the iron, which will be noticed, is nearly double the weight which gave the first permanent stretching of the wire.

Another series of the application of the successive weights from forty pounds upwards, was then begun, with the same iron; but no additional permanent set was given to the wire until four hundred and forty was passed. Five hundred and twenty was reached without breaking, which weight being removed and applied again, was suspended for several hours, stretching the wire slowly, as shown, when it was removed; and afterwards the wire was broken with five hundred and ten pounds tension.



From this we may conclude that if we find a part of a boiler which has burst, of an equal strength with the ruptured part, not stretched or distorted, that it was not the pressure of the steam which caused the initiatory rupture. If the pressure of the steam were the only force to be restrained in boilers, it would be easy for the boiler-maker, or engineer, to provide boilers which could not possibly be burst. For instance, if a boiler of certain dimensions, made of quarter-inch iron, should burst, make the next one to take its place of iron half an inch thick. Or why not four inches thick? If iron with a tensile strength of 50,000 lbs. to the inch is ruptured, why not take high steel, with a tensile strength of 120,000 lbs. to the square inch? These seem to be natural questions to ask, but they are answered by the statement that it is not the strongest boiler which is found to stand the best, but the boiler which is made of the softest and most ductile materials. A boiler might be made of iron so thick that it would not conduct heat enough through to the water to generate steam at all, while the iron would be entirely destroyed by unequal expansion, from the difference of temperature between the surface of the plates exposed to the fire, and the one exposed to the water. And although a boiler made of high steel would withstand a much higher cold water test than an iron boiler of the same thickness, it could not withstand unequal heating so well, on account of its greater density; and, consequently, the greater force with which it would expand and contract, as it was heated or cooled unequally. Metals expand, as they are heated, with a force which exactly equals the force with which they would resist compression at the same temperature, and contract with a force which exactly equals the force with which extension to the same extent would be resisted. A bar of railroad iron may have eight inches area of cross section, and a tensile strength of 20,000 to the square inch. Such a bar would be pulled apart if it were extended three-eighths of an inch lengthwise, and the force necessary to extend it would be 160,000. The same bar would be extended three-eighths of an inch by raising its temperature one hundred degrees: if, when so heated, its ends should be so fixed that they could not approach each other; and then, the bar being cooled, it could be broken in two simply by the force of contraction, which would come from a change of temperature of one hundred degrees. If the bar should not be actually broken by the first heating and cooling under such circumstances, it would at least receive a parmanent set, and repetitions of the same process would eventually break it. And this is probably the force, viz: unequal expansion or contraction from unequal heating or cooling, which causes all the leaks, ruptures, distortions, and explosions of steam boilers; a force not contemplated when boilers are subjected to the test of cold water pressure by the steam-boat inspectors; a force which does not effect the steam gauge or safety valve, and therefore these instruments do not indicate it. When we come to examine the ruptured, leaky, or the exploded boiler, we have no means of determining the extent of the force which caused the accident, and the engineer has no means of either determining or preventing it. The boilermaker cannot make a boiler to withstand it, for the stronger the boiler the greater the force. The only practical way to avoid the danger is to equalize the temperature in all parts of the boiler, at all times and under all circumstances, which happily it is easy to do.

It was once my privilege to have a chance to experiment with two boilers set up in brick work, side by side, but with separate furnaces under each. Occasionally the fire was made under only one boiler, and fifty pounds pressure of steam filled both. As water will not receive heat from its upper surface downward, the steam was not condensed by the cold water in the boiler under which there was no fire, and the water remained as cold as previous to the beginning of the experiment. The boilers were thirty feet long, and thirty inches in diameter, of the cylindrical form, without flues. With fifty pounds of steam, the one without the fire under it had a temperature of 301° Fah., in the water, and in the steam; and at that temperature was about one and a-half inches longer than when cold. The other, having water at a temperature of 60° in the bottom, and steam at a temperature of 301° degrees in the top, was bent into the form of a segment of circle, and was caused to leak badly along the bottom. I concluded the strain upon the boiler was quite as great as if it had been bolted down at the ends and jackscrews adjusted under it along the middle of its length, and 'worked up' until the boiler was bent to the same extent. It was considered extremely dangerous to carry fifty pounds of steam in a boiler under such circumstances, and the experiment was not repeated. Yet engineers frequently have a high pressure of steam on boilers while subjected to equal strains of unequal expansion, without knowing it. Boilers explode under such circumstances, and everybody wonders. Enormous pressures are attributed to steam accumulated suddenly in some mysterious manner, and the error is repeated again and again."—Norman Wiard.

14. *The American Steam Boiler.*—In 'Engineering,' under

date Dec. 4th, 1868, there is an account of this boiler, which has been recently introduced into this country, and which owes its existence to the designs of Mr. J. A. Miller of New York. The material is of cast-iron, but the peculiarity consists in the way in which this material is used. The boiler consists of two kinds of 'units,' as they are termed, bolted together by strong flanges. These units differ in form, one being made up of a pipe of a horseshoe or semicircular shape, connected at its lower ends with horizontal pipes, supported on the furnace, and the upper or central part of the horseshoe being provided with a vertical pipe leading to the steam delivery pipe. Each of what we may term the "furnace units" is connected to the next by two joints, one on each side of the firegrate; whilst each of the remaining sections is connected to that next it by a single joint near the centre of its bottom transverse water space, as shown in fig. 4. The joints are carefully made, and they are each held together by six bolts, whilst the flanges are broad and heavy. In the case of the furnace units the joints are kept below the level of the grate bars so that they are protected from the action of the fire. The unit which forms, as it were, the back of the furnace differs from those which succeed it, it being provided with two extra joint flanges, which serve to connect it with the units forming the furnace, as shown in fig. 4. The form of the other 'unit' is that of a vertical conical pipe, the lower end being smaller than the upper. These are placed together so that they form a series of five vertical conical tubes, connected by transverse tubes at the bottom and near the top. The water line is maintained about the middle of the depth of the upper transverse water spaces, and the water has thus a considerable surface area, a matter which exercises an important influence in reducing the tendency to priming, whilst it also renders the water level less variable under irregularities in the supply of feed water. The top of each of the main units is closed by a cover or bonnet, from which a wrought-iron pipe is led to the cast-iron steam drum, which extends the whole length of the boiler, as shown in the general views. The connecting pipes are bent so that they may expand freely. The joint connecting each unit and its cover is made before the units leave the factory, and it is a permanent joint, there being no occasion to break it afterwards. To assist the circulation of the water, each of the vertical tubes of the main units is fitted with a loose inner tube, as shown in fig. 2, but carried rather lower down than there represented. This arrangement is similar to that employed in Howard's well-known boiler, the inner tube dividing the ascending and descending currents of water. In the case of the units forming the furnace, the same end is attained by a division cast in the arched tubes, as shown in section in fig. 4, and by dotted lines in fig. 1. The current of heated water of course rises on the inner side of the partition, whilst the return current descends on the outer side.

We must now speak of the arrangement of the units in their setting. By reference to the sectional plan, fig. 4, it will be seen that the units are so placed one behind the other that the tubes of one are in a line with the spaces of the next, and so on. The object of this is to cause the heated gases passing through the spaces of one unit to impinge upon the pipes of the next. Although, however, the gases do to a certain extent pass through the spaces or openings in the units, yet the main current will flow into a zigzag course through the flue formed by the units themselves. In fact, in the case of boilers to be worked with bituminous coal, Mr. Miller casts feathers on the sides of the pipes of each unit, except the three or four next the furnace, these feathers almost closing the openings, and thus compelling the gases to traverse the longer route afforded by the zigzag flues. By this arrangement, a great length of run is obtained for the gases with a very moderate length of boiler. The arrangement of the brick setting will be readily understood from the longitudinal section. It will be seen that the units making up the main part of the boiler are supported on ledges formed by a reduction of the thickness of the side walls, there being a clear space left between the latter into which any soot, &c., can fall, thus keeping the flue portion clear. This pit, which is 2 ft. wide by 2 ft. deep, can be readily cleaned out at the necessary intervals. The feed water is admitted at the front end of the boiler, as shown in the end and side elevations, which views also show the arrangement of the gauge cocks, fire door, fittings, &c. The firebars employed by Mr. Miller are not shown in our engravings; they are of a peculiar, and, we think, exceedingly good section, and we shall describe them on an early occasion.

Altogether we consider the "American" boiler to be the best arrangement of cast-iron boiler which has yet been brought under our notice. The heating surface is well exposed to the action of the heated gases, there are good facilities for efficient circulation, whilst the joints are so placed that they are protected from the direct action of the fire, and are not influenced by unequal expansion and contraction. It is, moreover, very compact, each unit offering sufficient heating surface for the evaporation of about two cubic feet of water per hour: whilst, like other boilers composed of units, it is well adapted for transport, and can be readily enlarged from time to time as a demand for increased power may arise. For ironworks, where the boilers are heated by the waste gases, it appears to us to be particularly suitable.

15. *On the Construction of Steam Boilers.*—"In noticing lately," says the 'Mechanics' Magazine,' "the report of Mr. Henry Hiller, the chief engineer to the National Boiler Insurance Company, we expressed our intention to notice further Mr. Hiller's remarks on the construction of boilers, and we now redeem our promise. A large number of the boilers proposed for insurance are so weak in construction, or otherwise so defective, that some general remarks, based on extensive experience of the construction and working of all kinds of steam boilers, will doubtless be found useful to many owners and makers. Of the numerous varieties, none are more generally used than the Lancashire, or cylindrical two-flued, and the Cornish one-flued boilers, and where these are well constructed, properly fitted up, and carefully attended, their performance is generally satisfactory. There are various modifications of these forms, some of which are valuable. In designing such boilers, excessive length as compared with the diameter should be avoided. Long boilers strain considerably, and frequently give great trouble by leakage at the riveted seams. A fair proportion is when the length is about three and a-half times the diameter. The staying of the end plates, and the attachment of the flue tubes to the ends, should be so arranged that the tube may expand freely, unless there be some special arrangement in the form of the flue tubes to attain the same object.

Many boilers, otherwise well made, have given considerable trouble by leakage and fracture, owing to the severe strains of unequal expansion, to which their rigid construction exposed them. In some of the boilers inspected, the ends were so heavily stayed, and so rigid, that considerable leakage, and occasionally fracture at the ring seams of the lower part resulted. In others, the staying was so slight, that the ends were bulged outwards. and serious risk of explosion thus occurred. Flue tubes should never be stayed to the shell, but be attached at the ends only. Many boilers have given serious trouble through being thus stayed. The shell should be made quite circular, and the longitudinal seams, which should break joint, be so arranged that, when the boiler is set, all those below the water line may be accessible for examination in the flues, and be clear of the brick seatings. Many makers now double-rivet these seams, thus materially increasing their strength, and when the work is well performed, reducing liability to leakage.

Flue tubes are now constructed in various ways, some makers preferring to use thick plates not strengthened in any way, whilst others prefer comparatively thin plates; but by flanging them at the ring seams, or by welding each ring of plates, and connecting them by solid T-iron hoops, form a much stronger and more reliable flue tube. The liability to leakage, fracture, and excessive expansion, is thus much reduced; as the heat is more freely transmitted through the thin plates. The cross tubes and water pockets introduced by some makers in that part of the flue tubes beyond the furnace bridge, are of great value, chiefly from the manner in which they improve the efficiency of the heating surface by the diversion and breaking-up of the current of the gases; whilst they much increase the strength of the tubes to resist collapse. All large tubes exposed to high pressure should be strengthened by some of the means described. Where the tubes are formed with the ordinary lap-joints, the longitudinal seams should break joint, as a tube thus made is much stronger than where those seams are in line, and at the furnace end all longitudinal seams should be below the fire-grate level.

The plan of forming tubes with the plates laid longitudinally in narrow strips is very objectionable, as the tube cannot be made so circular, and the seams above the bars are injured by the action of the fire; whilst such tubes are much weaker than those made in the ordinary manner. Multitubular boilers should, as far as practicable, be so constructed that every part of the interior may be accessible for cleaning and examination; and it would be a great improvement if those of portable and locomotive engines were so constructed that the tubes could be drawn without difficulty, so as to allow occasional inspection of the internal surface of the plates. External flues are necessary to stationary cylindrical boilers of this class; otherwise the lower seams are strained, and become leaky through excessive unequal expansion of the boiler. Plain cylindrical externally-fired boilers, with egg or saucer-shaped ends, are preferred by some owners, chiefly on account of their simple form. Such boilers can never work so safely as a properly constructed internally-fired boiler, as they are so liable to fracture at the seams over the furnace, through the excessive alternate expansion and contraction to which they are exposed. The application of stout longitudinal stays would add materially to the safety of such boilers.

A large number of cylindrical vertical boilers are used in various ironworks. These boilers are generally heated from the puddling or similar furnaces, the heat first entering the external flues, and passing thence by an internal descending flue-tube to the chimney. They are especially liable to starting and fracture of the riveted seams opposite the furnace necks, owing to the intense heat at that point; and where the feed water deposits much sediment the solid plate is sometimes fractured. To avoid this liability, the part referred to should be protected by a screen of brickwork, or the boiler set at a higher level, that brickwork may be so arranged as to spread the heat before it reaches the boiler. The bottoms of these boilers are frequently quite inaccessible for examination, and serious corrosion may go on unknown to those in charge. If the boilers were supported by brackets at the sides, or by wrought-iron plate standards riveted to the bottom, so that a thin wall of brickwork would suffice to form the flues, the condition of the plates could be occasionally ascertained without much difficulty.

As the safety of boilers depends so much on the sufficiency and condition of their fittings, a few remarks thereon will be useful. It is well to have two safety valves to each boiler as a check upon each other; one of them should be a deadweight valve, loaded externally, and the other a lever weight valve, or a compound valve, which would allow the steam to escape if the water were allowed to fall below the proper level. Safety valves are frequently met with the levers of which are of such length, that the usual working pressure for which the boiler was made, would be much exceeded if the weight were fixed at the end of the lever. The weight should always be calculated and adjusted to hang at the end of the lever.

All boilers should be provided with correct pressure gauges, for the guidance of the attendants. The glass gauge is undoubtedly the best and most reliable water gauge, and it is a good plan to attach two gauges to each boiler. Where floats are used, there should be two, one of them fitted with an alarm whistle. Boilers with internal tubes should always be fitted with glass gauges. Fusible plugs should be attached to the furnace crowns of all internally-fired boilers. The feed regulating valve, which may be constructed to act also as a back pressure valve, should always be placed at the front end of the boiler, within the reach of the attendant, and where boilers work in connection, each should have a back pressure valve attached. The feed water should be delivered (a few inches below the surface of the water in the boiler, and above the level of the tube crowns) in a horizontal direction, or by means of a horizontal perforated pipe. Where the feed is delivered near or at the bottom of the boiler, it cools and contracts the lower plates, whilst those of the upper part are heated and expanded by the steam, frequently (especially in boilers rigidly stayed) causing fracture at the ring seams at the lower part of the shell. It is always preferable to heat the feed water before it is forced into the boiler.

The blow-out tap at the bottom of the boiler should be so placed that it may be examined at any time, and so that any leakage thereat would be at once noted. Valves should never be used, double-gland taps made altogether of brass are far preferable. Stout seatings with planed joint faces suitable for each fitting should be riveted to the boiler. All manholes should be strengthened by a faced mouthpiece, riveted to the boiler, so that the joint may easily be well made, and leakage with corrosion be avoided. Steam domes are unnecessary on stationary boilers; a perforated pipe placed in the upper part of the steam space is quite as efficient to prevent priming, and the boiler is not weakened. Where domes are preferred, they should never be of large diameter, and the shell plates inside them should not be all cut away.

The setting of stationary boilers is too often entrusted to men quite ignorant of what is necessary for their safe and efficient working, and Mr. Hiller has frequently had to point out serious errors in plans prepared by engineers and others, whose mistakes probably arose from a want of practical experience of the working of boilers. When boilers are about to be set, special care should be taken to thoroughly drain the ground, that no dampness may exist in the flues to cause corrosion of the plates. All the flues should be quite large enough to allow a man to pass through, so that every part may be accessible for examination. Midfeather seatings are very objectionable, and no boiler should be so set except those of very small diameter, and in such cases thick but narrow iron plates should be placed on the top of the brickwork to protect the boiler. Cylindrical boilers, internally fired, should be set on side walls, the boiler resting on fire-clay blocks made for the purpose, and so shaped that when built in place the bottom of the side flues may be much lower than the point where the boiler rests on the blocks. If the blocks be properly fitted to the plates, that the bearing thereon may be equalized, the total breadth of both side walls, where in contact with the plates, need not exceed one inch for each foot of diameter of the boiler. The top of the side flues should be level with the crown of the flue tubes.

All boilers should be roofed over to protect them from external moisture, otherwise the sides in contact with the flue brickwork will be weakened by corrosion. Where flues are properly arranged as described, no serious corrosion could exist in the seatings, which could not be detected on a careful examination by a trained inspector. The laws for the prevention of smoke are now being enforced in many districts, but boiler owners should be cautioned against too readily adopting any form of apparatus which may be pressed upon their notice, as many are unnecessarily complicated and expensive.

It frequently happens that good boilers are injured, and serious risk is incurred, through neglect and carelessness. Where the feed water contains much sediment, and no cleaning apparatus is in use, frequent internal cleaning is indispensable, or the plates may become overheated and injured whilst the efficiency of the boiler is reduced. The external flues are in many cases allowed to become almost choked before being cleaned, and the boiler plates so thickly coated with soot, that a wasteful consumption of fuel is the result. Some firms, on the other hand, clean their boilers thoroughly about once a-month, and are thereby considerable gainers, as the efficiency of the heating surface is retained, whilst any defects are at once discovered and made good, which, if neglected, might entail expensive repairs, or even lead to serious disaster. When boilers are being re-started after stoppage, they should be heated very gradually, so as to avoid as much as practicable the severe strains of unequal expansion, and when at work the feed supply and the firing should be as steady and regular as possible. Frequent and extreme alternations of pressure, especially with high pressure boilers, or irregularity of any kind, is most objectionable, and sometimes really dangerous.

Steam users are strongly cautioned against the purchase of second-hand boilers. Many instances have come under notice where such boilers have required very extensive alterations and repairs, costing nearly as much as new ones, to which they were, after all, much inferior. Where it is proposed to purchase old boilers, a thorough inspection should be made by some person of special experience in such matters, whose report would be a reliable guide to the purchaser. In constructing new boilers the very best materials and workmanship should be employed. Low priced boilers made with inferior material and workmanship are unreliable, and as a defective boiler must be a source of annoyance or danger, and the consequences of explosion are frequently so terrible, it is evident that in no case is special care more necessary than in the construction and fitting-up of boilers."

16. *Boiler Cooling Surface.*—From 'Engineering' of Oct. 9th, 1868, we take the following able article:—"It would be difficult to find a much better example of the 'penny-wise-pound-foolish' system of economy than is presented by an unlagged steam boiler. Yet such boilers are, unfortunately, by no means difficult to meet with; on the contrary, there are many situations where unprotected boilers are the rule rather than the exception. Thus it is but seldom that we see any cleading on the

boiler of a steam crane, on the fire-box of a portable engine, or on the upright boilers of those semi-portable engines of which such vast numbers are now in use for various purposes. Yet the boilers we have just mentioned are those which, of all others, most urgently require efficient protection, as they are, in the majority of instances, exposed to the cooling influences of rain, wind, &c., from which ordinary factory boilers are protected. The fact of such a state of things continuing can only be ascribed to the ignorance of those employing these unlagged boilers. We have frequently asked makers of portable engines why they do not protect their boilers properly, and in almost every case the reply has been, 'Because purchasers will not pay the extra cost.' We think that if these objecting purchasers knew how much they were paying for the privilege of having their boilers exposed to the weather, they would feel inclined to extend their outlay in the first instance.

Experiments made by Messrs. Perkins have proved that in the case of pipes filled with steam at 100 lb. per square inch, 100 square feet of surface exposed to the atmosphere are, under ordinary circumstances, sufficient to condense per hour the steam produced by the evaporation of a cubic foot of water. When the pipes were filled with steam at atmospheric pressure, the surface required to condense an equal weight of steam was about 150 square ft., the difference being partly due to the steam at atmospheric pressure containing a greater amount of latent heat, and partly to there being a less difference in the temperatures within and without the pipes. In the above experiment the pipes were under cover; but in the case of boilers freely exposed to the external air, there is strong evidence that, even in fine weather, the refrigerating effect of a given area of exposed surface is much greater. Even assuming, however, that in the case of boilers worked at ordinary pressures, 100 square ft. of exposed surface are sufficient to condense per hour the steam produced by the evaporation of a cubic foot of water, we shall have ample evidence of the necessity for protecting boilers by efficient cleading. Let us take, for example, a vertical boiler 3 ft. 3 in. in diameter and 8 ft. high—very ordinary dimensions—and let us suppose, as is but too often the case, that it is unprotected by lagging of any kind. In this instance the surfaces from which the loss of heat will take place are those of the sides and crown, and the area of the cooling surface, as we may term it, will be about 90 square ft. This area of surface would, according to the above estimate, be sufficient to condense per hour nine-tenths of the steam produced by the evaporation of a cubic foot of water, or an amount which, if supplied to an engine of moderately good construction, would generate quite 2-horse power. Following out the calculation, it will be seen that in a working day of twelve hours this surface will condense about 675 lb. of steam—an amount which it will, under ordinary circumstances, require about three fourths of a hundredweight of coal to generate. Supposing the boiler to work on an average twelve hours per day, it will require a weekly consumption of 4½ cwt. of coal merely to make up the loss due to the exposed surfaces; and taking the cost of coal at 12s. per ton, this will involve an expenditure of about £7 annually to replace losses which, about the same sum expended in proper cleading, would serve to prevent altogether. In all probability, also, this is a very low estimate of the monetary loss involved by such an area of exposed surface.

In the above calculations we have assumed 100 square ft. of exposed surface to be required to condense 62½ lb. of steam per hour; but, as we have already said, there is every reason to believe that in boilers freely exposed to the atmosphere the power of the cooling surface is very much greater than this. The experiments recently made by Messrs. Fox, Head, & Co. of Middlesborough, bear strongly on the matter under consideration. In this instance the boiler experimented upon, which was 4 ft. in diameter by 22 ft. high, was heated by the waste gases from a puddling furnace, these gases being led up through a central flue 2 feet in diameter, crossed by seven 5-inch water tubes. Two series of experiments were made, one with the boiler unprotected, and the other coated with Jones's boiler covering composition, each series lasting a week. As the same amount of fuel was burnt, and the same quantity of iron made during the two series of experiments, it is only fair to suppose that the boiler received the same amount of heat in the two cases; but the results showed that with the boiler protected the average evaporation per hour exceeded that obtained with the boiler unprotected by 5·6 cubic ft. The cooling surface exposed by the boiler was about 280 square ft., and assuming the above results to be correct—and there is every reason to believe that they were carefully ascertained—each 50 square ft. of this surface must have parted per hour with as much heat as would suffice to convert a cubic foot of water into steam at 50 lb. pressure, the pressure at which the boiler was worked. The refrigerating power of the exposed surface was thus twice as great as that deduced from Messrs. Perkins's experiments; but we consider that this difference is fully accounted for by the fact that the boiler at Messrs. Fox, Head, & Co.'s, was unprotected by a roof, was freely exposed to the air, and was worked night and day, the refrigerating effect during the night being probably, owing to the dew, &c., considerably in excess of that which obtains during the day. At the same time it should be stated that the experiments were conducted during fine weather; if the weather had been wet and cold the results would undoubtedly have been even more in favour of the protected boiler.

We have, we think, said sufficient to prove that it is but very false economy to begrudge the outlay necessary to protect a boiler by thoroughly efficient cleading; but before leaving the subject, there is another point connected with it on which we should say a few words. The point we refer to is the diminution in the evaporative power of a boiler caused by its external surface being unprotected. The exposed surface of a boiler, or, as we may term it, its cooling surface, in no way differs from its heating surface; it is subject to the same laws, and, under similar circumstances, would produce similar effects. That a square foot of cooling surface withdraws from the contents of the boiler a less amount of heat than is imparted to them by an equal area of heating surface is merely due to there being a less difference between the temperature of the atmosphere and that of the contents of the boiler, than there is between the latter and temperature of the gases in the flues. Other circumstances being equal, the transmitting power of any given area of boiler surface varies directly as the difference in the temperature on the two sides of it, any increase in this difference enabling the surface to transmit a proportionately increased amount of heat in a given time. In the case of both heating and cooling surfaces the outer surfaces of the plates are in contact with air or gases, whilst the inner surfaces are in the former case wholly in contact with water, and in the latter partly in contact with water and partly with steam. This latter fact tends rather to increase the comparative efficiency of the cooling surface, as the circulation of the steam is more perfect than that of the water, and the parts in contact with it are at all times exposed to the maximum temperature within the boiler. Any advantage due to this cause may, however, be disregarded here, and we may consider that the transmitting power of any given area of cooling surface bears the same proportion to that of the same area of heating surface, that the difference between the temperature of the steam within the boiler and that of the external atmosphere does to the difference between the temperatures of the steam and of the gases in the boiler flues. The next point is to ascertain the proportion which these differences bear to each other. In the classes of boilers in ordinary use 10 square feet of heating surface is a very fair allowance for evaporating a cubic foot of water per hour, and thus, if we take the results of Messrs. Fox, Head, & Co.'s experiments, it will be seen that a square foot of ordinary heating surface has about one-fifth the heat-transmitting power of a square foot of freely exposed cooling surface; or supposing that in any given boiler the areas of heating and cooling surface are equal; the effect of the latter, if freely exposed, would be to reduce the evaporative efficiency of the boiler twenty per cent.

In the case of Messrs. Fox, Head, & Co.'s boiler, the heating surface, consisting, as we have stated, of a 2 ft. flue, with seven transverse 5 in. water-tubes, amounted to 156½ square feet; and as, when the boiler was protected, 20·4 cubic feet of water were, on an average, evaporated per hour, there was a cubic foot evaporated per hour for each 7·67 square feet of heating surface. The efficiency of equal areas of heating and cooling surface were in this boiler therefore inversely as 7·67 to 50; and it is only fair to suppose that the differences between the temperature on the two sides of the heating and cooling surfaces respectively were in the same ratio. The pressure of the steam in the boiler being 50 lb., its temperature would be 307¼°, and we may assume that, on an average, the difference between the temperature and that of the atmosphere would be about 245°, and on this assumption the average temperature in the flue would be about

$(245 \times 50 \div 7 \cdot 69) + 307\frac{1}{2} = 1904\frac{1}{2}$. Had this boiler had equal areas of heating and cooling surface, the loss of heat produced by the latter would have amounted to $\frac{7 \cdot 67}{50}$ of the whole, or 14·34 per cent.; but the area of the cooling surface being larger than that of the heating surface in the proportion of 280 to 156½, the actual loss amounted, as we have seen, to $\frac{5 \cdot 6}{20 \cdot 4}$ or about 27½ per cent. Those who object, on the score of expense, to protect their steam boiler, should bear this fact in mind.

All that we have said concerning the necessity of protecting the surfaces of steam boilers applies with equal force to steam pipes, or any other channels through which hot liquids or gases have to be conveyed with as little loss of heat as possible; and we feel convinced that there are but few situations where the application to such pipes of a thoroughly efficient protection would not be found to pay. In conclusion, we should remark that the source of economy we have indicated is but seldom neglected by our first-class engineering firms, and our only object in adducing the above facts is to induce others to follow their example."

BOILER APPLIANCES.

17. *The most Recent Improvements on the Injector.*—In the volume of 'Engineering Facts and Figures for 1865' we gave a description and illustration of Giffard's Injector. The following is a paper under the above title, read before the Society of Engineers, W. H. L. Feuvre, Esq., in the chair, by Mr. James Gresham:—"The growing importance and increased application of the injector render it unnecessary to apologize for reintroducing the subject before this Society. The complete and admirable paper of Mr. Lewis Olrick, read at a meeting here some two years ago, pointed out with clearness and force the action of the apparatus, and gave a succinct account of the modus operandi of the instrument. The value of Mr. Olrick's paper was considerably enhanced by a series of elaborate and precise mathematical formulæ. The treatment of the injector in this paper will be from an eminently practical point of view, and such knowledge and information as the writer has gained from long and active experience

in working the injector, as well as a thorough knowledge of the experiments that have, from time to time, been found necessary for its further improvement, will now be laid before this Society, and the writer may be considered fortunate if, after a description of, and reference to, the models and drawings, he shall have removed a little of the prejudice which is inseparable from a new invention. Since the introduction of the injector into England, it has been the object of those interested in its success to obviate and overcome, step by step, the difficulties that were originally found attendant upon its working, by watching its performance over thousands of miles of railway, under every variety of circumstance, and by careful observance of its working, and numerous experiments on stationary as well as locomotive boilers, many improvements have been made, resulting in its present advanced state. The great objection raised by a driver to the use of the injector, when first applied to his engine, after his long use of the pumps, is the number of handles he has to manipulate at starting the injector, all of which must be open and closed in their proper order to secure the efficient working of the instrument; and though the increased labour may at first seem but a trivial objection, those experienced upon the 'foot-plate' will admit that it is a valid one, remembering the number of claims already on the driver's attention, which, by the original form of Giffard's injector, is increased by at least four necessary and distinct operations to be performed, as well as a no less important caution to be noted, as will be seen from the 'method of working' issued by the makers.

The method of working, as taken from the printed instructions, is as follows:—First, turn the wheel or handle to the position suited to the steam pressure in the boiler, the higher the pressure of steam requiring the greater opening. Second, open the cock on the steam pipe. Third, turn slightly the wheel or handle, which will admit a small quantity of steam to the apparatus, until water is seen to issue from the overflow pipe. Fourth, as soon as this happens, continue to turn upwards the wheel or handle until the overflow ceases, and thus give full liberty to the steam to act upon the water, and drive it into the boiler through the delivery pipe. If, however, after having turned the wheel or handle to the extent of its range, the overflow still continues, it should be stopped by reducing the quantity of water by the wheel or handle. The injector is working properly when there is no discharge from the overflow pipe, and no more steam is admitted than is absolutely necessary to prevent that discharge. N.B.—The jamming down of the wheel or handles should be avoided. The instrument is purposely neither made steam nor water tight, and when stopped the steam and water must both be shut off by the cocks.

This is certainly formidable, and one of the objects sought by the improvement about to be described is to remove the greater part of this manipulation at starting, while at the same time securing a more efficient and durable instrument, with nothing in the constructive detail that can fail, except through actual wear or tear. It has been found that more failures in the working of the injector have been traced to the burning or wearing away of the packing than to all other sources combined; and in the late improvements it has been determined to remove all the internal packing that cannot be reached from the outside. The adjusting of the injector to the various steam pressures has been reduced to one operation, or rather the adjusting of the exact proportion of water to steam for the various pressures, hitherto accomplished by two separate and distinct handles, has been arranged to be accomplished by one handle alone.

Fig. 1 in our engraving (not given here) shows an injector as constructed by the original inventor, M. Giffard, with a separate adjustment for both water and steam, to which applies the instructions for working previously quoted. It will be apparent that some considerable experience, only to be obtained by practice in the working of the injector, must be needed before an ordinary fireman would be able to turn the handle to the position suited to the steam pressure in the boiler, seeing that no further instructions can be given than 'the higher the pressure of steam requiring the greater opening.' It has been attempted to index these injectors for the various pressures, but without success, as the position of the water regulator not only varies for every different steam pressure, but also varies considerably for the same pressure, owing to the change of temperature of the water supply, and the height it may have to be lifted. It is to be attributed entirely to the amount of manipulation and attention required to adjust the injector to work properly at the different steam pressures, that on boilers with irregular work to perform, and having only small steam and water space, as compared with the heating surface, we see the injector constantly losing hot water at the overflow pipe, or, as some drivers call it, 'working sick.' This frequently occurs, and is a great objection as well as loss. Another disadvantage in the original form of injectors is the 'whipcord' packing on the ram.

The objections to this internal packing are fatal, especially when an injector has to lift its supply-water from a considerable depth; for it will be seen, on reference to the drawing, that it is by the fit of the ram in the body of the apparatus, and this packing alone, that the steam is prevented passing direct from the steam-pipe to the water-chamber, where the vacuum is formed to lift the supply-water for starting the injector; and it will be apparent that unless this packing is perfectly steam-tight, no such vacuum can be created. The frequent failures of this injector, when used for stationary boilers, where the supply water has been considerably below the level of the boiler-house, has long ago led to its abandonment, and the adoption of another form of injector, with a fixed partition between the steam and water cones, designed by the writer and Mr. Robinson. The original injector also fails upon locomotives from the same cause producing a different effect—that is, when the packing on the ram gets worn, which is soon the case if the driver only adjusts his injector as often as he should do. The steam passes direct into the water-chamber, and mixes with the supply-water before it enters the combining cone; and supposing the water in the tender to have been heated some 130 deg., say, whilst waiting at the station, the steam leaking past the packing on the ram will soon raise the temperature of the water enough to make the injector uncertain in its working, or stop altogether. Many drivers, finding out this, have given up adjusting their injectors, to save the trouble of frequent packing, and let the ram get fast in its place, preferring the lesser evil, viz., the occasional loss of hot water at the overflow pipe, from non-adjustment to the various pressures, rather than have the uncertainty of the injector working at all when the packing becomes inefficient.

The dispensing with packing is accomplished after this manmer:—In attaching the injector to the boiler, care is taken to have the steam-pipe sufficiently long; that it shall have the requisite elasticity to admit of its moving at the end attached to the injector—say in the case of a locomotive 1½in.; this requires the pipe only to move ¾in. up and down from a straight line—and those conversant with the bending of brass and copper pipes, will know that pipes of any considerable length are seldom bent nearer than ¾in. to their required positions when fixed, and that their elasticity readily admits of bringing them home to the desired place. Advantage has been taken of this to attach the steam-pipe direct upon the moving ram itself, placing it beyond all possibility for the steam to pass into the injector at any but the right point. Experience has proved that the steam-pipes for injectors at present in use on locomotive and other engines, are considerably larger in diameter than is requisite for the efficient working of the apparatus; and several large firms and railway companies are now fitting their injectors with steam pipes in the proportion of ⅛in. to the millimetre, equal to a 1in. pipe for a No. 8 injector; in fact, some No. 8 injectors are working at the present time with ¾in. steam pipes, or about 1-5th the area given by M. Giffard. This may seem strange at first, but we may be helped to believe it when a locomotive engine on one of the principal lines can be pointed out in which all the steam for the cylinders was made to pass through a 1in. pipe about 1-20th of the usual area. When the steam pipe is of necessity very short, a coil is made in it, after the manner of Allen's patent tender-pipe coupling. Another improvement claimed for this injector is the impossibility of steam blowing through it when not at work—a circumstance which happens under the original form of injector at nearly every station where a locomotive engine stands any length of time. This blowing of steam is prevented by a conical valve on the steam spindle shutting down firmly on its seating at the base of the steam cone, and by the removal of the packing from the ram.

Figs. 3 and 4 (not given), show two different methods of reducing the adjustment of the injector to the various conditions under which it may have to start working to one single operation. Fig. 3 represents an injector with the water supply self-regulating, the invention of Mr. William Sellers of Philadelphia, U.S., and is certainly the most elegant improvement that has been made upon the injector since it left the hands of the original inventor. The arrangements to enable this apparatus to dispense with internal packing, and to be started by means of one operation, are the invention of the writer. One handle regulates the steam supply, any increase or decrease of which will cause a corresponding increase or decrease in the water delivery. This self-regulation of the water supply is obtained by the alternate action of a pressure or vacuum, as the case may be, upon a piston attached to the water or combining cone, and working in a cylinder formed by the body of the injector.

In starting the injector—supposing it to be in communication with both steam and water—it simply requires the (steam regulating) spindle opening, say, a quarter turn, until water is seen to issue through the waste valve, then to continue opening up the spindle until this valve closes, which will take place immediately the relative proportion between the water and steam has been established. This regulation is obtained by the rising or falling of a piston, thus increasing or diminishing the annular space between the steam cone and the water or combining cone. Supposing more water is admitted between the annular space than is requisite for the proper formation of the jet, part of the surplus escapes through a hole into an air-tight chamber, and raises the piston, reducing the quantity of water admitted until it is in the right proportion to the volume of steam. The piston will then remain stationary until some change takes place in the pressure of the steam, or pressure of the supply-water. If the pressure of the steam diminishes, more water will be driven into the air-tight chamber, and the piston will continue to rise so long as the pressure of the steam continues to diminish; if, on the contrary, the steam pressure increases, it will require more water to condense it, and the increased velocity of the jet will carry along with it a portion of the water from the air-tight chamber, creating a vacuum therein; then the pressure of the atmosphere on the water in the supply tank will cause the piston to fall, and admit more water around the steam cone, until the exact proportion of steam and water be again established. The action of this injector is shown very clearly by the sectional model.

It will be seen that the lower end of the steam spindle is made hollow This arrangement enables the injector to lift its supply water with certainty from depths below that at which it is convenient to place the apparatus itself. By giving the steam spindle a quarter turn, it elevates a conical valve a short distance from its seat, and the steam is allowed to pass down the centre of the spindle in the requisite volume, and at a high velocity, carrying along with it the air existing in the water chamber and cones, passing out into the atmosphere at the waste valve, creating a much greater vacuum than can be produced by allowing the steam to pass round the end of the spindle, as is the case when the injector commenced to work. There may be a slight disadvantage in using the self-adjuster where the temperature of the supply-water is high, owing to there being no overflow pipe to allow of any surplus water escaping after the jet has been established. This is felt when the supply water has reached a temperature at which it requires more water to condense the steam than can be carried along with the jet into the boiler. Under these circumstances the injector would be difficult to start, and when started liable to stop, owing to the surplus water finding its way into the air-tight chamber, thereby forcing up the piston and shutting off the supply-water altogether. This drawback is overcome by one of the modifications about to be described."

Mr. Gresham illustrated his paper further by a drawing showing an injector in which the relative proportions of water and steam are regulated, or adjusted, by means of one and the same handle. The double adjustment is accomplished by means of two screws of different pitch upon the steam spindle, one screw working in a fixed nut, and the other working in a movable nut cut upon the sliding ram, thus producing a differential motion, causing the spindle to rise, and the steam cone to fall. The manipulation in starting this injector to work is exactly the same as for starting the "self-adjuster," previously described, viz.: Open the steam spindle one quarter of a turn, wait until water is seen to flow from the waste valve, then continue to open the steam spindle until this valve closes, which will take place immediately the relative proportions of water to steam have been established. Its action may be thus described:—By giving the spindle the requisite part of a turn, the supply is lifted in precisely the same manner as by the self-adjuster; then by continuing to turn up the steam spindle, the free volume of steam for working the injector is allowed to pass. At the moment this occurs there will be more supply of water than is required for condensing the steam, the surplus passing out at the water valve, but the continued upward movement of the spindle causes the steam cone to approach the water cone, reducing the supply water to the extent required to condense the steam. This point is indicated by the instant closing of the waste valve, showing that the jet is established, and passing into the boiler through the foot-valve, it being impossible for the waste valve to close until the foot-valve is opened by the passing of the jet into the boiler; therefore it will be seen that these two valves are combined, the action of the one being dependent upon the action of the other.

When the injector is stopped working the positive action of the foot-valve is secured, by making it act like a piston as well as a valve. This is accomplished by causing it to lift some distance from its seat before there is space for the fluid to pass; then in closing to shut off the passage for the fluid some distance before reaching its seat, the action changing into that of a piston in a cylinder. By this means the requisite amount of power is obtained for lifting the waste valve from its seat, and thereby giving the required opening to the atmosphere for again starting the injector. The area of the waste valve must not be more than 1·4 times the receiving cone, otherwise the pressure exerted by the injector would be reduced to such an extent that it would not be able to open the foot valve into the boiler. The advantages claimed for this injector over that of the "self-adjuster" are due to its being able to work with an open overflow or waste pipe. This empowers it to take its supply water some considerable number of degrees hotter than can be taken by the "self-adjuster." Another advantage of the open overflow is the peculiar singing noise made by the jet passing through the atmosphere, telling by the sound when the apparatus is working properly. Many drivers look upon this as a great desideratum. The open overflow arrangement is shown by the sectional model. The conical valve on the steam spindle is considered a better way for shutting off the steam than allowing the spindle to fit in the apex of the steam cone, and might be applied advantageously to every form of injector, preventing the possibility of bursting the cones by jamming down the spindle. The injectors shown in figs. 3 and 4 give an increased delivery in gallons per hour of 35 to 40 per cent. over Giffard's original calculations. This is owing undoubtedly to the improved proportions and the entire exclusion of the atmosphere attained by the use of the self-acting valve. (Abridged from the 'Mechanics' Magazine,' January 23d, 1868, where the paper is fully illustrated).

18. On the same subject we take the two following papers from the 'Scientific American:'—(a.) *The Principle of the Giffard Injector.*—"Probably there is no mechanical device in common use which is such a puzzle to mechanics and others as the Giffard injector. Its operation seems to defy the best known laws of the equilibrium of fluids, yet it acts effectually, and under some circumstances is preferable to the pump for feeding boilers with water.

Its construction is simply a pipe fed from the steam space of the boiler to the water space, below the water level. The steam-leading pipe is contracted at its lower extremity, between the steam and water level, in a space which is filled with the feed water, a fine jet of steam acting against the feed water and forcing it into the reception pipe through a small aperture. Of course, necessary valves and cocks are employed.

A correspondent asks, what is the principle employed in the action of this injector? We cannot state it more clearly, so far as it is understood, than to give the opinion of Mr. John Robinson, of Manchester, Eng. He says: 'The pressure on all parts of the interior of steam boilers being equal, some reason must be sought why steam taken from one part is able to overcome the resistance opposed to its entrance in another part of the same boiler. If a pipe conveying steam were turned directly back into the water of the same boiler, it is evident that equilibrium would ensue and no effect be produced. If, on the other hand, a break were made in the continuity of the pipe, so as to leave an interval open to the atmosphere, steam would rush from one pipe and water from the other in the boiler with a velocity proportioned to their different densities. In constructing the injector, the feed water chamber is placed at the break in the pipe, and this arrangement accounts for the power of the steam to overcome the resistance to its entrance into the receiving pipe of the boiler. The jet of steam, being concentrated on the water, forces its way through the interval surrounded by feed water, by contact with which it is gradually condensed, and reduced in volume and velocity, until it is entirely converted into water at the throat. In doing so, it imparts to the feed water a velocity proportioned to the pressure in the boiler and its own temperature; and, the water being non-elastic, it acquires sufficient momentum to overcome the resistance in the water space of the boiler.'

In short, the action of the injector is simply mechanical. The same principle has been lately applied—somewhat modified—in attempts to use liquid petroleum as fuel for steam boilers. But, whatever may be the advantages of the injector under some circumstances, it is not always economical. It is a great convenience on locomotive and other engines where the boiler cannot be fed by ordinary devices except when the machinery is in motion, and it is inconvenient or impossible to have a "donkey" engine. The injector cannot work as hot water as the pump, and the feeding must be very gradual, as the apertures of the pipes are very small."

(*b.*) *The Giffard Injector.*—" Messrs. Editors.—In your paper of the 2d of May you intimate that the principle of the Giffard Injector is not well understood, and present your readers with an explanation, given by Mr. John Robinson, of Manchester, Eng., as the best elucidation of the puzzle. I am of the opinion that Mr. Robinson himself does not show a very clear perception of the thing. At any rate, he fails to make it plain to any ordinary comprehension. With your permission, I will endeavour to do so myself.

The operation of the Giffard Injector is dependent on the laws both of pneumatics and hydrodynamics, and its secret lies in the fact that under any given pressure aeriform bodies are propelled with a very much greater velocity than liquids. Thus, if we would communicate to water a velocity far above anything that could be accomplished by hydraulic machinery, let us first convert it into steam, then set it in motion and suddenly reconvert it into water by condensation; the water will retain the velocity of the steam.

To illustrate by example. We have a steam boiler in operation, under 90 lbs. pressure. If we run a pipe from the steam chamber into the boiler, under or above the water level, equilibrium will exist. But if we open the pipe into the air, steam will flow in a jet. I have no means at hand to ascertain the velocity of a jet of steam under 90 lbs. pressure—about six atmospheres—but a table before me gives the velocity under one atmosphere at 650 ft., increasing in a constantly diminishing ratio to 1,600 ft. under 20 atmospheres. Perhaps under 90 lbs. a velocity of 1,000 ft. would be a fair estimate. At any rate I will assume it for the purpose of this illustration.

Suppose now that the steampipe is of just such length and calibre as to contain, under 90 lbs. pressure, the product, in steam, of one cubic inch of water. Remember it is moving 1,000 ft. per second. Suppose again, that it is suddenly and perfectly condensed, and we have a cubic inch of water flowing with a velocity of 1,000 ft. per second. Now if we open an orifice in the boiler below the water level, a jet of water will be projected from it with a velocity of about 114 ft., which is due to a pressure of 90 lbs. If, again, by means of outside machinery, we throw a jet of water of the same diameter with the orifice, and directed at it, with a velocity of 114 ft., there will evidently be equilibrium; because, as pressure and velocity are convertible into each other, the force of the jet will exactly counterpoise the jet seeking to flow from the orifice, and no water will pass into or out of the boiler. But if the jet, by additional pressure, attain a velocity of 115 ft., then the equilibrium is destroyed, and water will pass into the boiler through the orifice.

To recur now to the cubic inch of water in the steampipe, with its velocity of 1,000 ft. per second. How much more easily and rapidly will it penetrate, where even a velocity of 115 ft. is sufficient to overcome the resistance. And suppose, now, that it comes in contact with another cubic inch of water in a state of rest. It will part with half its velocity to the latter, and both commingled, will move on at the rate of 500 ft. Let these two come in contact with other two at rest, and again, the weight being doubled and the velocity halved, they will move 250 ft. per second. Still again, let these four strike four others in a state of rest, and we shall have eight cubic inches moving with a velocity of 125 ft. per second, which, as we have seen, is sufficient to effect an easy and rapid penetration into the boiler. Of these eight, one is the cubic inch that was condensed out of the steam in the pipe, and here we behold it commingling with and carrying along seven others, by which, in fact, it was condensed, with a velocity much greater than that of a jet projected from below the water level of the boiler under the existing hydraulic pressure of 90 lbs.

I have taken for illustration a given amount of steam and water. In fact, however, there is a constant flow of steam, a constant condensation by an uninterrupted stream of water, and an unbroken jet into the boiler.

It may be asked, if the steam jet itself were directed at an orifice in the boiler would it penetrate? It would not. It must be remembered that force is a product of weight and velocity, and here the weight of steam being so insignificant—it requiring 1,700 cubic inches under the pressure of one atmosphere to weigh as much as one cubic inch of water—the force would be insufficient to penetrate. But it is a very different thing when water moves with so great a velocity.

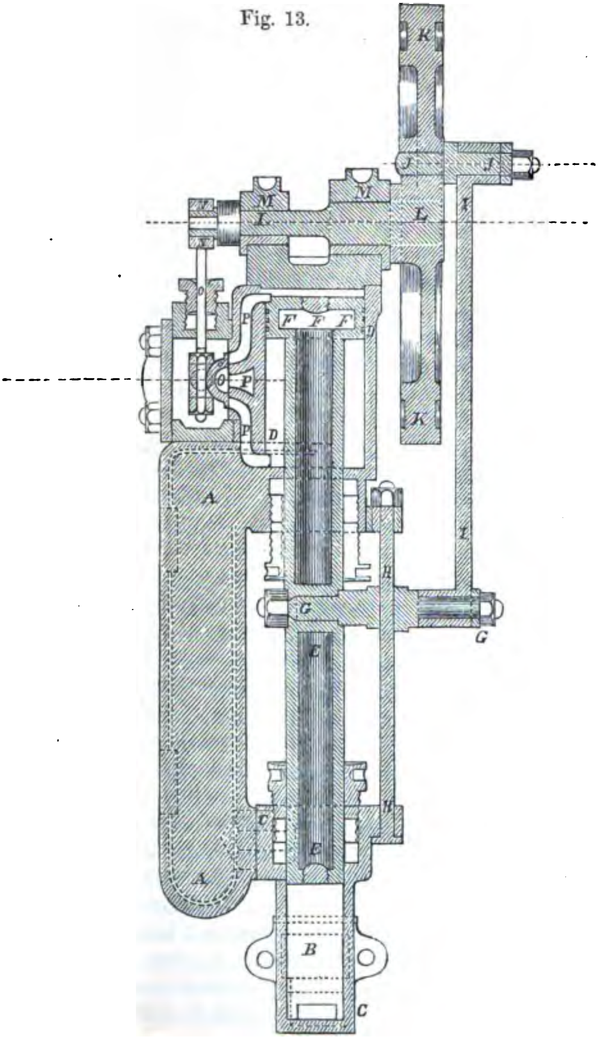
The principle of the Giffard Injector is applicable to other purposes than feeding boilers. It makes a good pump for shallow reservoirs. It would make a very powerful fire engine. It could be used to drive light machinery, by throwing its jet into a turbine wheel running at a high speed. I have used it to propel a toy boat—not very satisfactorily, however—having a small copper boiler heated by a spirit lamp, and throwing its jet back under the stern.

Nothing has been said, in this discussion, of the construction of the apparatus, nor was it necessary, as I presume that is familiar to all engineers. I have aimed only to develop the principle. It is a very beautiful invention.

Tuscaloosa, Ala. H. S. WHITFIELD."

19. *Wilson's Donkey Pump as exhibited at Havre.*—Messrs. Alexander Wilson & Co. of Vauxhall Iron Works, Wandsworth Road, London, exhibited several forms of donkey steam pumps for supplying boilers and pumping water. Messrs. Wilson have introduced some improvements in the arrangement of these pumps, which are on Brown's patent. The connecting-rod in Brown's pump was bent; this arrangement had a tendency to throw an indirect strain upon the rod and the crank-pin in the

Fig. 13.



face of the fly-wheel. Messrs. Wilson obviate this, and secure other advantages by their very simple—and valuable because simple—arrangement. To the pump-ram a stud is cast, projecting at right angles from it, and working in a vertical guide. The stud is brought sufficiently forward to admit of the lower end of the connecting-rod to be jointed to it, in a line with the crank-pin on the fly-wheel above, thus securing a direct line of action. By simply bringing the fly-wheel shaft, and the eccentric-cam which works the steam valve, outside the steam crank or casing, every facility for oiling is obtained. We give in fig. 13 a section of this pump, in which A A is the framing, which carries at its lower end the pump barrel B C C, and at its upper end the steam cylinder D D. The pump-plunger E E is continued upwards, and carries the piston F F; and at its centre a stud G G, the parallelism of the plunger being kept by the vertical guide H H. The outside end of the stud G carries a connecting-rod I I, jointed at its upper end to a face-pin J in the fly-wheel K K. The fly-wheel spindle or shaft L L is carried by two pedestals M M at the top of the framing. N is the eccentric fixed outside clear of the frame, and O O is the slide-valve for distributing the steam to the cylinder D by the ports P P.

20. *On the Generation of Steam.*—We take from the 'Engineer,' of date April 17th, 1868, the following excellent paper on this important subject. "It is not a little remarkable that small attention has been paid by engineers until within a comparatively recent period to the mode in which heat is applied in the generation of steam. The crude idea first carried out in practice was to place the fire under the boiler; and it evidently took its rise from the belief that heat possesses some inherent principle of ascension, and therefore tends more forcibly to pass through plates and enter water placed above a furnace than those located on either side. It is now perfectly well understood that no such principle of ascension has any existence, heat being freely radiated in all directions from incandescent fuel, upwards, downwards, or to either side alike. We place our pots and kettles *on* the fires, and in some cases our boilers over them, because the products of combustion being highly heated and rarified, tend to rise. But if we can suppose that no atmosphere existed, or that the products

of combustion were heavier than air, then it would be better to place a boiler under a fire than over it, did not the behaviour of the water within render such a system inadmissible. It is true that we cannot deprive the gases flowing from a furnace of their tendency to rise; but it does not of necessity follow that heating surface can be best disposed in the top of a flue, or the bottom of a boiler. Indeed, it may be shown that existing arrangements in which top surface is regarded as everything, and is made to play the most important part, are by no means the best or the most conducive to economy which can be adopted.

Gases conduct heat very slowly through their own substance, if we may be allowed the phrase. If a column of heated gas could be sent through the flue of a Cornish boiler without inducing any internal motion of its particles, so that the same particles would be in contact at the end as were in contact at the beginning, the waste of heat up the chimney would be enormous, and very little steam would be generated. If we suppose the column to be made up of a series of superimposed rings, each 1 in. thick, the outer ring might be cooled down to the heat of the plates, and it would then interpose as so much lagging to prevent any more heat passing to the water from the rings within. In practice, of course, internal motion goes on continually in the column of heated gases, and therefore fresh particles are brought against the iron. But it does not appear that in any large flue the change of place is sufficiently rapid, or the internal motion of the gaseous particles sufficiently energetic to permit all the heat to be absorbed by the boiler plates and water unless the flue is very long. In tubular boilers the diameter of the flues is usually very small, yet even in them heat is so slowly transmitted from one particle of gas to another that much heat escapes which, under better arrangements, need not escape. This passive reluctance to yield up heat displayed by the gases finds no parallel in the case of steam. In surface condensers, for example, steam resigns its heat so rapidly that the vacuum does not alter at each stroke; and 1 foot of surface in the condenser is as effective in converting steam into water as 4 ft. or 5 ft. of boiler surface are in converting water into steam, although the difference in the temperature at opposite sides of the metal of the tubes is greatly less than the difference which exists in the case of the flue and gases. If steam did not give up heat quicker than the products of combustion do, the surface condenser would be an impossibility.

Seeing, then, that the reason why gas yields heat slowly is simply that it is a non-conductor, the course of the boiler engineer is clear. As the particles of gas cannot give up their heat unless they are brought in contact with the metal, he must take care that every portion of the products of combustion shall touch the iron of the flues. This can only be effected by breaking up the escaping stream of gas, and throwing it into eddies and whirls by obstacles placed in its way. In theory this can best be done by causing the flame and smoke to ascend through a box filled with small horizontal tubes containing the water to be heated. Such boilers have been tried but have not answered well, because the circulation of the water cannot be maintained properly within very small horizontal tubes. This class of generator has generally proved economical in fuel, but liable to rapid deterioration by use, and an inveterate primer. Vertical water tubes, as in Martin's boiler, answer far better, provided proper precautions are taken to free water circulation within them. Unless much skill is manifested by the designer, however, it is difficult to prevent the gases from rising towards the upper ends of the water-tubes, which are usually filled with foam not well calculated to absorb heat. The only way to prevent this appears to consist in contracting the area of exit, so as to compel the gases to fill all the depth of the flue or tube-box. It cannot be said, however, that this expedient is quite satisfactory, and it is certain that a thoroughly good boiler with vertical water-tubes transverse to the direction of the current has yet to be produced. There are several such generators in use, however, which, although not quite perfect, are more nearly so as steam generators than any fire-tube boilers in existence.

In designing boilers of any type, and in setting them, the engineer should never for a moment forget that in breaking up the gas current as much as possible lies the great secret of economical generation of steam. Flame bridges operate beneficially for this reason. Galloway and field tubes act still more efficiently. No Cornish boiler should be without transverse tubes of some kind in the internal flue, and no cylindrical boiler should be externally fired. It must not be forgotten, however, that positive mischief may be done by these tubes if they are improperly used, simply because they are so effective that they cool down the gases before combustion is perfect, and then smoke is produced. With proper care this risk may generally be avoided. Probably better results would be obtained in connection with such tubes by constructing the furnace in the shape of a brick oven at one end of the boiler, and leading the gases in the state of vivid combustion into the flues than in any other way. The brick furnace would not cool down the gases too suddenly, and smoke would become an impossibility. The scheme has already been tried with some success, we believe, and we know that it deserves more notice than it has yet received from users of steam power."

21. *Government Tests for Boiler Plates.*—"Before proceeding," says a writer in the 'Mechanics' Magazine,' under date August 14th, 1868, "to the immediate subject of boiler plate tests, it may be as well to say a few words on the final process of manufacture as bearing upon the ultimate results of the testing. After the puddling has been completed, the iron is removed from the furnace in an irregular form, taken to the steam hammer, and there hammered; it is next passed through rolls, and rolled into slabs from about 12 in. to 18 in. wide and 1⅛ in. thick. Sometimes it is rolled in the form of narrow bars 3 in., 3½ in., 4 in., and sometimes 6 in. wide, for the purpose of cross-piling with the wide bars. These slabs and bars are then taken to the shears, and cut into the required lengths; the lengths are now taken to the rolling mills, and there piled according to the size of plate required. The narrow-bars are cross-piled with the wide bars, with the view to obtain a better result upon testing. But great objections exist to this practice, for, while the pile is being rolled down, the joints of the narrow bars appear to open, and by so doing the strength of the plate is injured rather than benefited by the process. From a very great number of experiments which have been made by cross-piling narrow bars with wide ones loosely placed together, and also with piles made solid (which had previously been cross-piled), it is demonstrated that the advantages gained by the latter process amount to about 7 per cent. for tensile strain, the hot and cold forge tests being in the same proportion.

In many instances complaints have been made by the makers of boiler plates to the effect that the Government tests are too severe to insure good iron, by requiring them to supply plates which shall stand a tensile strain of twenty-two tons per square inch lengthways, and eighteen tons per square inch crossways of the plate; also a good hot and cold forge test. In this case it has been said that the plates cannot be subjected to a high tensile strain without injury to the plate, with regard to the forged tests. It is, however, a well-known fact that iron plates can be made to stand the forged tests required by the Government; also a tensile strain of twenty-six tons per square inch lengthways, and twenty-one tons per square inch crossways of the plate, by care and attention on the part of the makers. The course taken by the Government with regard to framing a code of tests, by which plates of a certain thickness and quality must admit of bending both hot and cold, with and across the grain, to insure their being received at the dockyards, has been the means of drawing the attention of the makers to the requirements of the Government, whereby a better class of iron is now obtained than otherwise would have been. But a very few years since, the only result the makers sought to obtain was a high tensile strain.

The methods of testing iron plates for tensile strength differ very materially, according to the views of the different persons employed. Some hold that pieces cut out in a circular form are the best for the purpose; others, that pieces cut with parallel sides are preferable, and while some hold that the length of the piece taken for testing is a fair sample, others think it unfair, and so on, each trying to secure the advantage of the result of the test. From experiments made with circular and parallel-sided pieces the difference was found to be very great. The experiments to which we here refer were carried out as follows:—A certain number of pieces were prepared in a circular form, and a corresponding number in a parallel-sided form, both with and across the grain. The pieces of both shapes so prepared varied in diameter from 1 in. to 10 in., and the average of the results in every length that was tested was in every case in favour of the circular pieces. It will be apparent that when a parallel-sided piece of iron of any length is tested, the chance of its breaking at a point other than the centre, when the full strain is applied (or even under the required tensile strain), is in proportion to the length of piece tested, in consequence of the strain being the more likely to fall into a weak part of the plate, and also owing to the elongation of the plate. But when the pieces tested are circular in form, the probability of their breaking at any other part than the smallest is done away with, as the piece must break exactly at the smallest place to obtain the correct breaking strain. It will thus be seen that, in testing iron, pieces of a circular form have a decided advantage over pieces of similar length of a parallel-sided form. It is evident that this must be the case, for pieces of circular form have a greater body of iron behind the smallest part of the circle, which supports the piece while under heavy strain; and, further, pieces of circular form have a greater area of iron to support the weights when applied, and therefore are not so liable to elongation as parallel-sided pieces. Some manufacturers are of opinion that 1 in. in width, whatever the thickness of the plate, was sufficient to test the quality of the iron; on the other hand, others have preferred a much wider piece, each being anxious to obtain a better result in the tests. The following table shows the result of a number of experiments which have been made in order to ascertain what, if any, advantage would result from testing iron in broad pieces, over other pieces of a much narrower width. The test pieces varied in width from one to eight inches.

These experiments prove that there is a very great difference in the result with regard to the width of the pieces tested. The course adopted by the Government in testing iron for tensile strain is to take a plate indiscriminately, and cut it by planing at any part where it is thought most desirable, other than the edge; for instance, about a foot from the edge. The pieces are planed out so as not to contain less than one square inch in section; they are parallel-sided, and are held between the nippers, not less than 6 in. in length. In some works, the testing of the shearings from the plates is considered a sufficient guarantee of the quality of the iron. As a matter of course, it is the cheapest, but it is very far from being a satisfactory test. There can be no safer method adopted than cutting a piece from the plate, about one foot from the edges thereof, the same being prepared with parallel sides, and this will ensure

Temperature.	No. of Sample.	Size of Sample.	Breaking Strain per square inch.	Elongation.	Temperature.	No. of Sample.	Size of Sample.	Breaking Strain per square inch.	Elongation.
		With the grain.					Across the grain.		
Deg.		In.	Tons.	In.	Deg.		In.	Tons.	In.
80	1	1 by 5	21·0	15-16	80	1	1 by 5	19·0	⅝
,,	2	1 ,, 5	19·5	11-16	,,	2	1 ,, 5	18·25	7-16
,,	3	2 ,, 5	20·75	1⅛	,,	3	2 ,, 5	19·0	⅝
,,	4	2 ,, 5	21·0	⅞	,,	4	2 ,, 5	18·125	7-16
,,	5	3 ,, 5	20·333	½	,,	5	3 ,, 5	17·333	¼
,,	6	3 ,, 5	18·0	¼	,,	6	3 ,, 5	17·666	5-16
,,	7	4 ,, 5	19·25	½	,,	7	4 ,, 5	18·375	3-16
,,	8	4 ,, 5	18·5	¼	,,	8	4 ,, 5	17·375	⅛
,,	9	5 ,, 5	18·6	⅜	,,	9	5 ,, 5	16·8	¼
,,	10	5 ,, 5	19·8	½	,,	10	5 ,, 5	16·6	¼
,,	11	6 ,, 5	15·333	¼	,,	11	6 ,, 5	17·666	¼
,,	12	6 ,, 5	17·666	⅜	,,	12	6 ,, 5	16·0	3-16
,,	13	7 ,, 5	18·857	⅜	,,	13	7 ,, 5	16·928	3-16
,,	14	7 ,, 5	19·714	⅜	,,	14	7 ,, 5	16·82	3-16
,,	15	8 ,, 5	17·0	¼	,,	15	8 ,, 5	16·562	3-16
,,	16	8 ,, 5	18·25	¼	,,	16	8 ,, 5	17·406	¼

both to makers and consumers a good quality of iron. When iron is put upon its merits for tensile strain, the pieces to be operated upon should in no case be prepared by punching them from the plates, but by planing. From what we have above stated, it will be seen that the practice of testing iron in H. M. dockyards is based upon principles which will ensure the best materials being used in the service."

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DIVISION SECOND.

BOILER EXPLOSIONS.

22. *Boiler Explosions of* 1867.—"The reports of two of the Boiler Insurance Companies," says the 'Practical Mechanics' Journal,' "of late years which have sprung up, viz., that of the Midland Steam Boiler Inspection and Insurance Co., and that of

the National Boiler Insurance Co., both for 1867, are before us. Both are by the engineers of their respective companies, and are creditable to their authors.

The report of Mr. H. Hiller, the engineer of the second above-named company, is well classified and arranged as to the natures of the accidents (as they are charitably termed), and suggestions for prevention. In his district there were forty-two explosions during the year, resulting in fifty-eight persons killed, and eighty-one seriously injured. Of the forty-two explosions just one-half, or twenty-one, were due in equal proportions (seven to each) to external corrosion, overpressure, and malconstruction. In other words, one-half the *accidents*, each of which cost in round numbers one human life and a half, were due to ill-made, or ill-worked or worn-out boilers.

Mr. Edward B. Marten reports as engineer for the Midland Steam Boiler Inspection and Insurance Company. His classification is not as elaborate as in the preceding case, but the report is rendered practically valuable by a large number of well-executed wood-cut illustrations of the chief cases of exploded boilers,* which indicate clearly and suggestively the nature of the forces concerned.

In this district Mr. Marten reports forty-eight explosions within the year, causing the death of seventy persons, and the grievous injury of eighty-eight others. Of these forty-eight explosions no less than twenty-seven are attributable to malconstruction (fifteen), overpressure (five), or being worn out (seven). These statistics would be of very much greater value if it were practicable, as no doubt it must be, to ascertain the total number of boilers of all sorts in the area over which the report extends. As it is, we are quite unable even to guess at what may be the percentage of boilers which blow up within a given area, and within the year, in proportion to those that conduct themselves with greater peacefulness and propriety. But though we cannot reach this, we have far more than enough here to prove the fearful though silent and almost unnoticed sacrifice of life and limb, and the terrible amount of misery to survivors produced day by day in those regions where steam power is in much use, and the absolute and undeniable necessity for extending to our country

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* See the next article.

universally the same sort of law, as to government regulation and inspection of boilers as of all other trades and instruments that endanger life and health, which has so long and so beneficially existed in Germany and France.

It is appalling to cast the eye back upon the human holocaust that is yearly slaughtered, through what we are pleased to call accident, in connection with traffic and manufactures in the two British Islands. London street traffic produces its more than 300 victims; probably as many more could be found had we returns from all the rest of the great towns; the railways give us about half as many, we believe; the mines and collieries average about 1,000 per annum; shipwrecks we shall not meddle with, nor accidents by fire. Here, however, we have steam boiler explosions alone reaching in two small districts of England, nearly 130 killed per annum. Had we returns for the whole of the British Islands, we shall probably not be far wrong in assuming that from 350 to 400 persons are killed, and double as many maimed, by boiler explosions every year.

Now, whatever may be the case with regard to losses of life through city and railway traffic, and that upon the seas, and as to which, no doubt, we must admit the force of the remark with which the world in effect coolly dismisses these, viz., that 'we can't make omelettes without breaking eggs;' it admits of no doubt that were supervision of our mines and collieries not a make-believe, and, to use the vernacular, a humbug, but a reality, by having an adequate number of able and efficient mine inspectors, and paying them so well, as also looking after them so well, that their duty should be rigidly and impartially done, and enforced on others, then might the number of accidents in the mines and collieries be vastly diminished, and brought down much below what is even the continental coefficient of death in the pit. But as regards steam boilers, it is obvious to common sense that under a proper system of supervision *and control*, loss of life could be made to cease absolutely and totally, excepting in the very few cases which would remain, as justly coming under the category of accidents properly so called; namely, explosions due to some fortuitous event, or combination of events, such that human foresight, as ordinarily well exercised, had not been able to guard against.

A few such events must always be expected; but to call such things as six explosions of domestic kitchen-fire boilers (killing five people on their own hearths) *accidents*, because these boilers had been made hermetically close vessels, otherwise than by the supply water-pipes and the out-draft cocks, and which were frozen up, has about as much sense in it as it would be to say that a man who had deliberately lighted a grenade, and held it until it exploded, had been accidentally killed.

The manufactory boilers are quite in the same category; it is only that the chain of causation is here and there a little longer, or the links in it a little more out of sight; the nature of the case is as plainly matter of mere foresight and habitual watchfulness and caution in one instance as in the other.

We have no wish to say one word against the existence and work of these boiler insurance companies, unless it be so far as their existence may tend to blind the vision of the public and the legislature to the real necessities of the case. But we do unhesitatingly affirm that even if such companies were spread over the length and breadth of the land, which is not possible, and were greatly more on the increase in efficiency and in success than they are, or are likely to become, viewed as what they really or mainly are, mere financial associations looking to a money result, they never could produce any serious or sufficient reduction in the amount of steam boiler accidents. The reason of this is not far to seek; they are mere voluntary associations, devoid of the slightest power of control or of compulsion beyond that almost nominal amount that is supposed to spring out of the mutual moneyed interests of the insurers and of the insured. The real cases that demand inspection and control are just those where insurance would always be viewed as of quite secondary importance.

A needy or reckless manufacturer who had had a boiler insured, and whose financial or other circumstances strongly induced him to work it after it was dangerously worn out, or to a higher pressure than was safe, would not alter his course, or very probably would plead that *he could not*, because the boiler insurance company refused any longer to insure for him; he would take the risk and the consequences, because the unseen and possibly never to occur danger of explosion was a less present evil to him than to stop work, and go to the expense of a new boiler, with an already overdrawn bank account, or to be late with the completion of orders, the fulfilment of which alone could stave off insolvency, by working his inadequate boiler to a higher pressure than it was intended for, or was safe at.

These are extreme instances possibly, but there are thousands of cases in which more or less of such overmastering motives prevent volunteer associations, like these boiler assurances, from being much more than fine-weather guardians. At the very most, all that can be said for them is, 'This ought ye to have done, but not have left the other undone.' There is not any objection to be urged against them, except they never can result in any considerable good, nor fulfil the functions of state control. That, we affirm now, as we have done long ere now, ought to be without delay extended by the legislature over every steam boiler in Great Britain.

The writer of this article is personally cognizant of the nature and working of this state control in France, and more minutely and fully of that in Prussia, and can testify that it produces no annoyance to the manufacturers or to any other class, but, on the contrary, is recognized by all as a most wholesome and beneficent safeguard. It is in both countries a real *control*, not a mere useless doing of the goose step of supervision or inspection, without any power behind, as is the case with our railway inspection under the Board of Trade. At the design and creation of the boiler, the engineer or boiler maker is not harassed by any vexatious interference with his arrangements or proportions; the State tells him that the science and experience of its engineering advisers have pointed out certain proportions as advisable: he is not bound to follow them, but before the boiler, when made, can be set to work, the State, through its officer, steps in, examines and proves it, and, if all be right, certifies that it is so, and gives authority to go to work. Periodical inspection then must be submitted to; the intervals are not long; the inspection is not a sham; it is a real examination, and, if need be, a repetition of proof and a renewal of the formal certificate, permissive of work.

If any repairs, however trifling, be required to a boiler, a simple form of notice *must* be addressed to the nearest communal inspector, who, thus informed, uses his own discretion whether he shall require the parties to enable him to examine the boiler after the repair and before it goes to work again. In whatever instances these formalities are fulfilled, the manufacturer, or coal owner, or miner, has really no trouble, nor is a delay of an hour needlessly given him, for there are plenty of inspectors at hand, and these are competent men. But if the reckless or impatient man should try to evade the law, he is very soon found out, and finds out his mistake to his cost. The writer knew of an entire colliery in Westphalia being stopped and kept idle for forty-eight hours in consequence of the managers having executed a repair to the steam-chest, common to all the boilers of the winding engine, without having sent in the customary notice to the district inspector. They had done so before, and equally causelessly, and the inspector determined to read them a lesson. Adequate means are always at hand to find out what is going on of this sort; and so the managers on the same Friday that the repair was completed—it only occupied about three hours—were startled by receiving a prohibition to work the boilers until after inspection again. They went personally to the inspector to cry *peccavi*, and get their sentence, if possible, commuted; but the inspector, it was found, had gone to another and more distant part of his district to examine new boilers, and they must now wait his return.

Here, now, is a salient example of that 'pestiferous interference with private rights and actions' that makes such fine stump oratory and newspaper writing against 'paternal governments' in the mouths or from the pens of Englishmen. But is the case one of any real hardship? those that will break the law, which is for the protection of all, have most righteously to suffer for doing so. Which is best, that those who deserve it should so suffer, when more regularity in obedience proves that its yoke is easy and its burden light, or that those who don't deserve to be injured should be left at the mercy of those who are ignorant, reckless, or grasping, and thereby try to evade the law?

The inspection, too, is, as we have said, a real one: the staff of inspecting officers, the system of notice, examination, proof, record, and report, are not of the beautiful hap-hazard sort, so characteristic of every institution, almost, in this 'free and independent nation.' It has all been thought out and arranged with the foresight and wisdom that belong to the legislative and social arrangements of France and Germany. Each smallest district inspector is himself inspected, and has to report to an officer above him; and, finally, the whole of the official system condenses its annual results and reports at head quarters, and government has before it at a glance the entire workings. Nor is the steam-boiler owner left by the law at the mercy of a cantankerous or exacting, or possibly venal, inspector; he has his power of complaint, of investigation, and of remedy, if justly demandable, close at his elbow. In effect, nothing can work better or more smoothly for all concerned than does the system in Prussia, and we believe it does so nearly as well in France, though in the latter country the law is in some few respects a little more exacting, and the power put in the hands of individuals rather more stringent. At the present time, when the public mind is busy with the important—we admit, *more* important—subject of education, primary and technical, it is not amiss to urge the necessity of legislatively taking care of the bodies of the working class as well as of their minds; and now would be a most suitable moment for a complete reconsideration and consolidation into an adequate and symmetrical form of our mine inspection, our factory inspection, and of a comprehensive system of inspection of all that comes within the scope in France of 'insalubrious or dangerous arts or manufactures,' including in this steam-boiler inspection. It would be now easy; in some year to come, if these boiler insurance companies multiply, vested interests will arise in them, and personal opposition have to be encountered, and difficulties, which as yet scarcely exist, will have to be met in Parliament. We do not think these companies are likely to extend very fast; they have not done so as yet, and the more they shall, the more their utter incapacity to deal with the evils will become apparent.

'During the past year,' says Mr. Hiller, 'four instances have occurred where explosion has been ascribed to deficiency of water, and blame thrown on the attendants *who were killed.* In these cases I believe that the juries (coroners' juries) were entirely misled by the erronous character of the evidence. The chief officers of this and other institutions are always ready to render their services in matters of this kind, and in the interest of both boiler owners and of the public generally, it would be well if all cases of explosion were investigated by them, or some one of equal experience, in order that the juries may not be led into returning mistaken verdicts.'

What a picture is here dimly seen in *chiaro scuro* of that time-honoured institution of 'crowner's quest law'—an old world thing utterly incompetent to deal with the complicated questions of science and practice, that these so called 'accidents,' as well as a thousand other incidents arising out of our modern arts and manufactures, are daily giving rise to. Somebody is to blame in nearly all of these; what chance is there of getting at the truth, when twelve men picked up at hazard out of the highway, are called upon to decide what, if honestly spoken out, may influence the pockets or reputation of those neighbours whose wealth or connection, &c., influence them? How is truth to be got at when these mostly illiterate men have 'scientific evidence,' or what is often far worse, the dogmatic unreasoned dicta sworn before them of so-called 'practical men'—'men in the trade'—'men of great experience,' and so forth—who are produced sometimes much at haphazard, but more commonly 'to order,' by one party or the other of those implicated, and who have looked about for exculpation for their retainers?

Doubtless the evidence of competent men, holding known positions, such as Mr. Hiller, or Mr. Marten, or Mr. Fletcher, would be greatly to be desired in place of this. But is absolute impartiality to be surely anticipated in all cases from engineers who have clients *in* these boiler companies who may get into scrapes, as well as those whom they have no anterior relations with? We are all fallible, our minds are easily warped more or less too, in dealing with questions as to which we have been known to have enunciated fixed opinions, and to have publicly acted on declared maxims more or less correct.

Here then are many and grave grounds for taking the investigation of boiler explosions and accidents, if not away from the coroner altogether, at least making him take for his examinations as to fact, and for his assessors, those officers of government inspection whose appointment we urge, and who should be by position as to district, as well as by scientific and social station, above the reach of any local or of any other deflecting influence. One sentence in Mr. Hiller's report alone is sufficient to show the entire inadequacy of the 'voluntary system' of these boiler companies, even in such a close, dense region of steam, and amidst so intelligent and lively a population of manufacturers as that about Manchester:—'A large number of firms have not yet insured, nor placed their boilers under the inspection of any company, chiefly, I believe, through a misapprehension of our advantages. I beg to remind those owners that our inspection is not intended to supersede their own care, or that of their servants, but to assist them in every way. Where desired, we undertake the periodical inspection of boilers without insurance. I trust that all boiler owners will, by their voluntary action, procure such inspection of their boilers as will render unnecessary that government interference which has so often been recommended.'

Just so; 'the voluntary system' here, as everywhere else, in education and the rest, proves a failure. It is mighty good where, and so long as, 'the wishes are father to the wills,' of those who employ and applaud it. But let the former run counter, and the volunteering becomes a rope of sand. So it is with the boiler owners. It is just those who most need inspection that don't wish to have it; just as the brickmaker who prefers the shilling or two a week he gets out of his children of seven or eight years old, compelled by him to drag wet bricks when they ought to be at school, prefers the voluntary system, and deprecates any government interference. But state supervision, and within just and mild limits, state compulsion, are just as much wanted, and would be as wholesome in the one case as in the other."

23. *Boiler Explosions in* 1867.—Through the kindness of Mr. E. B. Marten, the engineer of the Midland Boiler Association, we are enabled to give here the following portion of his report for the year 1867, with illustrations.

No. 1. *January 2d*, 1867. 1 *killed*, 1 *injured*.

A small boiler to heat a bath. It exploded, causing great damage, because the connecting-pipes were frozen. All such boilers should have a proper safetv-valve.

No. 2. (Fig. 14.) *January 2d.* 3 *killed*, 3 *injured.*

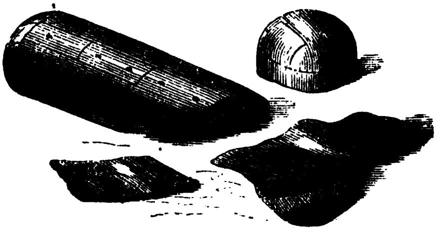

Fig. 14.

Plain cylinder, 33 ft. long, 6 ft. diameter, 33 lb. pressure. Only set two days, but was old and deteriorated, and had worked before at another place. It had been turned ¼ round, and old fitting-holes stopped. First rent was supposed to be in a seam at front end over the fire. Main portion of shell was driven back, and front end forward, and torn in its flight. The cause of explosion was, that the seam in front was over-heated and injured, and also incautious working without a steam-gauge.

No. 3. (Fig. 15.) *January 2d.* 1 *killed*, 4 *injured.*

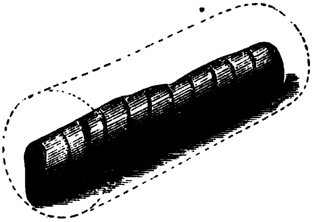

Fig. 15.

One tube externally fired, 30 ft. long, 6 ft. 6 in. diameter, with dished ends. Tube 2 ft. 9 in. diameter, slightly oval. Pressure 60 lb. Tube collapsed sideways from end to end, because it was not strengthened by hoops or other means, which were the more needed because it was slightly oval and the longitudinal seams were nearly in one line.

No. 4. *January 3d.* 1 *killed.*

Boiler for heating apparatus. Fire was lighted without noticing that, as there was no safety-valve, all escape of steam was prevented by the connecting-pipes being frozen.

No. 5. *January 5th.* 1 *killed.*

Cast-iron boiler for heating water for a horse shower-bath, fixed behind an ordinary fire-place. Burst, and caused great damage, owing to the pipes being frozen. There was no safety-valve.

No. 6. *January 16th.* *none injured.*

Kitchen boiler. Burst, and did great damage, because pipes were frozen, preventing escape of steam. There was no safety-valve.

No. 7. (Fig. 16.) *January 26th.* 3 *injured.*

Fig. 16.

Plain cylinder, 30 ft. long, 6 ft. 2 in. diameter. Pressure 30 lb. to 35 lb. Rent into four pieces, which were flattened out and scattered on to other boilers, but are arranged in sketch so as to show their original position in the boiler. It had worked a very long time, and was overheated and injured along the fractured line.

No. 8. (Fig. 17.) *January 30th.* 2 *killed*, 2 *injured.*

Fig. 17.

Elephant boiler, 16 ft. long, 5 ft. diameter; tubes, 1 ft. 10 in. diameter; 45 lb. pressure. Flat end blew out, throwing boiler upwards by reaction, but shell and tubes were not injured. The flat end was not sufficiently stayed, having only one stay-rod to the centre, the bolt of which was broken.

No. 9. *January 23d.* 1 *killed.*

Kitchen boiler. Fire had been out some days, and the boiler burst soon after rekindling it, and did much damage, because the supply-pipes were stopped by frost, and there was no safety-valve for escape of steam.

No. 10. *January 9th.* 1 *killed*, 3 *injured.*

Kitchen boiler, which burst because the supply-pipes were stopped by frost, and there was no safety-valve.

No. 11. *February 8th.* 1 *killed*, 4 *injured.*

Small boiler to 6 horse power engine. Gave way at centre of furnace, and water forced out at both ends, and it was suspected that the water was low.

No. 12. (Fig. 18.) *February 11th.* 4 *injured.*

Cornish, about 30 ft. long. Tube, 3 ft., unstayed. Tube collapsed sideways, and was rent from grate-bars to end, without

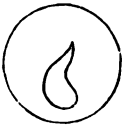

Fig. 18.

injuring front plates or shell. It was said to be short of water, but most likely the true cause was the weakness of the tube.

No. 13. (Fig. 19.) *March 12th.* 1 *killed*, 3 *injured.*

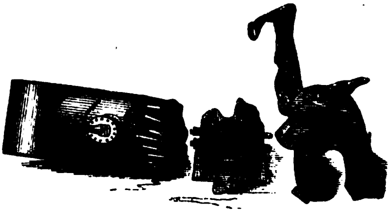

Fig. 19.

Agricultural, 45 lb. pressure. Fire-box blew off, and the outer shell separated from it. The cause of explosion was over-pressure from the safety-valve being screwed down.

No. 14. (Fig. 20.) *March 19th.* 8 *killed*, 4 *injured.*

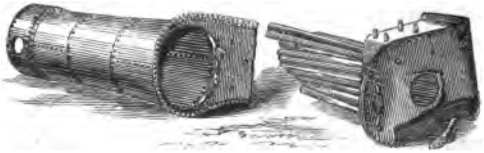

Fig. 20.

Agricultural, 45 lb. pressure. Fire-box and tubes blew out. The cause of explosion was over-pressure, as the safety-valve was tied down with string.

No. 15. *March 23d.* 3 *killed*, 1 *injured.*

Colliery boiler, 30 lb. pressure. Rent in two while the engine was standing, but no details obtained.

No. 16. (Fig. 21.) *March 29th.* 2 *killed*, 2 *injured.*

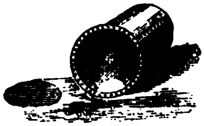

Fig. 21.

Small plain cylinder with nearly flat ends, 4 ft. 7 in. long, 2 ft. 4 in. diameter; plates $\frac{3}{16}$th inch. No emptying-plug or feed-pipe, and only a very small hand-hole. Front end attached by slight angle-iron, which gave way, leaving the shell unmoved. The cause of explosion was the internal corrosion of front end, owing to very bad water being used. The plates were reduced to a knife edge in line of fracture.

No. 17. (Fig. 22.) *April 10th.* 1 *killed*, 1 *injured.*

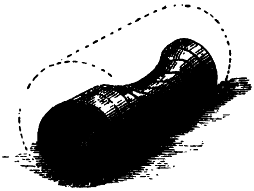

Fig. 22.

Cornish, one tube 32 ft. long, 6 ft. diameter; tube 3 ft. 10 in. diameter; plates $\frac{3}{8}$ in.; pressure 25 lb. to 40 lb. It was twenty years old, but just repaired and reset. Furnace-tube failed, and collapsed from one end to the other, except about 4 ft. of front, owing to its weakness, being unstrengthened by hoops or cross-tubes.

No. 18. (Fig. 23.) *May 9th.* 2 *injured.*

Fig. 23.

Plain cylinder, 3 ft. 2 in. long, 1 ft. 8 in. diameter; plates $\frac{5}{16}$th in.; pressure 30 lb. Workmanship and material very inferior. Piece of top ripped out from manhole, and allowed manlid to blow out through manhole. The cause of the explosion was the large manhole and over-pressure. The safety-valve was too small, and very roughly made.

No. 19. (Fig. 24). *May 10th.* 1 *killed,* 1 *injured.*

Fig. 24.

Locomotive, 130 lb. pressure. Barrel blown away and broken to pieces, leaving fire and smoke boxes. The cause of the explosion was supposed to be the strain on the boiler caused by its being made a stay to the frame without allowance for expansion, and thereby weakening a horizontal seam.

No. 20. (Fig. 25.) *May 18th.* 4 *injured.*

Fig. 25.

Cornish, one tube 20 ft. 6 in. long, 5 ft. 4½ in. diameter; tube 3 ft. diameter; plates ⅜ in.; pressure 64 lb. The ends came out and tube collapsed for its full length, every joint being broken. The cause of explosion was bad construction and workmanship, and tube too weak for pressure.

No. 21. (Fig. 26.) *June 4th.* 2 *killed.*

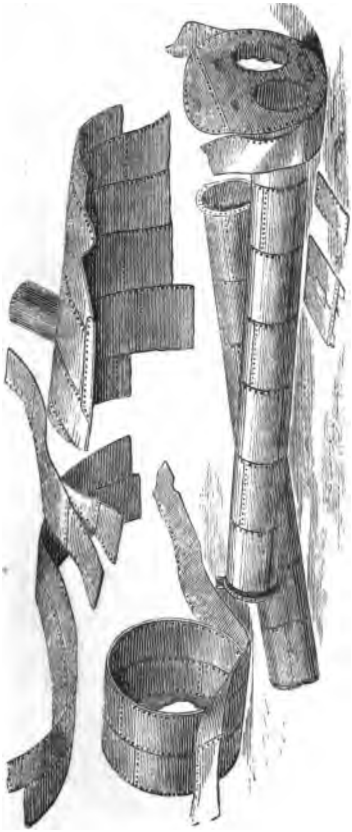

Fig. 26.

Two tube, externally fired, 30 ft. long, 7 ft. diameter; tubes

2 ft. 4 in. diameter; pressure 50 lb. Two plates lately put in bottom gave way, and shell rent along bottom and opened out, dividing into several pieces, which were scattered to great distances, but are arranged in sketch so as to show their original position. The cause of explosion was too frequent repair over the fireplace, and external firing.

No. 22. (Fig. 27.) *April* 20*th*. 1 *killed*, 2 *injured*.

Fig. 27.

No. 23. (Fig. 28.) *July* 10*th*. 1 *killed*, 2 *injured*.

Fig. 28.

(No. 22). Plain cylinder, 6 ft. long, 2 ft. 5 in. diameter; plates ¼ in.; pressure 90 lb. The end blew out from excessive pressure, as the escape from the safety-valve was prevented by a plug in the exit-pipe.

(No. 23). Balloon, 22 ft. diameter; pressure, 5 lb. Bottom blew out, and was torn in pieces. Main portion of shell fell over on to another boiler. The cause of explosion was deep corrosion along the bottom where it rested on the brickwork.

No. 24. (Fig. 29.) *July* 11*th.* 3 *killed*, 3 *injured.*

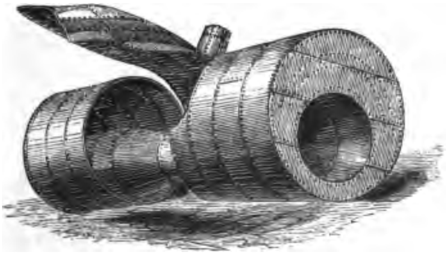

Fig. 29.

One-tube Cornish, 26 ft. long, 8 ft. 10½ in. diameter; tube, 5 ft. diameter for 8 ft. 6 in. of front end, tapering to 4 ft. diameter at back; pressure, 30 lb. Rent along bottom, allowing central ring of plates to open out. The whole boiler was thrown some distance by the reaction of issuing contents. The cause of explosion was corrosion at midfeather wall, the plates being little thicker than paper.

No. 25. (Fig. 30.) *July* 13*th.* *none injured.*

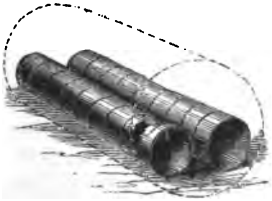

Fig. 30.

Two-tube Cornish 31 ft. long, 7 ft. diameter; tube, 2 ft. 7 in., tapering to 2 ft.; pressure, 55 lb. Left-hand tube collapsed, and about the centre of collapse plate was torn in two pieces from seam to seam. The cause of explosion was overheating, because the water was being let low before all the fire was out.

No. 26. (Fig. 31.) *July 24th.* 1 *injured.*

Fig. 31.

Locomotive. Side-plate in the upper part of high top firebox blew away. The cause of explosion was most likely the boiler being made the frame of the engine without allowance for expansion.

No. 27. *January 11th.* 1 *killed.*

Cornish, 12 ft. long, 4 ft. 6 in. diameter; tube, 2 ft. 4 in. diameter; pressure, 40 lb. Small piece of plate was blown out near the bottom, and the boiler was displaced by the reaction of issuing contents. The cause of explosion was extensive external corrosion on the lower part.

No. 28. *February 15th.* *None injured.*

Two-flued, 28 ft. long, 6 ft. 9 in. diameter, slightly oval; plates $\frac{3}{8}$ in.; tube, 2 ft. 8 in. diameter; pressure, 45 lb. Shell had once been externally fired. Rent along the seams, which were in one line, and a large piece of the plate blew away, leaving tubes uninjured. The cause of explosion was defective form and worn-out state of shell.

No. 29. (Fig. 32.) *August 27th.* *7 killed,* 3 *injured.*

Fig. 32.

Cornish, 18 ft. long, 4 ft. 9 in. diameter; tube, 1 ft. 6 in. diameter; plates, ⅜ in.; pressure, 50 lb. There were no stays. End plate blew out while being caulked at a jump-joint in back angle-iron. The cause of explosion was bad construction and want of stays, and also want of proper care in working.

No. 30. *October 4th.* 4 *injured.*

Water heater made of large bottle-shaped pipes placed in the flue. The force of explosion caused the neighbouring boilers to be unseated. No details have been obtained as to the cause of the explosion.

No. 31. (Fig. 33.) *October 7th.* 1 *killed.*

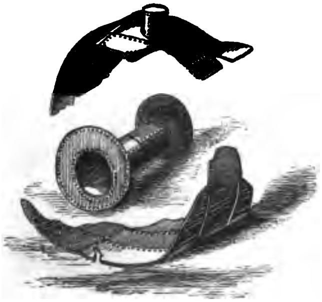

Fig. 33.

One-tube Cornish, 11 ft. long, 4 ft. diameter; plates, ⅜ in.; tube, 2 ft. 1½ in. diameter; pressure, 50 lb. Gave way underneath. Top thrown upwards. Front part and tube thrown to the front. The cause of the explosion was extensive corrosion at the bottom where it touched the walls.

No. 32. *September 2d.* 2 *injured.*

Locomotive, but no details obtained.

No. 33. (Fig. 34). *November 3d.* 1 *killed,* 1 *injured.*

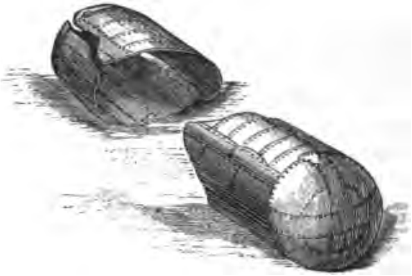

Fig. 34.

Plain cylinder, 19 ft. long, 6 ft. diameter; pressure 40 lb. It was 36 years old, and iron deteriorated, and also much patched. The cause of explosion was over-pressure for so old a boiler.

No. 34. (Fig. 35.) *November 6th.* 2 *killed,* 3 *injured.*

Fig. 35.

Agricultural, wagon-shaped, 6 ft. 5 in. long, 3 ft. high, 2 ft. 4 in. wide; plates $\frac{3}{8}$ in. wide; pressure 50 lb. Upper portion of barrel blew off. The cause of the explosion was over-pressure from locked safety-valve and defective construction.

No. 35. *August 5th.* 1 *killed*, 2 *injured.*

Full particulars are not obtained, but the steam and hot water were allowed to come in from a neighbouring boiler through the blow-off pipe while the men were cleaning.

No. 36. (Fig. 36.) *November 7th.* 1 *injured.*

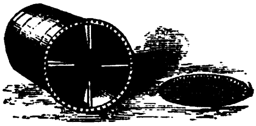

Fig. 36.

Plain cylinder, 12 ft. 3 in. long, 3 ft. 11 in. diameter; pressure 20 lb.; flat front and round back end. Main portion thrown back, and front forward. Front torn all round the root of angle-iron, and stay-rivets drawn through flat end. The cause of explosion was weakness of construction of flat end, and bad safety-valve, which could have been loaded to 60 lb.

No. 37. (Fig. 37.) *November 11th.* 3 *killed*, 10 *injured.*

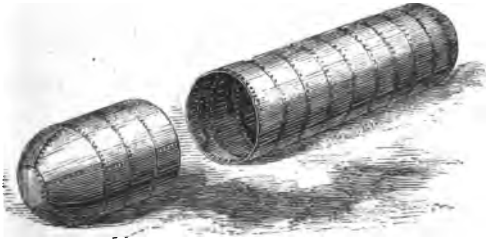

Fig. 37.

Plain cylinder, 40 ft. long, 5 ft. diameter; plates $\frac{7}{16}$th in.; pressure 45 lb. to 50 lb.. Parted at third seam, and front thrown forward, and main portion backwards. The cause of explosion was a seam-rip of old standing near patch at place of first rupture.

No. 38. (Fig. 38.) *November* 14*th*. 4 *killed*, 3 *injured*.

Fig. 38.

Breeches tube, 25 ft. 6 in. long, 7 ft. 6 in. diameter; plates 7-16th in.; pressure 30 lb. Front end and fire-grate tubes and taper junction were thrown to the front in one piece. Main shell not injured. Back part of tube remained in boiler. Bottom part of taper junction, where flattened to receive the two fire-tubes, collapsed upwards. The cause of explosion was the want of proper stays or strengthening tubes, and consequent weakness. There was only one safety-valve of small size.

No. 39. (Fig. 39.) *November* 21*st*. 3 *killed*, 2 *injured*.

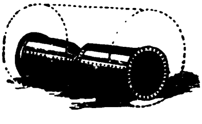

Fig. 39.

One-tube Cornish, 11 ft. long, 5 ft. diameter; pressure 44 lb. Tube gave way at an old crack at back of strap-plate and partially collapsed.

No. 40. (Fig. 40.) *November 27th.* 1 *killed.*

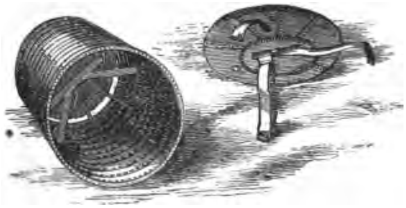

Fig. 40.

Plain cylinder, 25 ft. long, 6 ft. diameter; plates 7-16th in.; pressure 50 lb. Had been a one-tube Cornish, but tube had been taken out, leaving flat ends. Back end was blown out. Main shell thrown forwards. The cause of explosion was weakness of construction in not sufficiently strengthening the flat end to compensate for loss of tube.

No. 41. *October 31st.* *None injured.*

Cornish, 26 ft. long, 5 ft. 6 in. diameter; tube 2 ft. 11 in. diameter; plates ⅜ in.; pressure 30 lb. Tube collapsed for want of proper strengthening hoops, blowing out back end and blowing boiler forward.

No. 42. (Fig. 41. *December 7th.* *None injured.*

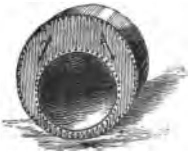

Fig. 41.

One-tube Cornish, 28 ft. long, 6 ft. diameter; tube 4 ft. diameter; plates ⅜ in.; pressure 28 lb. Tube collapsed for the whole length, but no particulars of the cause obtained.

No. 43. *December 14th.* 2 *killed.*

Some repair had been done to a boiler, and a blank flange used to stop off the steam was being removed without shutting the stop-valves to the other boilers, and the joint blew out when the bolts were loosened.

No. 44. (Fig. 42.) *December 23d.* 6 *killed*, 4 *injured*

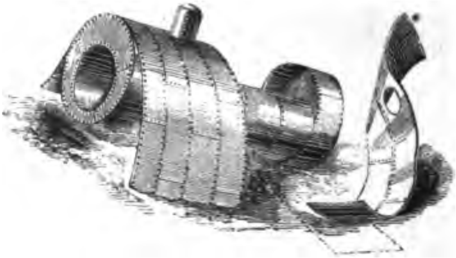

Fig. 42.

One-tube Cornish, 18 ft. long, 6 ft. diameter; tube 3 ft. 2 in. diameter; plates ⅜ in.; pressure 25 lb. Rent along bottom, and two rings of plates blown away, but tubes and ends not much injured. The cause of explosion was extensive corrosion on the part resting on the midfeather wall.

No. 45. (Fig. 43.) *December 28th.* 1 *killed.*

Fig. 43.

Balloon, 11 ft. 6 in. diameter, and 11 ft. 6 in. high; plates $\frac{3}{8}$ in. Bottom domed up 3 ft. 6 in. over fire; ordinary pressure 8 lb. Boiler had worked two days at 25 lb. pressure, but safety-valve loaded to 16 lb. The cause of explosion was undue pressure for an old boiler of such weak shape.

No. 46. (Fig. 44.) *December 30th.* 2 *injured.*

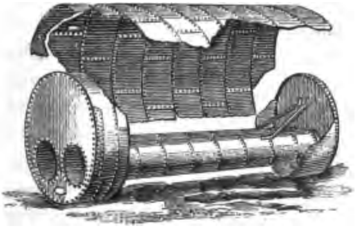

Fig. 44.

Two-tube Cornish, 22 ft. long, 7 ft. 2 in. diameter; tubes 2 ft. 7 in. diameter; pressure 15 lb. Rent along bottom, and shell blown away, leaving tubes and ends nearly uninjured. The cause of explosion was that the bottom was corroded to a knife edge all along the midfeather wall.

No. 47. (Fig. 45.) *December 31st.* 2 *killed,* 1 *injured.*

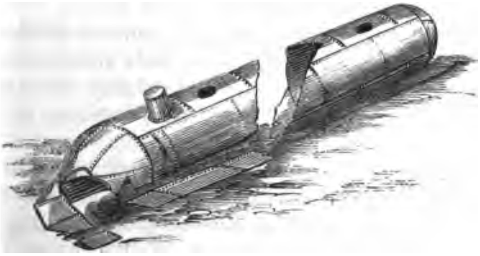

Fig. 45.

Plain cylinder, 30 ft. long, 4 ft. 6 in. diameter; plates $\frac{3}{8}$ in.; pressure 29 lb. Rent over fire near where a new plate had lately been put in. Front part of shell opened out and rent, and back end blew away in one piece. The cause of explosion was deterioration from 20 years' wear, and bad management.

No. 48. *September 9th.* *none injured.*

Two-flued, 40 lb. pressure. The cast-iron mouth-piece of man-hole fractured from insufficient strength, and allowed lid and upper flange to blow off.

24. *Coroners' Inquests and Boiler Explosions*:—Read before the British Association at Norwich by Lavington E. Fletcher, C.E. "The most casual reader of the public newspapers cannot fail to be struck with the frequency of steam boiler explosions and the great amount of life sacrificed by them. Sometimes as many as ten and even twenty lives have been sacrificed by a single explosion. On referring to the records of the Association for the Prevention of Steam Boiler Explosions, in operation at Manchester, under the Presidency of Wm. Fairbairn, Esq., C.E., F.R.S., LL.D., &c., it appears that since the commencement of 1855 up to the 31st of July last, there occurred in different parts of the kingdom as many as 464 explosions, by which 789 persons were killed and 924 injured. This, however, is by no means the total number of lives sacrificed. In the earlier years of the Association's operations such complete records were not kept of all the explosions occurring throughout the United Kingdom as has been the case more recently; added to which there can be little question that some have always escaped its vigilance, so that the whole number occurring from year to year has never been fully reported. The list just given, however, of the lives sacrificed is a sufficiently serious one to excite attention, while it may be stated, in round numbers, that about fifty steam boiler explosions occur on an average every year, resulting in the loss of seventy lives.

Explosions have too frequently been attributed to unaccountable and mysterious causes, so that they have been regarded by some as catastrophes which science could not grapple with or caution prevent. The experience of the Association already named proves, however, that this view is totally incorrect, and that explosions arise from the simplest causes, and are perfectly within the grasp of common knowledge and common care to prevent. Many explosions arise from the use of old worn-out boilers, which have been allowed to be so eaten away either by external or internal corrosion that the plates have become reduced to the thickness of a sheet of brown paper, when explosion has taken place at the ordinary steam pressure simply from the dilapidated condition of the boiler. Others arise from collapse of the furnace tubes, through the neglect of the simple precaution of strengthening them with encircling hoops, flanged seams, or other suitable provision. Others, again, are due to weak manholes or defective fittings, while some occur through the carelessness of the attendants in holding down the safety-valves, or neglecting the water supply. Whatever may be the precise circumstances of each case, the cause of every one may be given in one word, viz., *neglect*, while the simple preventative is *care*.

At the inquiries conducted by coroners as to the cause of explosions, the public naturally look for all the facts of the case to be brought out so that they may not only be informed that so many poor fellows have been blown to death, and so much property damaged, but also instructed as to the true cause of the catastrophe, so that a recurrence may be avoided. These hopes are, however, as a rule, grievously disappointed. The public are misguided rather than instructed, and instead of any practical suggestions being given for the prevention of similar disasters, they are generally stated to be perfectly unaccountable and accidental, that no one is to blame, and that nothing could have prevented the catastrophe. The evidence admitted is of the most absurd and frivolous character. In many cases, too numerous to refer to in detail on the present occasion, witnesses are adduced to prove that the exploded boiler which has just been rent in fragments was a thoroughly sound one, indeed the best of the series, and perfectly safe at the pressure at which it was worked, or at one twice or three times as high, so that the explosion was perfectly mysterious. On one occasion a witness attributed the explosion of a weak and mal-constructed boiler to wind in the pipes, produced by lifting the safety-valves; on another occasion one of the witnesses attributed the explosion to the formation of an explosive gas within the boiler, which, he thought, had become ignited by a flame from the furnace leaping through a crack in the plates. In another case an explosion was attributed to the steam of one boiler mixing with that of another at a different pressure, which, it was imagined, would form an explosive compound. Another explosion was attributed to the water being allowed to rise two or three inches above its ordinary level, the witness stating that "water was very turbulent and would burst a boiler much quicker than steam, adding that as the boiler was but partially clothed, he thought that atmospheric influences had a good deal to do with the explosion in consequence of the boiler being but half clad on a cold frosty morning. Many other similar cases might be given, but these will suffice to show the character of evidence too frequently given at coroners' inquests as to the cause of boiler explosions.

With such investigations it must be clear no progress can be made, and fatal boiler explosions recur with sad constancy.

There are, however, a few, though very few, exceptions to this rule; one of which occurred in the city in which this meeting of the Association for the Advancement of Science is now held. The explosion in question happened about two years since, killing seven persons, and laying the premises in which it occurred in ruins. The cause of this sad disaster was simply that the boiler was a bad one though new, and made under special contract. This the jury plainly stated in their verdict, and the maker of the boiler had to pay heavy damages to the amount, I believe, of £2,000. A few such verdicts would shortly rid the country of boiler explosions, and it is in behalf of such plain and outspoken verdicts that this paper is written.

This paper does not by any means profess to follow out to the full the interesting and important subject of the cause of boiler explosions, but to call attention to the inadequacy of the investigations with regard to them usually made by coroners, and to advocate these being more searching and complete. To accomplish this the following plan is proposed:—

Let any coroner be empowered and instructed, when holding an inquiry on a boiler explosion, to call in two competent and perfectly independent scientific engineers to investigate the cause of the explosion and report to the jury thereon—these engineers to visit the scene of the explosion and examine the fragments of the boiler, to attend the inquest, hear the evidence given by parties concerned in the charge of the boiler, and aid the coroner in conducting the inquiry; while in addition, they should report to him either jointly or severally on the cause of the explosion, and accompany their report with suitable scale drawings of the exploded boiler, showing its original construction, and the lines of fracture as well as the flight of the parts as far as they can be ascertained. The inquest to be open to the public under the control of the coroner, and also to the press, both scientific and general, so that the entire proceedings may have as wide a circulation as possible. A full account of the inquiry, including the engineers' reports, accompanied with the scale drawings, to be printed and deposited at the 'Patent-office,' and to be accessible both to the purchase and inspection of the public, as is at present the case with the specifications of patents. Also a report of each inquiry to be sent to the members of both Houses of Parliament as issued.

Such a course, it is thought, would stimulate coroners to make searching and full investigations, and if at the outset incompetent engineers were selected by the coroner, the publicity given to their proceedings as recommended above would bring them under the criticism of the press and general engineering public, which it is thought might be relied on as a corrective. If full investigations were brought to bear upon boiler explosions and those steam-users who produce them by working on old worn-out boilers, were fairly brought to the bar of public opinion, and compelled, when necessary, to compensate the widow and orphan for the results of their negligence, the mystery of boiler explosions would soon be dispelled, and their occurrence put a stop to.

The frequency and fatality of steam boiler explosions has frequently been used as a plea for a Government system of compulsory inspection, and juries have frequently coupled with their verdicts a recommendation to this effect. There are, however, serious objections to this course. Such a system of inspection must necessarily be carried on by rule, and however wisely such a code of rules might be framed, and however liberally carried out, it would be impossible to prevent its proving a harass to the individual steam-user, and an impediment to progress; so that it should only be adopted as a last resort. These objections would be avoided by confining Government action to investigations carried out by means of coroners' juries consequent on fatal explosions. Under this system the steam-user would be left perfectly free as regards the management of his boilers, but would be held responsible for results, and the Government would not interfere until a fatal explosion had occurred, when they would then make a faithful investigation and freely report the facts. It is firmly believed that faithful investigations and plain speaking would do much to put down explosions in the course of a single year, and therefore the plan suggested for rendering coroners' inquests with regard to boiler explosions of greater efficiency, is commended to the consideration of this section of the British Association for the Advancement of Science, believing that it would prove a practical step towards the prevention of the present loss of life through the constant recurrence of steam-boiler explosions, and render a system of compulsory Government inspection unnecessary."

25. *Boiler Explosions at Ironworks.*—"The inquest," says the 'Engineer,' under date October 30th, 1868, "on the two workmen who were killed on the 2d instant at the Elsecar Ironworks, near Barnsley, belonging to Messrs. Dawes, was concluded on the 22d instant with a verdict of 'Accidental Death.'

The boiler was a two-furnace upright, or Rastrick boiler. It was 20 ft. high, and 7 ft. diameter. It had one down-flue and two cross-flues, was supplied with two 5-in. safety-valves, and was worked at a pressure of 45 lb. The plates were 7-16ths gauge, and the boiler, which had been in use some years, appeared to be in good condition. It possessed a self-feeding apparatus, and was insured in the National Insurance Company, who sent persons to examine the boilers at the Elsecar Works every month or six weeks. It was generally worked with water about 18 in. above the top of the down-flue, and the alarm whistle was supposed to act when the water was at 18 in. on the top of the flue. The engine tenter, who had charge of the boiler at the time of the accident, deposed that he was upon the top of the boiler two or three minutes only before the explosion. At that time, as indicated by the float, it was full of water. The pump was, at the same time, working in good order. Another witness, who was injured, spoke to there having been a rush of steam, by which he was scalded, three minutes before the explosion. Whilst he was running away from the steam, with a scalded arm, the explosion happened. He described the noise of the escaping of steam as resembling that caused by water being thrown upon hot 'slags.' The explosion tore a piece of plate, about 3 ft. 6 in. square, out of the side joint, by one of the side tubes, through which the flame passed from the outside to the central tube, removed the boiler itself some twenty yards from its place, and scattered the bricks and masonry a distance of from fifty to sixty yards.

The scientific witness examined at the inquest was Mr. D. Macuee, jun., C.E., of the Brinsworth Ironworks, Rotherham. He said that the plate torn from the boiler appeared to have been burnt, but that the valves and apparatus seemed to be all right. The boiler also appeared to be a good one, and in good working order. The first fracture was from the seam of rivets; there may have been a crack between the rivet holes, which, being opened, would cause an escape of water from the boiler. The furnace being in full operation at the time, the torn plate may have got overheated (assuming, Mr. Macnee explained, that the steam went off three minutes before the explosion), an immense quantity of steam would be generated, and an explosion ensue. On the other hand, if the explosion was not preceded by any notice, like that spoken of, then the cause would have been from a deficiency of water. If the water were low, then, the evidence was to the effect that the whistle did not give the alarm. If a furnace is working very furiously into one part of a boiler, it is possible for the water to be forming steam so rapidly as to prevent proper contact of the water with the heated plate. Such a cause was assigned for the explosion of a three-furnace upright boiler, 24 ft. by 7 ft. 9 in., in Birmingham, in 1865. A piece of plate, about 3 ft. by 1½ ft., was blown out of the side at a place where an enormous flame impinged continually. The plates at first bulged out, and then gave way in the centre of the bulge, each edge being doubled back and broken off. There was no positive evidence as to the water supply; but the crown of the centre tube, which was much above the bottom of the part blown out, remained uninjured. The cause which produced these evidences in the Birmingham boiler led, in a great measure, we are inclined to believe, to the Elsecar explosion.

Each ironmaking district has adopted different modes of applying the heat of furnaces to boilers, although, as may be imagined, there are specimens of all kinds in each locality. South Staffordshire has used chiefly the two, three, or four furnace boilers of the class described above, and of that also to which the recently exploded Moxley boiler belonged, with also that at Millfields, in the same district, by which last twenty-five work-people were killed. The boiler which blew up, with disastrous consequences, at Hall End, also in South Staffordshire, was of the same class. There is much reason why, in this part of the kingdom, the upright furnace boiler should be used, for Mr. Rastrick, by whom it was invented perhaps twenty years ago, was sometime engineer with Mr. James Foster (Messrs. John Bradley & Co.), of the Stourbridge Works, which have long occupied the position of the leading works in South Staffordshire. But Mr. Rastrick is not responsible for the abuse of his invention which, we shall presently show, has taken place.

South Wales has applied the furnaces to single-tube boilers like those used in Cornwall, with the boiler behind the furnaces. The boilers are thus outside the works; but the drawback is, that the tubes of these boilers are generally 4 ft. diameter, which Mr. Fairbairn has proved to be unfit to bear safely the high pressure of 50 lb. and 60 lb.

Shropshire has generally applied the furnaces in somewhat the same way, but with two tubes through the boilers, reducing the diameter to 2 ft. 6 in., and making them much safer, as far as the danger of collapse is concerned.

Middlesborough and the north of England have used more frequently the chimney boiler; or they use the same as South Wales, with the boiler set on end, like that which exploded so recently at the Mersey Steel and Iron Works. Lately, however, what is called the elbow boiler has been used very extensively for furnaces, in the north of England. In this boiler the flame passes through the bent tube enclosed in the shell.

Many ironmasters doubt the real economy of the furnace boilers, as the furnaces are not under quite the same amount of control as when there is a separate chimney from each. Hence they prefer to have only one or two furnaces to each boiler, whereby the difficulty is lessened. But, by this means they accomplish something more. They are enabled to diminish the risk of explosion, and when explosion happens, to decrease the probable severity of the accident. When Mr. Rastrick invented the upright furnace boiler, his design was one of 16 ft. 6 in. in height, and 7 ft. in diameter; but it has grown in some cases to 28 ft. by 10 ft., worked by four furnaces. It will be remembered that 22 ft. by 10 ft. 6 in. were the dimensions of the boiler (that at the Moxley Works) which was sketched upon page 278 of the present volume of 'The Engineer.' The Elsecar boiler was not, as we have just shown, so large, nor, indeed, had it heat equal to that of four ordinary puddling furnaces, as was the case with the Moxley boiler at the time of its explosion. Whilst the Moxley boiler was riven into ten fragments, that at Elsecar had one piece only blown out; and whilst, also, in the former case thirteen, in the latter only two deaths resulted.

A few years ago an upright boiler blew up, with terrible consequences, at Etruria Ironworks, near Stoke, belonging to Earl Granville, but commercially known as the concern of the Shelton Bar Iron Company. That explosion resulted from the weakness of the internal fireplace of the boiler, which was of large dimensions. After that disaster it was determined that the liability to accident from explosion, and also the probable fatality, should be reduced. Twenty-one boilers were, therefore, put up, each worked by two furnaces, all but four occupying a semicircle upon one of the boundaries of the works. The boilers here are 18 ft. 6 in. by 8 ft., and are worked at about 40 lb. By this arrangement, not only is the risk brought down to the minimum in such boilers, but an ironmaster will at once perceive that the iron can be brought to the hammer at either end of the forge with a facility which will mark out the arrangement as otherwise to be commended. Therefore, when these upright boilers are used, they should not exceed the dimensions of those now in use at the Etruria Works; they should have only two furnaces each, and should be planted in positions in which least mischief would ensue upon an explosion. But a further step in the right direction will be taken when more attention is given, throughout the iron trade, to the using of the fine slack, or small coal, now unsaleable, for raising the steam for the works. This can undoubtedly be done by simple self-acting firing apparatus; and a little attention to the subject would produce a form of grate, for general use, which would accomplish the object. When the steam is made by burning such cheap refuse as slack, and it will be needless to place any boiler where any men, other than those in charge, need work near them. In the meantime, however, there is no need for the boilers, placed as at present, to cause danger if they are carefully tended and examined.

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DIVISION THIRD.

FURNACES AND FURNACE ECONOMY.

26. *Blast Furnace Economy.*—"No ironmaster," says a writer in 'Engineering,' under date August 7th, 1868, "need be told that if his coal and ironstone were fed to the blast furnace in blocks of a ton weight each, there would be a very great waste of fuel in smelting, even with the greatly lessened blast which would be admitted were such a practice followed. The total surface presented by the stone to the action of the heat would be enormously less than where the materials were finely broken, and hence the temperature at the tunnel head would be higher, and the waste correspondingly greater. Worse than this, the furnace would not only work to but perhaps half its proper duty, but it would work irregularly, and make an iron of which no uniform quality could be depended upon.

If, on the other hand, the materials were too finely broken, the blast could not be got through them, and the furnace would 'gob up.' Where the materials are already liquified, as in the Bessemer converter, the oxygen of the air and the silicon and carbon in the iron are presented to each other in an infusion of boiling atoms, and as all are free to move in any direction, there is no 'gobbing.' In the best makes of iron known in commerce, viz., the Swedish, the ironstone, already calcined, is broken, according to Dr Percy, into pieces of from ½ in. to 1 in. cube. The limestone is as finely crushed, and the charcoal is carefully broken into moderately small pieces. In the Belgian and some other Continental furnaces, great attention is paid to the fine subdivision and thorough mixture of the materials. The surface presented for action is exactly in proportion to the fineness of subdivision; thus, if the materials be broken into 1 in. cubes, they will present twice the surface of 2 in. cubes. More than this, the opportunities for mixture are much greater in the former case, and it is of great importance that each atom of iron, coal, or coke, and limestone, should be in the closest possible contact with each other in the blast furnace.

In the present English practice neither the ironstone nor the limestone is broken nearly as finely as it should be. Broken by hand labour into rough, large lumps, the limestone costs but from 2½d. to 4d. per ton for breaking, but it is not broken into a fit state to act as effectually as it might as a flux. Hand labour cannot, indeed, break it at all to the proper degree of fineness except at an enormous cost. Even pauper's labour in breaking road metalling costs 18d. and upwards per ton, this cost representing that merely of their bare food and shelter.

The only efficient machine now in use for breaking stone, whether for blast furnaces or road metalling, is Blake's, as made by Mr. Marsden, at the Soho Foundry, Leeds. Even a three-horse engine will break 40 tons of hard stone into fine fragments daily, at a cost of 3d. per ton, or 10s. a day in all, exclusive of carting the stone to and from the machine. This machine not only enables steam to be applied to what cannot be nearly so cheaply effected by hand, even in breaking to coarse sizes, but by, perhaps, the simplest combination of the eccentric, toggle joint, and lever yet known in mechanics, it breaks to sizes far smaller than any to which hand labour is applicable unless at a monstrously extravagant cost. A full description of this machine was given in 'Engineering,' vol. iv., page 167."

27. *Dorsett's Petroleum Furnace.*—Whatever successes have attended the application of the various systems of generating steam by means of liquid fuel to land boilers, it is quite certain that up to the present time no one of them has proved successful, in a practical point of view, as applied to steam navigation. Trials have been made, both at home and abroad, to effect this object, but until now we have not been able to record a steam trip, made with liquid fuel, which satisfied all the conditions demanded by the present position of this important question. It is, therefore, with more than ordinary satisfaction that we now place before our readers particulars of the most successful voyage

yet made with a steam ship of considerable size burning liquid fuel. This was accomplished on Monday last by the screw steamer 'Retriever,' of 90-horse power nominal, and 500 tons burthen, fitted with a liquid fuel furnace upon the principle invented by Mr. Edward Dorsett, of 12, London Street, city. Amongst the company on board we observed Captain Selwyn, R.N.; Captain Crown, of the Russian Navy; Mr. Silverlock, of the Citizen Steamboat Company; Mr. Parker, Mr. Crowe, Dr. Paul, Mr. Stewart, Mr. Lammerton, of the Carriage Department, Woolwich Arsenal; and Mr. Steel, from the Admiralty.

Mr. John Bourne, in his treatise on steam, air, and gas engines, after referring to several arrangements for burning liquid fuel, says:—'I can discern no very much better arrangement for burning liquid fuel than that long since adopted by myself, of feeding tar and steam into a hot retort, and conducting the vapours through hollow furnace bars to be burnt by ascending through an artificial fire of some intractable brick or stone.' This is, in effect, to burn the vapour of the oil, and is exactly what Mr. Dorsett does, only without the steam and stone of Mr. Bourne. Had the latter gentleman seen the invention of the former before he wrote the above sentence, we think he would have expressed a modified opinion upon the point. Mr. Dorsett's system is extremely simple in its details; it consists of a generator, which is nothing more than a small portable vertical boiler, in which the creosote is vaporized under a pressure of from 35 lb. to 40 lb., the vapour being led through a pipe to the furnace of the steam boiler, under which it is burned in jets. In the present instance there were two of these generators, which were placed on the deck of the vessel against the boiler casing, the pipes being carried down from them to the boiler furnaces. The creosote is pumped into the generator, a shovelful of live coal is placed under it, and as soon as the vapour begins to distil over, it passes down a pipe into the furnace of the generator. There it issues from perforations in the pipe, and continues the duty commenced by the coal, and supplies the vapour to the boiler furnace.

The adaptation of the coal furnace to the purpose of burning liquid fuel was effected on board the 'Retriever' by removing the furnace bars and filling the ash-pit with two layers of perforated fire-bricks. On these bricks lay the coiled pipe leading from the generator, and from which issued four jets of flame. Two more jets were burned in the return box, thus making six jets in each furnace, or eighteen jets in all, there being three furnaces. The boiler had eight rows of tubes, and the four upper rows over each furnace were stopped; the bridges were removed. The engines had two overhead 30-inch cylinders with 2 ft. stroke, and they made an average of fifty-eight revolutions per minute throughout the trip. The steam was maintained evenly at 15 lb. (the usual working pressure), the vacuum being 25 in., and the feed water being supplied at 108 deg. The propeller was a 3-bladed ordinary screw, 8 ft. in diameter and 9 ft. pitch. The 'Retriever' was built about 1854, and has seen some service. On the present occasion she left the Patent Fuel Company's wharf at Deptford, in charge of Captain Brown, about half-past 11 o'clock, and steamed down the river as far as Thames Haven. On the return journey, it was stated that the vessel made one knot more per hour than she had been accustomed to make with coal. The consumption of creosote was between 35 and 40 gallons per hour, as against 8 cwt. of coal, and considering that the present price of creosote is only about one penny per gallon, the great saving is at once apparent.

In determining the degree of success achieved in this trial trip, we have to take one or two matters into consideration. In the first place, the arrangements were of a purely temporary character. The generators were placed on the open deck upon brickwork foundations, the creosote was fed to them by a hand-worked force-pump, the vapour was conducted to the temporary furnaces through a considerable length of pipe, and there was no arrangement for regulating the supply of air to the furnaces with any degree of nicety, so essential to the success of any system. The hands, too, were new at the work, and it was not surprising to see an occasional escape of carbon from the funnel. But this was very exceptional, and was chiefly remarked during the temporary absence of the engineer from the engine-room, when the second in command tried a little bit of regulating on his own account, regardless alike of the proportions of vapour and air he was admitting. But notwithstanding these drawbacks, which are inevitable in the first trial of any new system, the trip was a decided success, demonstrating as it did the perfect practicability of Mr. Dorsett's invention as applied to marine boilers. It showed that the present coal-burning furnaces can be easily and inexpensively adapted to burn liquid fuel, and it proved conclusively that a ship of 500 tons burthen could, without a preliminary trial, make a successful day's run, and attain better speeds, than she had previously made. Although a certain amount of roar was produced in the furnaces, it was far less than we have heard with other systems. Another point that struck us was that, although the smell of the petroleum was somewhat objectionable, yet the engine-room had a far less sickly atmosphere than is usual where coal is burned. This fact the engineers admitted and appreciated; and it is certain that with proper fittings and permanent arrangements even this amount of smell will be reduced to a minimum. On a public trial like the present, of course no opportunity offered for obtaining accurate results by measuring the fuel used, and noting the water evaporated. There was ample evidence, however, that the principle was correct, and the general results were eminently satisfactory. To Mr. Dorsett we must give the credit of having been the first to practically demonstrate the fact that a ship of 500 tons burthen could be successfully propelled by steam generated by liquid fuel. We congratulate Mr. Dorsett on the results of a system which appears only to require attention to a few details in order to render it a perfect success.—*Mechanics' Magazine*, Oct. 16, 1868.

28. *The Swedish Reheating Furnace, with Gas from Sawdust as Fuel.*—From an illustrated article in the 'Practical Mechanic's Journal' of September 1st, 1868, we prepare the following abstract:—"The producer and regenerative furnace of Siemens has recently been adapted by M. F. Lundin, of Carlstad and Munkfors, in Sweden, for the production and utilization of gas from sawdust; and as this application has been found to effect great economy in the manufacture of iron, we deem it important to draw attention thereto, for in many other countries where iron abounds but coal is scarce (such as Canada), there can be no question but that the Swedish adaptation points with much weight. These furnaces are arranged to produce gas arising from any combustible materials, but the remarkable economy resulting from M. Lundin's application is due to the low value of saw-

dust in Sweden, which at the great sawmills is charged for at the rate of 8,000 francs (equal to about £330) a-year for the quantity produced per saw. At one end of the apparatus is the sawdust receptacle, the material being charged by a workman into a funnel, the lower end of which is closed by a drop cone, which is connected to a counterpoised lever in order that it may be lowered when the sawdust is charged, and thereafter when raised constituting a close joint with the funnel bottom. This is placed immediately below the charging funnel. This chamber, which is vaulted or arched, is separated from the hearth by cast-iron plates, the first or higher ones being inclined, thus causing the sawdust to fall towards a horizontal plate, situated below the gas conduit. These plates are at present formed so that the air which enters by a conduit not only serves for the combustion of the sawdust which falls upon the hearth (which is shut or closed), but again penetrating the distillatory chamber raises the temperature of the sawdust and consequently facilitates the distillation. The gas extracted directs itself into a conduit; it cannot escape through the drop cone on account of the great thickness of sawdust which fills up the passage situated below the funnel of the chamber. In the conduit the temperature of the gas ranges from 400° to 420°. By means of the pipe the gas is led towards the condenser. In this travel it loses about 50° of temperature, so that it arrives at the condenser at about 350°. Above the condenser a pipe is situated, provided with eight smaller pipes of 4 to 5 millimetres in diameter, which enter into the condenser. The water which arrives by these tubes is projected on all sides through copper roses. The gas passes accordingly in thin layers between spaces formed by iron bars, whose weight is 1,700 kilogrammes, or thereabouts, disposed in transverse planes. For the purpose of keeping these bars constantly cold, a pipe, which turns in different directions, is perforated with a large number of holes through which the water escapes and sprinkles them. Lastly, a conduit leads the condensed gas towards the furnace.

The sawdust employed is partly of green timber, and contains about 45 per cent of moisture, the gas distilled in the pipe containing 35 per cent.; after the condensation the quantity of water is reduced to 2 in 100 parts of gas by weight, or 3 in 100 of volume. The consumption of water for cooling is 70 litres per minute; its temperature after the condensation has been effected is augmented about 30°. This quantity of water serves for a single regenerative furnace, but if a preparatory furnace is at the same time used the quantity must be doubled.

The composition of the gas expressed in volume and weight by M. Lundin is as follows:—

COMPOSITION.	VOLUMES.	WEIGHT.
Carbonic acid, . . .	11·8	19·6
Carbonic oxide, . .	19·8	20·8
Hydrogen, . . .	11·3	0·87
Marsh gas, . . .	4·0	2·4
Nitrogen, ...	53·1	56·3
	100·0	99·97

The composition is the same before as after condensation. The very great quantity of carbonic acid is carried off by means of hydrated lime mixed with the water in the condenser. We have above stated that the sawdust used in these furnaces in Sweden contains about 45 per cent. of moisture; if the sawdust was all new it would contain from 50 per cent. to 60 per cent., which high proportion is reduced either by mixing with it a portion of dried sawdust or some pieces of wood. The gas circulates in the pipes or conduits at the low pressure due to a column of 3 millimetres of water. And as one of the products of the distillation, there is obtained about 164 litres of wood tar per week. A pipe conducts the gas into a box containing two valves, one of which allows the gas to pass into the conduit which leads it to the furnace, and the other communicates by a pipe by which the excess of gas escapes into a gas-holder.

There are two furnaces—the one for re-heating, the other as an auxiliary or preparatory furnace for primarily heating the charge. Both are composed of two similar parts, which together constitute two furnaces, united and operating alternately. From the valve-box two conduits proceed which lead to the boxes situated at the central part of the two furnaces, between the two hearths, opposite to which two other boxes are situated, connected by a pipe with a blast-producer. From each of these boxes other conduits proceed, which conduct the gas and air to the corresponding regenerators, situated at each end of the furnace. The gas regenerators are situated at the extreme part of the furnace, and those for the air near the sides of the hearth. The boxes contain a valve or cock, which, by being turned in one of two directions, leads the gas and air towards one or the other of the furnaces. Between the furnaces a conduit is placed, which leads the smoke and other products of combustion to the chimney.

The cost of a furnace of the foregoing construction is about 8,600 francs, and on 1,700 tons of 1,000 kilogrammes produced a-year, an economy of at least 8,760 francs is effected, and that by employing a Siemens' condenser and regenerator, just as is used for gas extracted from wood, charcoal, or other fuel. The necessity for repairing the furnaces is found to be very rare when even very elevated temperatures are employed. Through a six-aperture furnace about 487 kilogrammes a-week can be produced, by means of four hammers, the weight of each being 400 kilogrammes. The iron made at Uddcholm, where the first furnace of this species was constructed, in October, 1865, is always reheated to a very high temperature. Each 100 kilogrammes requires about 400 litres of sawdust, containing at least 8·50 kilogrammes of carbon, 8·50 of hydrogen and oxygen, and 14 kilogrammes of water, when the sawdust comes direct from waterborne timber. The loss appears less than usual, this no doubt resulting from the excessive heat, and consequently greater rapidity with which the iron is drawn out. It should be explained that in Sweden the iron is *hammered* into bars and plates, and not *rolled*, as in this country and elsewhere—hence the term 'drawn out.' The first heating, made with coal in the old gas furnace, necessitates the consumption of a hectolitre and a half of coal for each 100 kilogrammes of iron in bars. The auxiliary furnace has been served since January, 1860, by means of the same generators and condensers which supply the reheating furnace. Actually 0·60 metres to 0·80 metres of sawdust are consumed for the preparatory heating and final reheating of 100 kilogrammes of iron in the bar. In the furnaces provided with gas from charcoal 0·30 to 0·38 cubic metres of charcoal are employed; therefore in this last case the real quantity of carbon to

100 kilogrammes of iron is from 90 to 100 kilogrammes, and more, having regard to the loss caused or due to the heat taken up in desiccating the wood.

The gas which passes from the furnace into the chimney is of a temperature of about 300°, containing at least 7 per cent. of aqueous vapour. Good dry wood charcoal, which contains 8 per cent. of water, produces in generators constructed on Ekman's system a gas of 1,394° temperature, and in the furnace a temperature of 2,666°, the combustion being effected with the air at the ordinary atmospheric temperature; but if the temperature of the air is raised to 100°, the temperature, instead of being as above stated, becomes 1,473° and 2,757° respectively. On the contrary, the gas from wood charcoal contains but 1 per cent. of aqueous vapour. The gas produced from desiccated wood coutains more water than that led through Lundin's condenser. The durability of the furnace is notable, and said to be due to the absence of cinder. During eight weeks the thickness of the roof (10 centimetres) has only diminished from 6 to 9 millimetres, and the walls appear equally undestroyed. The bricks composing the two or three upper layers of the regenerators attached to the furnace for the final reheating ordinarily are renewed in from four to six weeks, whilst the regenerators for the preparatory furnace last much longer.

Such are the results with Siemens' regenerative system, that any kind of fuel can be employed.

OBSERVATIONS.

The two furnaces working with charcoal served at the same time as furnaces of reserve to that working with sawdust, and operated simultaneously only in the single case where the latter needed repair. During the first six months 789·13 tons of iron were drawn out into bars, and during the following six months 1,013·11 tons, of which 557·27 tons were produced during the latter three months, this being equivalent to an annual production of 2,229·14 tons. The furnace with the sawdust has produced during the three last months of the year—that is to say, during 56 days (of 24 hours each) and 20 hours—471·18 tons, being equivalent to an annual produce of 1,884·74 tons, or 8½ tons during 24 hours. After each repairing of the furnace

304·55 tons were drawn out, all the iron being twice reheated. The consumption of sawdust was not observed with regularity, but it is valued at 0·776 metres per 100 kilogrammes, according to careful calculations made during the latter half of the year. During the last week 750 cubic decimetres of sawdust were used for each 100 kilogrammes of finished iron.

In comparing the quantity of carbon used in the sawdust furnace and in the charcoal furnace, it will be found that in the former case 300 kilogrammes of iron are reheated with the same quantity which reheats but 100 in the second case; so that by what we have said it is evident how greatly the produce of regenerative furnaces in Sweden has been increased.

In conclusion, we may give some of the last-mentioned results. Since November 10, 1866, up to April 18, 1867, or during 105 days of 24 hours each, 926·06 tons of iron have been reheated and drawn into bars, with a loss of 12·04 tons per 100, and with 0·76 metres of sawdust per 100 kilogrammes of iron. In one week 56·18 tons of iron were drawn into bars, with 0·617 metres of sawdust per 100 kilogrammes, the loss being only 9·90 tons per 100. At present the average loss is 11 tons per 100.—V.D."

29. *On the Regenerative Gas Furnace as Applied to the Manufacture of Cast Steel*:—From a Lecture delivered before the Fellows of the Chemical Society, May 7th, 1868, by C. W. Siemens, F.R.S., Mem. Inst. C.E., we take the following:—"I shall proceed to describe the construction and working of the regenerative gas furnaces (similar to those at Birmingham) which are now at work, or in course of erection, in this country and abroad, for the production of cast steel, both by the old method of fusion in pots, and by the new system of making cast steel on a large scale and on an open furnace bed, from scrap iron and from the ore.

The regenerative gas furnace consists of two essential parts, the gas producer, in which the coal or other fuel used is converted into a combustible gas; and the furnace, with its 'regenerators' or chambers for storing the waste heat of the flame, and giving it up to the in-coming air and gas.

Any combustible gas might be burned in the regenerative furnace; I have used ordinary lighting gas very successfully on a small laboratory scale, but it is far too costly to be employed in larger furnaces, and the only gas generally available is that generated by the complete volatilisation of coal, wood, or other fuel, with admission of air in a special 'gas producer.' Any description of carbonaceous matter may be worked in a suitable gas producer, and will afford gas sufficiently good for the supply of even those furnaces in which the highest heat is required. Coal is the fuel chiefly used for gas furnaces in England; small coke has been employed in some cases, as in gasworks, where it is to be had at a cheap rate; wood is used in France, Bohemia, and Spain; sawdust in Sweden, furnishing gas for welding and other high-heat furnaces; lignite in various parts of Germany; and peat in Italy and elsewhere; this last being applicable with the greatest relative advantage.

The accompanying illustration (not given here. See former vol. of 'Engineering Facts and Figures' for illustration of Mr. Siemens' Furnaces,) represents a gas producer suitable for burning non-caking slack.

In form it is a rectangular firebrick chamber, one side of which is inclined at an angle of from 45° to 60°, and is provided with a grate at its foot. The fuel is filled in at the top of the incline, and falls in a thick bed upon the grate. Air is admitted at the grate, and as it rises slowly through the ignited mass, the carbonic acid, first formed by the combination of the oxygen with the carbon of the fuel, takes up an additional equivalent of carbon, forming carbonic oxide, which diluted by the inert nitrogen of the air, and by a little unreduced carbonic acid, and mixed with the gases and vapours distilled from the raw fuel during its gradual descent towards the grate, is led off by the gas flue to the furnace. The ashes and clinkers that accumulate on the grate are removed at intervals of one or two days.

The composition of the gas varies with the nature of the fuel used, and the management of the gas producer. That of the gas from the producers at the Plate Glass Works, St. Gobain, France, burning a mixture of $\frac{3}{4}$ caking coal and $\frac{1}{4}$ non-caking coal, is as follows, by an analysis dated J ly, 1865:—

	Volumes.
Carbonic oxide, ...	23·7
Hydrogen, ...	8·0
Carburetted hydrogen, . .	2·2

Carbonic acid,	4·1
Nitrogen,	61·5
Oxygen,	0·4
	99·9

The trace of oxygen present is no doubt due to carelessness in collecting the gas, or to the leakage of air into the flue, and allowing for this, the corrected analysis will stand as under:—

	Volumes.	
Carbonic oxide,	24·2	34·6
Hydrogen,	8·2	
Carburetted hydrogen,	2·2	
Carbonic acid,	4·2	65·4
Nitrogen,	61·2	
	100·0	

Only the first three of these constituents, say 35 per cent. of the whole, are of any use as fuel, the nitrogen and carbonic acid present only diluting the gas. It is the presence of this large proportion of inert gases, which must be heated to the full temperature of the flame, that renders it so difficult to maintain a high heat by gas of this description burned in the ordinary way. In using such gas in a regenerative furnace the presence of so large an amount of nitrogen is not objectionable, as the heat it carries off is given up again to the air and gas coming in.

The gas as it passes off from the fuel contains also more or less aqueous vapour, which is got rid of by cooling it, with some tar and other impurities, and a small quantity of suspended soot and dust.

Any air drawn in unburned through a hole in the mass of fuel, reduces the value of the gas by burning the carbonic oxide again to carbonic acid. To prevent the indraught of air in this way at the side of the grate, I have found it very advantageous to set the side walls of the gas producer back, forming a broad step about 9 or 10 in. above the grate; any air creeping up along the wall is thrown into the mass of fuel and completely burned. The effect of this feature in the form of the producer on the quality of the gas has been very striking.

Three-tenths of the total heat of combustion of solid carbon are evolved in burning it to carbonic oxide; but in the gas producer, a small portion only of this heat is really lost, because it is in a great measure taken up and utilised in distilling the tar and hydrocarbon gases from the raw fuel; and it may be still further economised, especially in burning a fuel, such as coke or anthracite, which contains little or no volatile matter, by introducing a regulated supply of steam with the air entering at the grate. This is effected very simply by keeping the ash-pit always wet. The steam is decomposed by the ignited coke, and its constituents, hydrogen and oxygen, are rearranged as a mixture of hydrogen and carbonic oxide, with a small variable proportion of carbonic acid. Each cubic foot of steam produces nearly two cubic feet of the mixed gases, which being free from nitrogen have great heating power and form a valuable addition to the gas. The proportion of steam that can be advantageously introduced into the gas producer is, however, limited, as it tends to cool the fire, and if this is at too low a heat, much carbonic acid is produced instead of carbonic oxide, causing waste of fuel.

From the high temperature of the gas, as it rises from the fuel (1,000° F. to 1,300° F.), and from its comparatively low specific gravity, it is considerably lighter than atmospheric air, and ascends into the upper part of the producer with a slight outward pressure. It is necessary to maintain this pressure through the whole length of the gas flue, in order to insure a free supply of gas to the furnaces, and to prevent its deterioration in the flue, through the indraught of air at crevices in the brickwork. The slight loss of gas by leakage, which results from a pressure in the flue, is of no moment, as it ceases entirely in the course of a day or two, when the crevices become closed by tar and soot.

Where the furnace stands so much higher than the gas producer, that the flue may be made to rise considerably, the required plenum of pressure is at once obtained; but more frequently the furnaces and gas producers are placed nearly on the same level, and some special arrangement is necessary to maintain the pressure in the flue. The most simple contrivance for this purpose is the 'elevated cooling tube.' The hot gas is carried up by a brick stack to a height of 8 ft. or 10 ft. above the top of the gas producer, and is led through a horizontal sheet-iron cooling-tube, of not less than 60 square feet of surface per gas producer, from which it passes down either directly to the furnace, or into an underground brick flue.

The gas rising from the producer, at a temperature of about 1,100° F., is cooled as it passes along the overhead tube, and the descending column is consequently denser and heavier than the ascending column of the same length, and continually overbalances it. The system forms, in fact, a syphon, in which the two limbs are of equal length, but the one is filled with a heavier fluid than the other. The height of cooling tube required to produce as great a pressure in the flue as would be obtained by placing the gas producers, say 10 ft., deeper in the ground, may be readily calculated. The temperature of the gas, as it rises from the producers, has been taken as 1,100° F., and we may assume that it is cooled in the overhead tube to 100° F., an extent of cooling very easily attained. The calculated specific gravity, referred to hydrogen, of the gas of which I have quoted the analysis, being 13·14, we obtain the following data:

	lb.
Weight of the gas per cube foot at 1100° F.	=·022
,, ,, ,, 100° F.	=·061
Weight of atmospheric air per cube foot at 60° F.	=·076

And from these we have, on the one hand, the increase of pressure per foot of height, in a flue rising directly from the gas producer,

=·076—·022=·054 lb. per square foot;

and on the other hand, the excess of pressure at the foot of the downtake from the cooling tube, over that at the same level in the flue, leading up from the gas producer (for each foot in height of the cooling tube),

=·061—·022=·039 lb. per square foot.

The height of the cooling tube above the level of the flue that will be sufficient to produce the required pressure, equal to 10 ft. of heated gas column, is, therefore,

$$\frac{\cdot 054}{\cdot 039} 10 \text{ ft.} = 13 \text{ ft. } 10 \text{ in., or, say, } 14 \text{ ft.}$$

This method of obtaining a pressure in the gas-flue by cooling the gas has been objected to as throwing away heat that might be employed to more advantage in the furnace; but this is not the case, because the action of a regenerator is such, that the initial temperature of the gases to be heated has no effect on the final temperature, and only renders the cooling of the hotter fluid more or less complete. The only result, therefore, of working the furnace with gas of high temperature is to increase the heat of the waste gases passing off by the chimney flue. The complete cooling of the gas results, on the other hand, in the great advantage of condensing the steam that it always carries with it from the gas producer; and in the case of iron and steel furnaces, in burning wet fuel, it is absolutely necessary to cool the gas very thoroughly, in order to get rid of the large amount of steam that it contains, which, if allowed to pass on to the furnace, would oxidise the metal.

There is, undoubtedly, a certain waste of heat, which might be utilised by surrounding the cooling tube with a boiler, or by otherwise economising the heat it gives off, as, for instance, in drying the fuel; but the saving to be effected is not very great, for as 100 volumes of the gas require for combustion about 130 volumes of air, including 20 per cent. above that theoretically required, the heat given off in cooling the gas 1000° is no more than would be lost in discharging the products of the complete combustion of the fuel, at a temperature 435° in excess of the actual temperature of 200°, and this loss is greatly diminished if a richer gas is obtained.

In erecting a number of gas producers and furnaces, I generally prefer to group the producers together leading the gas from all into one main flue, from which the several furnaces draw their supplies. The advantages of this are saving of labour and convenience of management from the gas producers being all close together, and greater regularity in working, as the furnaces are seldom all shut off at once; nor is it likely that all will require at the same time an exceptional amount of gas.

From the fact that the gas producers may be at any distance from the furnaces that they supply if they are only at a lower level, it would be perfectly practicable to erect them in the very coal mine itself, burning the slack and waste coal *in situ* (in place of leaving it in the workings as is now often done), and distributing the gas by culverts to the works in the neighbourhood, instead of carrying the coal to the different works, and establishing special gas producers at each. In rising to the mouth of the pit the gas would acquire sufficient pressure to send it through several miles of culvert.

In the regenerative furnace the gas and air employed are separately heated by the waste heat of the flame by means of what are termed 'regenerators,' placed beneath the furnace. These are four chambers, filled with fire bricks, stacked loosely together, so as to expose as much surface as possible; the waste gases from the flame are drawn down through two of the regenerators, and heating the upper rows of bricks to a temperature little short of that in the furnace itself, pass successively over cooler and cooler surfaces, and escape, at length, to the chimney flue nearly cold. The current of hot gases is continued down through these two regenerators until a considerable depth of brickwork, near the top, is uniformly heated to a temperature nearly equal to that of the entering gas, the heat of the lower portion decreasing gradually downwards at a rate depending on the velocity of the current and the size and arrangement of the bricks. The direction of the draught is then reversed; the current of flame or hot waste gases is employed to heat up the second pair of regenerators; and the gas and air entering the furnace are passed in the opposite direction through the first pair, and coming into contact, in the first instance, with the cooler brickwork below, are gradually heated as they ascend, until, at some distance from the top, they attain a temperature nearly equal to the initial heat of the waste gases, and, passing up into the furnace, meet and at once ignite, producing a strong flame, which, after passing through the heating-chamber, is drawn down through the second pair of regenerators to the chimney flue. The temperature attained by the ascending gas and air remains nearly constant, until the uppermost courses of the regenerative brickwork begin sensibly to cool; but by this time the other two regenerators are sufficiently heated, and the draught is again reversed, the stream of waste gases being turned down through the first pair of regenerators, re-heating them in turn, and the gas and air which enter the furnace being passed up the second.

By thus reversing the direction of the draught at regular intervals nearly all the heat is retained in the furnace that would otherwise be carried off by the products of combustion, the temperature in the chimney flue rarely exceeding 300 degrees Fahr., whatever may be the heat in the furnace. The proportion of heat carried off in an ordinary furnace by the products of combustion is generally far greater than that which can be utilised, as all the heat of the flame below the temperature of the work to be heated is absolutely lost. The economy of fuel effected in the regenerative gas furnace, by removing this source of loss, and making all the heat of the waste gases, however low its intensity, contribute to raise the temperature of the flame, amounts in average practice to fully 50 per cent. on the quantity used in an ordinary furnace, and the saving is greater the higher the heat at which the furnace is worked. In addition to this economy in the amount of fuel used, a much cheaper quality may generally be burned in the gas producer than could be used in a furnace working at the same heat, and in which the fuel is burned directly upon the grate in the ordinary way.

When the heat of the furnace is not abstracted continually by cold materials charged into it, the temperature necessarily increases after each reversal, as only a very small fraction of the heat generated is carried off by the waste gases. The gas and air, in rising through the regenerators, are heated to a temperature nearly equal to that at which the flame had been passing down, and when they meet and burn in the furnace the heat of combustion is added to that carried up from the regenerators, and the flame is necessarily hotter than before, and raises the second pair of regenerators to a higher heat. On again reversing, this higher heat is communicated to the gas and air passing in, and a still hotter flame is the result.

The temperature that may be attained in this way by the gradual accumulation of heat in the furnace and in the upper part of the regenerators appears to be quite unlimited, and the heat at which a suitably designed furnace can be worked is limited in practice only by the difficulty of finding a material sufficiently refractory of which it can be built.

Welsh Dinas brick, consisting of nearly pure silica, is the only material, of those practically available on a large scale, that I have found to resist the intense heat at which steel melting furnaces are worked; but though it withstands perfectly the temperature required for the fusion of the mildest steel, even this is melted easily if the furnace is pushed to a still higher heat.

As the gas flame is quite free from the suspended dust which is always carried over from the fuel by the keen draught of an ordinary furnace, the brickwork exposed to it is not fluxed on the surface and gradually cut away, but fails, if at all, only from absolute softening and fusion throughout its mass. A Stourbridge brick, for example, exposed for a few hours to the heat of the steel-melting furnace, remains quite sharp on the edges, and is little altered even in colour; but it is so thoroughly softened by the intense heat that on attempting to take it out the tongs press into it and almost meet, and it is often pulled in two, the half-fused material drawing out in long strings. It results from this perfect purity of the flame, that where the heat is not sufficient to effect the absolute fusion of the bricks employed, the length of time is almost unlimited, during which a gas furnace will work without repairs.

Another advantage in employing the fuel in the manageable form of gas, is that the rate of combustion may be regulated at pleasure, to produce an active heating flame of any length from little more than 2 ft., as in the pot steel-melting furnaces, to 30 ft. in the largest furnaces for the fusion of plate glass; and the most intense heat may be thrown exactly upon the charge, the ends of the furnace and the apertures through which the gas and air are introduced being actually protected from the heat by the currents of unburned and comparatively cool gases flowing through them, and only mixing and burning at the very point at which the heat is required, and where it is taken up at once by the materials to be fused or heated. This is of especial importance in the case of those furnaces in which a very intense heat is employed.

The amount of brickwork required in the regenerators to absorb the waste heat of a given furnace is a matter of simple calculation. The products of the complete combustion of one pound of coal have a capacity for heat equal to that of nearly 17 lb. of firebrick, and (in reversing every hour) 17 lb. of regenerator brickwork at each end of the furnace per pound of coal burned in the gas-producer per hour would be theoretically sufficient to absorb the waste heat, if the whole mass of the regenerator were uniformly heated at each reversal to the full temperature of the flame, and then completely cooled by the gases coming in; but in practice by far the larger part of the depth of the regenerator chequer-work is required to effect the gradual cooling of the products of combustion, and only a small portion near the top, perhaps a fourth of the whole mass, is heated uniformly to the full temperature of the flame; the heat of the lower portion decreasing gradually downwards nearly to the bottom. Three or four times as much brickwork is thus required in the regenerators, as is equal in capacity for heat to the products of combustion.

The best size and arrangement of the bricks is determined by the consideration of the extent of opening required between them to give a free passage of the air and gas, and by the rule, deduced from my experiments on the action of regenerators in 1851-2, that a surface of 6 square feet is necessary in the regenerator to take up the heat of the products of combustion of 1 lb. of coal in an hour.

Corresponding Nitrogen, . .	9·616
Nitrogen in the fuel, . .	·018
Total, ...	9·634

Gases produced from 1 lb. of coal.		Specific heats.	Equivalent weight of water.
Carbonic acid,	= 2·881	·217	·625
Water (steam),	= 0·476	·480	·228
Sulphurous acid,	= 0·004	·154	·001
Oxygen in excess,	= 0·479	·218	·104
Nitrogen,	= 9·634	·244	2·350
Total equivalent weight of water, . .			3·308
,, ,, ,, firebrick (sp. heat=0·2)			16·540

By placing the regenerators vertically and heating them from the top, the heating and cooling actions are made much more uniform throughout than when the draught is in any other direction, as the hot descending current on the one hand passes down most freely through the coolest part of the mass, while the ascending current of air or gas to be heated rises chiefly through that part which happens to be hottest, and cools it to an equality with the rest.

The regenerators should always be at a lower level than the heating chamber; as the gas and air are then forced into the furnace by the draught of the heated regenerators, and it may be worked to its full power, either with an outward pressure in the heating chamber, so that the flame blows out on opening the doors, or with the pressure in the chamber just balanced, the flame sometimes blowing out a little, and sometimes drawing in.

The outward pressure of the flame prevents that chilling of the furnace, and injury to the brickwork from the indraught of cold air through the crevices, which is otherwise unavoidable in any furnace worked without blast.

The action of the furnace is regulated by the chimney damper, and by valves governing the supply of gas and air, and the draught is reversed by cast-iron reversing valves, on the principle of the common four-way cock.

Fusion of Steel in Crucibles..—In the application of the system to the fusion of steel in closed pots or crucibles, the melting chamber, containing generally 24 pots, is constructed in the form of a long trench, 3 ft. 6 in. wide at the bottom, and gathered in to under 2 ft. at the top. The sides of the melting chamber are arched both horizontally and vertically, to keep them from sinking together in working, and the work is strengthened by cross walls at intervals. The pots are set in a double row along the centre of the melting chamber, and the flame passes from side to side, the gas and air from the regenerators being introduced alternately from one side and from the other, opposite to each pair of pots. The melting chamber is closed above by loose firebrick covers, which are drawn partly off in succession by means of a lever suspended from a pulley above the furnace, when the pots are to be charged or drawn out. The pots stand in a bed of finely-ground coke-dust, resting on iron plates. The coke-dust burns away only very slowly, if it is made of hard coke and finely ground, and it presents the great advantage of remaining always in the form of a loose dry powder, in which the pots stand firmly, while every other material that I have tried either softens at the intense heat, or sets after a time into a hard, uneven mass, in which the pots do not stand well.

The process of melting carried out in this form of gas furnace is the same in all respects as that in the small air furnaces or melting holes fired with coke which are commonly employed, but a great saving is effected in the cost of fuel, and in the number of crucibles required.

The ordinary consumption of hard coke, costing 22s. per ton in Sheffield, is between three and four tons per ton of steel fused, while in the gas furnace the same work may be done by the expenditure of 15 to 20 cwt. of common coal slack (worth only 5s.

to 8s. per ton), at a cost that is of only 5s. against 75s. per ton of steel melted. There is a further saving in the number of crucibles required, as they may be used in the gas furnace four or five, and sometimes even ten times; while in furnaces heated by coke two or three casts are as much as are ever obtained. The lining of the furnace lasts at least 15 to 20 weeks without repair (in working day and night), while 4 to 5 weeks is the longest duration of the ordinary coke-fired holes.

Fusion of Steel on the Open Bed.—The furnace employed for the fusion of steel on the open bed is similar in shape to a reheating or puddling furnace; the direction of the flame is from end to end; and the regenerators are placed transversely below the bed, which is supported on iron plates, kept cool by a current of air. The air enters beneath the bed plates in front, and escapes by two ventilating shafts at the back of the furnace, near the ends. This cooling of the bed is very necessary to keep the slag or melted metal from finding its way through into the regenerator chambers. The upper part of the furnace is built entirely of Dinas brick.

There are three doors in the front of the furnace, one in the centre immediately over the tap-hole, and two near the bridges, through which the bed can be repaired when necessary, and ingot ends or other heavy scraps may be charged in. Sloping shoots are provided at the back of the furnace, through which long bars, such as old rails, may be conveniently charged, and beneath these are openings for charging the pig iron. The upper end of the shoots is on a level with an elevated charging platform behind the furnace.

The bottom of the furnace is formed of siliceous sand, which answers exceedingly well if properly selected and treated.

Instead of putting moist sand into the cold furnace, as is usually done in preparing the bottoms of furnaces for heating or melting iron or copper, I dry the sand, and introduce it into the hot furnace in layers of about 1 in. thickness. The heat of the furnace must be sufficient to fuse the surface of each layer; that is to say, it must rather exceed a welding heat to begin with, and rise to a full steel-melting heat at the end of the operation, in order to impart additional solidity to the uppermost layers. Care must be taken that the surface of the bath assumes the form of a shallow basin, being deepest near the tap-hole. Some white sands, such as that from Gornal, near Birmingham, will set under these circumstances into a hard impervious crust, capable of surviving from 20 to 30 charges of liquid steel, without requiring material repairs. If no natural sand of proper quality is available, white sand, such as Fontainebleau sand, may be mixed intimately with about 25 per cent. of common red sand, to obtain the same results.

In tapping the furnace, the loose sand near the tapping-hole is removed, when the lower surface of the hard crust will be reached. The lowest point of this surface is thereupon pierced, by means of a pointed bar, upon the withdrawal of which the fluid metal runs out from the hottest and deepest portion of the bath into the ladle in front of the furnace.

M. Le Chatelier now proposes to mix the natural Bauxite, of which the bottom of the experimental furnace at the works of MM. Boignes, Rambourg, & Co., near Montluçon, was first made, with about 1 per cent. of chloride of calcium in solution, to calcine the mixture, and to form it into moulded masses of highly refractory material. A hard bottom being thus prepared, and the heat of the furnace being raised to whiteness, it is ready to receive the materials to be melted.

If these materials consist of bar iron, or of old iron and steel rails, they are cut into lengths of about 6 ft., and are introduced into the furnace through slanting hoppers from the elevated platform at the back, so that their ends rest upon the sand bottom forming the bath.

If the capacity of the boiler is such that charges of 3 tons can be formed, about 6 cwt. of grey pig iron is introduced through the ports or short hoppers, below the main charging hoppers before mentioned. As soon as a bath of pig metal is formed, the heated ends of the rails or bars begin to dissolve, causing the bars gradually to descend. By partially closing the mouths of the charging hoppers, a regulated quantity of flame is allowed to escape from the furnace, in order to heat the descending bars of metal previous to their entry into the melting chamber, the object being to maintain the high temperature of the furnace, notwithstanding the constant introduction of cold metal. The escaping products of combustion, which are thus withdrawn from the regenerators, are a positive gain to the heat of the furnace, because, having been in contact with comparatively cold metal, they would be at a heat inferior to that of the upper portions of the regenerators, and would therefore only lower their temperatures.

As the bars sink in the hopper by their gravity, they are followed up by additional bars until the metal charged amounts to about 3 tons, all of which will be rendered fluid within about four hours from the time of commencing the charge. The metallic bath is tested from time to time by the introduction of a bar through one of the front doors of the furnace, and if the bath should become thick before the end of the operation, although the heat has been maintained, it will be necessary to introduce an additional quantity of pig metal. All the metal being liquid, a sample is taken out by means of a small iron ladle, and plunged into cold water while still red hot. In breaking this sample upon an anvil, the temper and quality of the metal may be fairly judged. Its fracture should be bright and crystalline, betokening a very small proportion of carbon (not exceeding ·1 per cent.), and the metal should be tough and malleable, notwithstanding its sudden refrigeration. From 5 to 8 per cent. of spiegeleisen (containing not less than 9 per cent. of manganese), is thereupon charged through the side openings upon the bank of the furnace, and allowed to melt down into the bath, which is then stirred and made ready for tapping in the manner before described. The amount of carbon introduced with the spiegeleisen determines the temper of the steel produced, the manganese being necessary to prevent red-shortness, unless Swedish or Styrian iron is used.

When old iron rails or scrap of inferior quality are charged, the addition of manganese does not suffice to effect the necessary purification of the steel produced; but the perfectly liquid condition of the bath, together with the unlimited time available for chemical reaction, offer extraordinary advantages for the introduction of such materials as may be found to combine with sulphur, phosphorus, silicon, or arsenic, which are the usual antagonists to be dealt with.

The experiments which I have been able to institute in this direction are by no means complete;—nevertheless, I have obtained most beneficial results from the introduction into the bath of litharge, in conjunction with oxidising salts containing strong bases, such as the alkaline nitrates, chromates, chlorates, stannates, titanates, &c. The choice of the reagents, and the quantity to be employed, depend naturally upon the quality and quantity of objectionable matter to be removed.

By the aid of the process just described, it will be possible to convert old iron rails into steel rails of sufficiently good quality at a cost scarcely exceeding that of re-rolling them into fresh iron rails. The non-expensive nature of the process may be judged by the fact that extremely little labour is required in conducting it; that the loss of metal does not exceed from 5 to 6 per cent., and that from 10 to 12 cwt. of coal suffices to produce a ton of cast-steel.

Ore.—Although I have succeeded in producing malleable steel from ordinary English iron by this process, it would be unreasonable to expect steel of really high quality in using those materials which are already contaminated in the blast furnace; and I am sanguine in the expectation of producing cast-steel superior in quality, and at a low cost, directly from the better description of ores, such as the hematites, magnetic oxides, and the spathic carbonates. My experiments in this direction extend over several years; and last year I sent a few bars of steel produced from hematite ore to the French Exhibition, which had stood a high test in Kirkcaldy's machine. A 'grand prix' was awarded for this and other applications of the regenerative gas furnaces.

Having tried various modifications of the furnace, I have arrived at a form of apparatus not dissimilar to the one just described. The furnace and tapping arrangements are, indeed, the same, except that for the slanting hoppers vertical hoppers over the middle of the bath are substituted, in which the ore gradually descends. Each hopper is formed of a cast-iron pipe, supporting a clay pipe, which is attached to it by means of a bayonet joint, and reaches down into the furnace, while the cast-iron pipe rests with its flange on the charging platform.

A fire space is provided surrounding each hopper, through which flame ascends from the furnace, and is allowed to escape in regulated quantities near the upper extremity of the retort, the object being to heat the latter, and the ore contained in it, to a red heat. A wrought-iron pipe descends into each hopper from a general gas tube above, through which a current of ordinary producer gas is forced in amongst the heated ore. The propulsion of the gas is effected most conveniently by means of a steam-jet in the gas tube leading from the main gas channel to the top of the furnace, care being taken to effect a total condensation of the steam by passing the gas finally through a small scrubber, in which water trickles over pieces of coke. In this way the gas is at the same time purified from sulphurous acid, the sulphur of which might otherwise combine with the reduced ore.

The furnace is charged in the following manner:—

The hoppers and gas-pipes being placed in position, about ¼ cwt. of charcoal is charged through each hopper to form a basis for the ore with which these are afterwards filled.

About 10 cwt. of pig metal is charged through the ports at the back or front of the furnace, which, upon being melted, forms a metallic bath below the hoppers. In the meantime, the ore in the lower parts of the hoppers being heated in an atmosphere of reducing gas, has become partially reduced into metal sponge, which, in reaching the metallic bath, is readily dissolved in it, making room for the descent of the superincumbent ore, which is likewise reduced in its descent, and dissolved in due course, fresh ore being continually supplied on the charging platform. The dissolution of the reduced ore proceeds with extraordinary rapidity, but is practically limited by the time necessary to effect the reduction of the ore in the hopper, which occupies several hours. It is, however, not essential that the ore should be thoroughly reduced before reaching the bath, because the carbon contained in the cast metal serves also to complete the operation.

I prefer to employ a mixture of hematite and spathic ore, containing the elements for forming a fusible slag, which will accumulate on the surface of the metallic bath, and may be from time to time removed through the centre door. If the ore contains any silica, it is necessary to add some lime or other fluxing materials, but it is desirable to employ ores containing little gangue, in order not to encumber the furnace with slag, reserving the poorer ores for the blast furnace. The ore should, moreover, be in pieces ranging from the size of a pea to that of a walnut, in order to be pervious to the reducing gases. If ores in the form of powder are employed, it is necessary to mix them with about 10 per cent. by weight of light carbonaceous materials, such as dry peat, wood, or charcoal.

The metallic bath having sufficiently increased in the course of from three to four hours, the supply of ore is stopped, and that contained in the hoppers is allowed to sink. Before the hoppers are empty, a false cover of cast-iron, lined with clay at its under side, is introduced, being suspended from above by a strong wire, in order to prevent the access of flame to the interior of the empty hoppers. Charcoal and ore are filled in upon the top of this false cover, and, on cutting the wire, afterwards from the commencement of the succeeding charge.

When all the ore has disappeared, the metallic bath is tested as before described in reference to the melting of scrap. If it should be partially solidified, cast-iron is added to re-establish complete liquefaction; but if, on the other hand, the bath contains an excess of carbon, oxidising agents may be added, as before described, in requisite proportion. From 5 to 8 per cent. of spiegeleisen is then added, and the furnace is tapped as already described.

The quality of the steel produced is chiefly dependent upon the quality of the ore, but considering that ores of great freedom from sulphur, phosphorus, or arsenic, can be had in large quantities, this process contains all the elements for producing steel of high quality.

Having tried a variety of ores, I do not attach much importance to their precise composition, so long as they are comparatively free from gangue, and from sulphur and phosphorus, the heat being sufficient to reduce the most refractory. My experience is, however, as yet limited to experimental working.

I hoped to have been in a position to have given you the temperature of this furnace, as determined by an electric resistance pyrometer, which I have constructed for this purpose, but have not yet been able to obtain satisfactory results, owing to the destruction of the coil of platinum wire which has to be exposed to the heat. My efforts were baffled, moreover, by the fact, interesting in itself, that platinum wire produced by fusion in Deville's furnace, does not increase in electrical resistance with increase of temperature in the same ratio as that produced by the old process, owing probably to the presence of carbon or other alloy in fractional quantities.

Avoiding the use of fused platinum wire, I have measured temperatures by electrical resistance up to a full welding heat, which I estimated at 1600° C.=2900° F.; and in judging the heat of the steel-melting furnace by comparison of effects, I should put it at not less than 2200° C.=4000° F. The effect of this degree of heat may be judged by the following:—

An ingot of rather hard cast-steel, weighing 6 cwt., was introduced into the furnace to be incorporated with the bath of steel. The ingot was nearly cold, and was allowed to remain fifteen minutes upon the bank before it was pushed into the bath, where it was completely dissolved in fifteen minutes, the time occupied in heating and melting the ingot being thirty minutes. A cube of wrought metal, of nearly 8 in., weighing 130 lb., was also introduced cold into the furnace, and allowed to remain upon the bank during ten minutes to be heated externally to whiteness, before being pushed into the metallic bath, when twelve minutes sufficed to render it completely liquid. It must be borne in mind that these results are produced without a strong draught, the flame being indeed so mild as not to oxidise the unprotected metal, which can be maintained for several hours as liquid steel in the furnace without adding carbon in any form.

It may be matter for surprise that the material composing the furnace can be made to resist such a heat; and it must be admitted that the best Dinas brick is the only brick capable of resisting for four or five weeks, by which time the thickness of the arch is reduced to about 2 in. by the absolute fusion of the inner surface; but this excessive heat is confined to the heated chamber only, the regenerators being at such a moderated heat that the chequer-work will stand for months, and the arches for years.

In conclusion, I wish to express to you my sense of the disproportion that exists between the magnitude of the task I have brought before you and my ability to accomplish it in all its ramifications. It may be granted that the regenerative gas furnace itself has passed beyond its experimental stage, but much is yet to be done in working out the applications of the system to the useful arts, and the modifications and improvements in processes which it frequently involves.

Much also is yet to be done before the method of producing cast steel, in one direct process from the ore, can take its place as the recognised system of making steel on a large scale from the purer iron ores—a position that I firmly believe it will assume, sooner or later. It is my earnest hope that in bringing this subject before your Society, I may induce some of its members to forward this result by taking up particular branches of the scientific inquiries upon which I have only been able to touch lightly in my present communication. I have much pleasure in acknowledging the assistance I have received in working out this subject from Mr. William Hackney, my principal superintendent, and Mr. Willis, the chemist in charge of my experimental works."

30. *Keesen's Moveable Fire Bar Furnace.*—A model of this was exhibited at the Havre Exhibition in 1868, and of which the following is a description and illustration:—This moveable bar furnace, invented by M. Keesen of Havre, mechanician in chief to the "Compagne Générale Transatlantique," is illustrated in fig. 46. The aim of the inventor has been to provide a means for regulating the consumption of the burning fuel in the furnace proportioned to the speed at which it is desired to work the engine. Thus, for example, if the captain, during a favourable wind, wishes to save steam, he orders one or two of the boiler furnaces to be drawn; but if the wind changes, and the same speed of vessel is to be kept up, the fires have to be relighted, or fired-up. By Keesen's system of furnace the surfaces of the grating are diminished, and the fuel is drawn up towards the dead-plate when the speed of the engine is to be reduced; and when required to be full speed the surfaces of the grating are again increased, and the fuel spread over it; the apparatus is also useful as preventing clinkers. The furnace illustrated in fig. 46 is composed of a moveable bridge A, the bricks of which are carried by an iron shoe, the extremities of the sides of which are united by a cross-bar *a*, which receives the end of a screw D, which is carried forward to the front of the ash-pit, and provided by a hand-wheel I, by turning which the bridge A is made to be drawn to, or made to recede from, the dead-plate of the furnace. The plate I prevents the ashes, &c., falling upon the screw. The spring-chain K serves to bring back the moveable bridge A, when the screw is reversed.

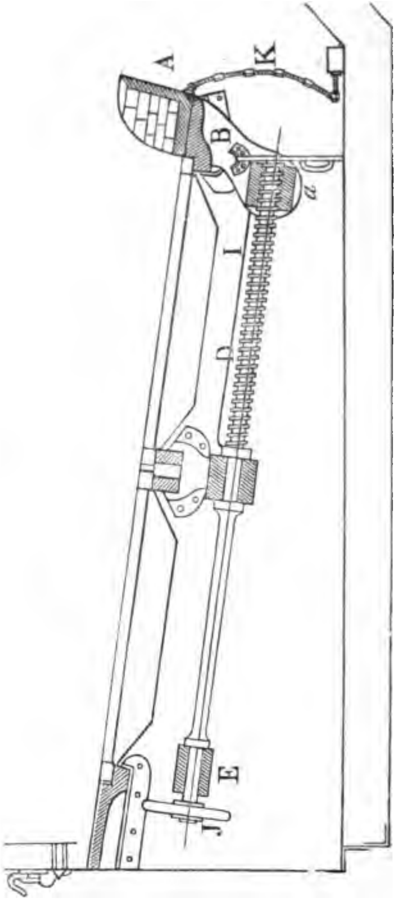

Fig. 46.

DIVISION FOURTH.

FUEL.

31. *Experiments on the Coals of South Lancashire and Cheshire.*—In order to establish the high commercial value of the coals of the above districts, the "South Lancashire and Cheshire Coal Association" requested Dr. Thomas Richardson and Mr. Lavington E. Fletcher, to institute an elaborate and careful set of experiments. These gentlemen have now published their Report, to which Mr. M. W. Peace, the secretary of the Association, furnishes the following preface:—"The recent discussions in the House of Commons upon our coal-fields, and the appointment of a Royal Commission to inquire into their probable duration, have directed public attention so prominently to the subject of coal, that it will hardly be necessary to do more than allude to its importance as one of the great sources of our national wealth. It may be well, however, to remind our readers that the coal district of South Lancashire and Cheshire is the third largest coalfield in this country. A large capital has been embarked to develope its resources. It gives direct employment to nearly 50,000 persons, and yields an annual output of about thirteen million tons.

The coal-owners who conduct this large and important trade find many questions constantly arising which affect them as a body, and some years ago they formed themselves into a society, called the South Lancashire and Cheshire Coal Association, to protect and advance the common interests of the trade, in the widest acceptation of the term. One of their fundamental rules is to exclude from consideration all questions relating to the price of coal, and to the rate of wages paid to the miners. The working of the Acts for the Regulation and Inspection of Mines—the Parliamentary Select Committees upon those Statutes, and upon the Law of Master and Servant—the tolls, terminal charges, byelaws, and regulations of railway and canal companies, find abundant materials for exercising the watchfulness of the Association. Its attention is also directed to the improvement of railway and canal transit, and to the increase of facilities for the shipping and export of coal. As an illustration of the public spirit of this body it may be mentioned, that they have recently offered for competition to the world prizes of £500, £200, and £100, for the 1st, 2d, and 3d best coal-cutting machine, which, in the opinion of the committee appointed for that purpose, shall be deemed most suitable to the requirements of the trade. The successful adoption of such a machine would tend not only to cheapen production, but materially to lessen the most laborious work of the miner.

In 1864, Mr. John Lancaster, then the president, called the attention of the trade to the absence of the steam coals of the district from the Admiralty list of coals to be supplied for the use of steam ships in H. M. navy. It appeared that out of the numerous workable mines of coal in this district many were suitable for steam purposes, but that these steam coals were not on the Admiralty list.

The absence of almost any demand for the navy at the shipping ports of Lancashire and Cheshire had probably prevented any combined movement to procure the admission to the Admiralty list of the steam coals of that district It was only when the export trade of coal from the Mersey was shown to be seriously affected by this state of affairs that remedial measures were taken. Foreign orders received there for the shipment of coal, directed vessels to be laden with coals 'on the Admiralty list,' showing that it had unintentionally become a commercial standard of quality in foreign markets. The result was that vessels in the Mersey, returning abroad with coal could not avail themselves of the abundant supplies ready for them in the harbours to which they had been sent, but were obliged to go in ballast to the ports of South Wales and the Tyne for their cargoes. Thus, then, a list issued by the Admiralty, perhaps the most important department of the Government, professing to name '*the*' steam coals of the country suitable for H. M. ships, was defective and partial in giving some, and not all, of the steam coals of the kingdom applicable to the purpose.

The incompleteness of the list not only injuriously affected the coal and general shipping trade of Lancashire and Cheshire, but, it is submitted, the interests of the nation at large, in shuting out from the navy a large source of supply of steam coal.

It became, then, an object of the Association either to have the value of their steam coals recognised by being placed on this list, or to establish a general test by a Government department, accessible to all, as of right, whose certificate would be satisfactory in foreign commercial circles. The assistance of the county and borough members of the district was invited, and in many instances the appeal was cordially responded to. On the 31st May, 1864, a deputation from the trade waited upon the Duke of Somerset and explained the whole subject. This was followed by the permission of the Lords of the Admiralty for the testing of the steam coals of the district at Keyham, and by an inquiry for the descriptions of the coals intended to present.

The Association, wishing to have a selection of steam coals made by impartial authorities, requested Mr. Dickinson and Mr. Higson, H.M. Inspectors of Mines for the locality, to select such of the steam coals as in their opinion ought to be forwarded to Keyham. These gentlemen kindly complied with this request, and made a report on the subject.

It was deemed advisable that the Government trials should be superintended by some scientific gentlemen on behalf of the trade. The advice of Dr. Richardson, of the Durham University, was sought, and he recommended that, before the coals were tried by the Admiralty engineers, experimental trials should be made at some central place in the district. This was at once agreed to, and Dr. Richardson, by permission of the Admiralty authorities, obtained plans of the marine boiler, feeding and test apparatus in use at Keyham. The Association, at considerable expense, erected in Wigan *fac similes* of the machinery. Dr. Richardson and Mr. Lavington E. Fletcher, of the Manchester Boiler Association, an engineer unconnected in any way with the coal trade, were requested to experiment and report upon the coals. Under their supervision the elaborate trials detailed in the report were made. These numerous trials extended over eighteen months, during which period Mr. John Lancaster, Mr. Fereday Smith, and Mr. John Knowles were successive presidents of the Association. They have all been conducted strictly in accordance with the Admiralty rules, and by a government stoker who had never used Lancashire coal until he commenced to work at these trials.

The result has proved that the steam coal of this district is distinguished by the following characters:

1st. Hardness and durability, with the power of resisting the action of the weather.

2d. Smokelessness under the conditions mentioned below, even when the fires are driven as hard as possible.

3d. Great evaporative power and remarkable speed.

4th. The facility with which it can be used to work up the duff, or small refuse Welsh coal invariably arising from exposure to climate.

5th. That it is more completely under the control of the stoker than other steam coals, and materially lightens the labour of the men.

The following details will prove the value of the coal as compared with other steam coal:

1st. The average of all the experiments at Keyham,
9·41 with Hartley and hand-picked Welsh coals,
36·50 was 9·41 lb. of water evaporated per pound
of coal from 100° F., with a total evaporation of 36·50 cubic feet of water per hour.

2d. The average of the steam coals of the Lan-
10·10 cashire and Cheshire district was 10·10 lb.
46·67 of water evaporated per pound of coal from
100° F., with a total evaporation of 46·67 cubic feet of water per hour.

Making a gain in favour of the steam coals of this district of nearly 10 per cent. in power, and of above 25 per cent. in speed.

3d. The results in some experiments were as high
11·77 as 11·77 lb. of water per pound of coal,
76·65 in other experiments with a steam-jet, a
total evaporation of 76·65 cubic feet of water per hour was realized.

One very important fact shown by these trials is the smokeless quality of these steam coals when used with a suitable length of firebar, a proper thickness of fire, and with ordinary attention to the stoking.

With these results the Association requested the Admiralty to send down engineers to Wigan to verify the trials. Similar concessions had been made in 1858 and 1859, when Admiralty engineer officers were sent down to Elswick and Cardiff to report upon experimental coal trials. Eventually, after great efforts, and repeated representations to the Lords of the Admiralty, their lordships were pleased to consent to this course, and to direct that engineers should be sent to Wigan from Plymouth and Portsmouth Dockyards to make a similar report.

From the careful manner in which these trials have been conducted, and from the results appearing from them in the tables of the following report, there is little doubt that a favourable statement of the coals will be made to the Admiralty.

P.S.—Since the above report was written, the Government engineer officers have visited this district, to examine and report upon the experiments recorded in the following columns. During the course of their inquiry, it was suggested that an experiment should be made on board a large steamer. For this purpose, the Lindsay steamship, of 800 tons burthen and upwards, was placed at their disposal, and the results proved that these coals could be burnt with ease, by ordinary stokers, at sea, without the production of any smoke, whilst, at the same time, a full supply of steam was continuously maintained throughout the whole trial of four hours.

REPORT.

WIGAN, 1*st July*, 1867.

Messrs. '*The South Lancashire and Cheshire Coal Association.*'

GENTLEMEN,—1. We have now the honour of reporting the results of the experiments to which we have submitted your coals in a marine boiler, built according to the type of boilers used in the navy.

2. The coals which we have tried were selected for this inquiry in accordance with a circular, from which we extract the following details:

South Lancashire and Cheshire Coal Association,
Rooms, Clarence Hotel, Manchester,
22*d September*, 1864.

ADMIRALTY COAL LIST.

DEAR SIR,—The committee on this subject have determined on the reports of Joseph Dickinson, Esq., and Peter Higson, Esq., inspectors of mines (who have kindly assisted in the matter), that the following mines shall be sent to the Admiralty authorities for trial, and that the samples forwarded shall be taken from the colliery named opposite thereto.

MR. DICKINSON'S DISTRICT.

Worsley top four feet, . .	The Bridgewater Trustees, Worsley.
Upper Crumbouke, . .	Messrs. Green and Holland, Tyldesley.
Lower Crumbouke, . .	Messrs. Andrew Knowles and Sons, Pendlebury.
Upper three-yards, . .	Messrs. Knowles and Hall, Radcliffe.
Six-feet Rams, ...	Atherton Colliery, near Manchester, J. Fletcher and others. The Kirkless Hall Company, Westleigh,
Great seven-feet, ...	James Diggle, Esq., Westleigh.
*Roger, ...	The Lordsfield Colliery Company, Ashton-under Lyme.
Yard, ...	The Arley Main Colliery Company, Blackrod.
*Arley four-feet, . . .	The Executors of J. Hargreaves, Burnley.

MR. HIGSON'S DISTRICT.

From the Pemberton Little Delf, or two-feet mine, and Pemberton four-feet mine, where the two are so near together as to form one seam, . . .	Hindley Hall Colliery, belonging to Messrs. Pearson and Knowles.
From the Haigh or Arley Yard Mine, ...	Kirkless Hall Colliery, belonging to the Kirkless Hall Coal Company,
From the Furnace Mine, .	Ince Hall Colliery, belonging to Ince Hall Coal and Cannel Company.
From the Bickerstaffe four-feet, a Blaugate Mine, . .	Bickerstaffe Colliery, belonging to Messrs. Bromilow, Foster, and Co.
From the Rushy Park and Little Delph Mines, worked simultaneously and Mixed, .	The Garswood Park Colliery, St. Helens, belonging to Messrs Bromilow. & Brothers.
From the Ince three-feet, four-feet, and seven-feet mines, worked simultaneously and mixed, ...	Strangeways Hall Colliery, belonging to Wm. Heyes, Esq.
From the Arley Mine, . .	Haigh Colliery, belonging to Earl of Crawford and Balcarres.

3. In order to render the mass of details as intelligible as possible, we have arranged our report to embrace the various points in the following order, viz.:—

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* These coals were not tried, as the proprietors declined to send samples to the experimental boilers.

Hindley Yard Coal was submitted to experiment by a decision of the committee of the Association in lieu of those just named.

I. *The Apparatus.*
  1. Boiler.
  2. Feed.
  3. Draught.
  4. Temperature.
II. *Mode of Conducting the Experiments.*
III. *Modifications.*
  1. Firedoor.
  2. Grates.
  3. Fire Bridge.
  4. Steam Jet.
  5. Smoke.
  6. Clinker.
  7. Tubes.
IV. *Stowage.*
V. *Mixed and other Coals.*

I. THE APPARATUS.

1. *Boiler.*

4. The boiler is of the marine multitubular type, and corresponds in every respect to the one employed at Keyham for testing steam coal for use in the Government service. It is a type of the class used on board Her Majesty's steamers, though smaller than any in actual service, but preserving their general proportions. It is 8 ft. 10 in. high, 7 ft. 8 in. long, and 5 ft. wide, containing two furnaces, each 1 ft. 8⅝ in. wide, with wrought iron bars, 4 ft. long, 1 in. thick, and ½ in. spaces, and an ordinary vertical bridge. There are 124 available internal tubes, 5 ft. long, and 2¼ in. inside diameter, giving 364·7 square feet of heating surface. The area of the firegrate is 13·749 square feet. The chimney is 18 in. diameter, and 52 ft. high from the top of the boiler.

2. *Feed.*

5. The feed apparatus is extremely simple. The boiler is fed from a water-tank by a 2-in. direct pipe through a 2-in. stop-cock. The tank is situated a little distance from the boiler, and so placed that the bottom is nearly level with the top of the boiler. It is 9 ft. 6 in. long by 5 ft. 3¼ in. broad, having a superficial area of 50 square feet, with a capacity, therefore, in pounds, for every inch in depth, of 260½ lb. To this tank is affixed a graduated scale in feet and inches, the indicator of which is worked by an ordinary wooden float, so that the exact amount of water passed into the boiler can be correctly measured at any time. The stop-

cock for the admission of water is worked by hand, and so regulated as to keep the same level in the boiler, as nearly as possible, during the whole of the experiment.

3. *Draught.*

6. The draught in the chimney is correctly gauged by a syphon glass tube partly filled with water, the rise and fall of which indicates the strength of the draught. The draught in the flame chamber is also gauged in the same manner.

4. *Temperature.*

7. When the experiments were commenced, the boiler was uncovered and exposed to the air, which exerted a strong cooling action. The boiler is now protected with patent hair felt, upon which a covering of canvass is placed.

8. The results of this protection from the weather are shown by the following temperatures, which were carefully noticed at the time:—

Temperature of Air at Date.	50° Fah.	46° Fah.
Position of Thermometer.	Naked Boiler.	Covered Boiler.
	Degrees.	Degrees.
East side of boiler, ⅛ in. distant,	103	60
West side of boiler, 4 in. distant,	87	65
Back of boiler, ⅛ in. distant,	100	69
Top of boiler, 6 in. distant,	147 to 158	70

In front of ash-pit, 178° to 200°.

II. MODE OF CONDUCTING THE EXPERIMENTS.

9. The tubes are perfectly cleared and the boiler is filled with water to the standard level, at which point it is maintained, as nearly as possible, during the experiment.

10. The fires are lighted, and when they are brought into good ordinary working order, the time is noted, with other details, and the various observations are recorded from time to time until the experiment is finished.

11. The usual mode of stoking has been generally pursued, viz.: Charging the fresh coals in the front and pushing them forward as the combustion progresses, which we term the coking

system, or careful firing. In some experiments a random system of firing was adopted, which consisted in spreading the coal over the whole area of the grates. In all cases the mode of firing is recorded. Each furnace was fired alternately; but in some instances the furnaces were charged simultaneously without producing any perceptible effect as far as the appearance of smoke was concerned.

12. The thickness of the fuel on the grates has proved to be an important element in the proper management of your coals. We have tried 9, 12, and 14 in. fires, and in all instances, whatever were the other conditions, the greater the thickness of the fires, more speed and power were obtained from the coals. We select the following data from the records annexed in illustration of this point:

COAL.	Power, or Pounds of Water Evaporated per Pound of Coal.	Speed, or Cubic Feet of Water Evaporated per Hour.
Great 7 ft., 9 in. fires, . .	9·779	48·145
Blackrod yard, 9 in. fires, . .	10·236	44·748
Great 7 ft., 14 in. fires, . .	10·494	53·302
Blackrod yard, 14 in. fires, . .	11·057	45·363

13. The appearance and continuance of any smoke was recorded, according to the system adopted in the Government experiments at Keyham; and we would remark that, with thick fires, the formation of smoke was reduced to zero.

14. The fires were pricked whenever it appeared necessary, but in some instances this was dispensed with, and in such cases the fact is recorded. Nearly all the experiments prove the advantage of this practice, by which the grates being kept clear, more air is admitted, and both speed and power are increased.

15. In the management of this and every other point connected with the most profitable use of coal for raising steam, we cannot insist too strongly on the employment of men as fully trained for such duties as enginemen are expected to be, who have charge of the machinery in which the steam is employed or used. On all these points in our experiments, we think this the

proper place to record our warm approval of the skill and judgment of Mr. George Weeks, who has had charge of the fires during the whole period over which the experiments extended.

16. It would be tedious to you minutely to enter into a full description of all the details of the other observations made during the course of each experiment. These observations were recorded by Mr. Booth, who, being an independent party, has conscientiously noticed every fact, whether favouring or opposing our preconceived opinions as to the effect of any particular alteration.

17. In order to convey a better idea of the mode of conducting each experiment, we have made a copy of a few pages of the note-book, which will show the manner in which the record was kept. The figures in the columns headed *Water* indicate the number of inches run from the tank, while the figures in the columns headed *Coal* give the number of the weighings, each being 200 lb.

COPY OF RECORD OF EXPERIMENT.

	Index No. of Experiment,	220A.
	By whom witnessed,	W. I. Booth.
Date	Day of week,	Monday.
	Day of month,	March 25th, 1867.
	Hour and minute of Commencing experiment,	10 A.M.
	Description of coal tried,	Lower Crumbouke.
	Description of firedoor,	Perforated, No. 7.
	Area of perforations,	16·7 sq. in. (8·375 sq. in. in one door).
	Dead plate,	Closed.
	Total area of firegrate,	10·3125 sq. ft.
	Particulars of furnace bars,	Wrought iron.
	Length, thickness, windage,	3′ 0″ × 1″ × $\frac{1}{4}$″.
	Number of bars in row,	14 in each furnace.
	Temperature of air,	54°—53°.
	Temperature of feed-water,	42°—42°.
	Damper	Full open.
	Vacuum in chimney,	$\frac{3}{8}$″ full.
	Vacuum in flame-box,	$\frac{5}{16}$″.
	Temperature in flame-box,	No pyrometer.
	Temperature in smoke-box,	See stokes. Average 448.
	Ashes,	23 lb.
	Clinker,	24 lb.

REMARKS.

Careful firing—fires 14″ thick.
Intermittent perforations with fire-doors open occasionally—ashes used.
Verification of trial No. 220.
Experiment closed at 1.42 P.M.

RESULTS.

Duration of trial—3 hr. 42 min.
Water evaporated—41 in. = 10·677½ lb.
Pounds of water at 100° evap. per pound of coal = 11·278.
Cubic feet of water at 100° evap. per hour—48·77.
Smoke marks per hour—2·16.
6¾ in. of water evaporated from tank after experiment closed with the fuel left on the bars.

Hour of day 10 A.M., Monday, March 25th, 1867.					
Minutes.	Stoke Left.	Stoke Right.	Smoke.	Water.	Coal.
1	...	...	...	0	$\frac{1}{200}$
2	...	...	...	...	...
3	...	434°	...	...	...
4	1	...	...	...	...
5	...	...	1	...	...
6	...	...	1	...	...
7	...	454°	1	...	...
8	...	1	...	...	...
9	...	...	1	...	...
10	...	...	...	...	...
11	...	...	...	...	...
12	...	...	...	...	...
13	...	...	...	...	...
14	...	...	...	...	...
15	...	426°	...	...	...
16	1	...	...	...	...
17	...	...	...	...	...
18	...	...	...	...	...
19	...	...	...	...	...
20	...	...	...	...	...
21	...	...	...	...	...
22	...	426°	...	...	...
23	...	1	...	...	...
24	...	...	...	...	...
25	...	...	...	...	...
26	...	...	...	...	...
27	...	...	...	...	...
28	...	...	...	...	...
29	...	424°	...	...	...
30	1	...	..	...	...
Carried forward	3	2	4	0	200

19. In concluding our remarks on this portion of our report, we may perhaps explain that all the preliminary experiments were

made with the same coal, viz., from the yard seam. This was necessary in order to enable us to acquire a knowledge of the best mode of testing your coals, and to guide our opinion in forming a correct judgment of the importance to be attached to the various modifications as they were made, and which are explained in the following sections. If we had used first one coal and then another at this stage of our inquiry, we might have been at a loss whether to attribute the improvement or declension to the alteration introduced or to the change of fuel.

19A. In nearly every instance, each experiment was repeated, in some cases more than once, so that no error might escape our notice from want of verification.

20. In using fuel for raising steam, it is obvious that the success, commercially or otherwise, depends upon the quantity and the way in which the air is supplied to the fuel.

21. In all our experiments the air was admitted through the grates and a perforated fire-door.

22. The character of the coal must regulate the quantity of air to be admitted through the door or dead-plate. The combustion of Welsh coal being almost, so to speak, local, it does not require the admission of air through the fire-door; while the combustion of Hartley coal is greatly facilitated by a supply of air in the front of the furnace.

23. We had therefore to determine how far your coals required a modification on this point.

24. The sketches (two only of the best were given) of the fire-doors Nos. 1 to 7 will enable you to form a correct idea of the modifications we have tried.

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  o o o o o o o o o o o o o o o o o o o o o o o
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```
                          7
            o o o o       o o o o o o o
      o o o o o o o o o o o o o o o o o o
    o o o o o o o o o o o o o o o o o o o o o
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25. These modifications have been tried in connection with long and short grate-bars, and placed at different levels.

26. Having regard to the number of smoke marks, the temperature of the smoke-box, and the work performed, we have found that the perforations of the door, as shown in sketch Nos. 2 and 7, are those best adapted for your coals. With closed doors the combustion is imperfect, and accompanied with loss of power, as shown by the following experiments:

COAL.	Fire-door.	Power, or Pounds of Water Evaporated per Pound of Coal.	Smoke Marks.	Fires.
Haigh or Arley Yard,	Closed	10·421	277	12″ thick
Ditto.	Perforated	10·99	4	12″ thick
Ditto.	Perforated	11·246	0	14″ thick

27. The best mode of using these limited perforations, is to work the slides so as to close them altogether soon after a new charge has been thrown on the grates. The extra supply of air is needed just as the fresh coal commences to evolve its gas, while the air passing through the grates is amply sufficient, for perfect combustion, after the coal has been partially carbonised.

28. The experiments made with a perforated dead-plate, in connection with a smaller area of perforation in the fire-door, did not lead to any decisive result. This is due, as we believe, to the fact that the dead-plate is not under the same control as the door, and to the tendency of the combustion of the fuel to extend to the dead-plate; or, in other words, to a point where it is so desirable that the air, when admitted, should only mix with the coal gases in course of distillation for combustion in contact with the conducting surface of the boiler. We select the following results to show the difference between perforated and closed dead plates.

Coal.	Dead-plate.	Power, or pounds of water evaporated per pound of coal.	Speed, or cubic feet of water evaporated per hour.	Smoke marks.
Yard coal.	Perforated.	10·728	46·89	14
Ditto.	Ditto.	10·712	47·83	12
Ditto.	Closed.	11·311	47·21	9
Ditto.	Ditto.	10·749	49·107	5

2. *Grates.*

29. The different points to which we directed our attention in reference to the grates were their length, thickness, windage, and level.

30. We tried lengths of 2 ft. 3 in., 2 ft. 6 in., 3 ft., 3 ft. 3 in., and 4 ft., a thickness and windage of 1 in. × $\frac{1}{2}$ in., $\frac{7}{16}$ × $\frac{1}{4}$, $\frac{3}{8}$ × $\frac{3}{8}$, $1\frac{1}{16}$ × $\frac{3}{8}$, $1\frac{1}{16}$ × $\frac{5}{16}$, with three levels, *high*, *middle*, and *low*, the former being $9\frac{1}{2}$ in. below the crown of the furnace, the second $13\frac{1}{2}$ in., and two of the latter respectively 16 in. and 18 in.

31. We also tried bars of cast and wrought iron.

32. As regards the first of these modifications, without going into a minute criticism of our observations, we found that with bars 2 ft. 3 in. long it was impossible to burn off the coal to the best advantage, while with bars 4 ft. long there was a great loss of heat.

33. The length of grate which is evidently best adapted for your coals in this boiler is 3 ft., showing an area of 10·3155 square feet, with which we have practically a smokeless fuel, and accomplish the largest amount of work with the greatest economy.

34. The high level brings the grates too close to the crown of the furnace to enable the stoker to use the thick fires which are so advantageous, and the same remark applies to the mid-level grates.

35. The low-level grates have given the best results, as they enabled us to use fires 14 in. thick.

We select the following experiments in illustration:

Coal.	Level and length of grates.	Fires. Thickness.	Power, or pounds of water evaporated per pound of coal.	Speed, or cubic feet of water evaporated per hour.	Smoke marks.
Yard	High, 3′ 0″ × 1″ × ⅓″	About 6″	10·183	41·776	14
do.	do.	do.	10·178	42·188	19
do.	Mid, 3′ 0″ × 1″ × ½″	12″	10·712	49·54	10
do.	do.	do.	10·976	50·672	25
do.	Low, 3′ 0″ × 1″ × ½″	12″ to 14″	11·311	49·45	12
do.	do.	do.	11·289	48·16	9
do.	Low, 3′ 0″ × 1″ × ½′	12″ to 14″	10·153	44·38	8
do.	do.	do.	9·557	45·28	16

36. The thick fires undoubtedly act in virtue of the quantity of heat which is produced at the point best adapted for its conduction to the water. It is also probable that their more efficient action depends upon their bringing a mass of solid incandescent fuel in direct and close contact with the iron of the boiler. The conduction of the heat is much more rapid between these two solids—the fuel and the metal—than between mere heated gases and the tubes. The flame which sometimes passes over and under the bridges into the flame-chamber may be regarded as the contact of two solid substances, the flame in such cases being really solid particles in a state of incandescence, and, in good management, this flame never extends to the end of the tubes.

37. We believe that, with your coals, the great object ought to be to accomplish as much of the work as possible on the grates, and looking to the flame-chamber and tubes as auxiliaries to use the escaping heat of the flame and hot gases.

38. When so managed, coals of the type of this coal-field are admirably suited for marine boilers.

3. *Fire Bridges.*

39. Our modifications of this part of the apparatus were confined to the thickness of the bridge at the end of the grates, the air space above, and the addition of a hanging bridge with the air space below and that between the two bridges.

40. The variations in the case of the vertical bridges were limited to two thicknesses, 9 and 15 in., with an air space of 6 in., 9 in., and 14 in. above.

41. With the hanging bridge, the air space, between it and

the vertical bridge, was varied from 9 in. to 13 in., and below, 12 and 15 in. spaces were tried.

42. No material benefit was obtained by increasing the thickness of the vertical bridges, nor did the quantity of heat, thereby accumulated, assist in the prevention of smoke, and dispense with careful stoking.

43. When the air space was reduced to 6 in. above the bridge, with a view of deflecting the flame towards the boiler and increasing the reverberation in the flame-chamber, we found that the obstruction to the draught more than counterbalanced any advantage otherwise obtained.

44. The adoption of the hanging-bridge proved a decided improvement, not so much by increasing the power of the fuel, but by giving greater steadiness to the whole operation. The stoker was enabled to act with more freedom, and the accumulation of heat in the bridge at this point proved of great advantage in preventing the formation of smoke. For example:

COAL.	Power, or Pounds of Water evaporated per Pound of Coal.	Speed, or Cubic feet of Water evaporated per Hour.	Smoke marks.
Haigh yard, without hanging-bridge	11·068	50·596	20
Do. with do.	11·246	48·631	4

4. *Steam Jet.*

45. When experimenting with some of the coals, and in certain conditions of air, we found the draught of the chimney was occasionally too sluggish to elicit the full power and speed of the fuel.

46. The effect of the steam jet was most decided. The rate of evaporation was considerably increased, while with some of the coals the economy was but slightly diminished, as shown in the following results:

COAL.	Power, or Pounds of Water at 100° evaporated per Pound of coal.	Speed, or Cubic feet of water at 100° evaporated per hour.
Ince Mixed.		
Without steam jet, . .	9·855	47·309
With steam jet, . . .	9·582	76·658
Furnace Mine.		
Without Steam jet, . .	9·375	45·704
With steam jet, . . .	9·308	67·690

47. We would refer you to experiments Nos. I., II., in corroboration of the above statement.

48. It is almost needless to point out how important such a power as this application of the steam jet would become on board a ship under certain circumstances.

5. *Smoke.*

49. We have already more than once directed attention to the fact that when your coal is used in a manner suited to its character, it is truly a "smokeless fuel," and in the course of this inquiry we made some experiments in reference to this point.

50. The formation of smoke doubtless arises, in the case of coals of the character of those we have used, from the sudden evolution of gas when fresh coal is thrown on the furnaces, and when an extra supply of air becomes necessary for the perfect combustion of the gases.

51. This extra demand for air, under the circumstances above mentioned, is fully provided by the use of the perforated door; but, acting on our idea as to the too sudden evolution of gas, we brought a small water-pipe to the front of the boiler, with a branch entering each furnace just above the firedoor. This branch pipe was bent with a slight curye downwards in direction of the coal, and the end covered with a rose.

52. When a fresh charge of coals was thrown on the dead-plate, a fine shower of water was discharged on the surface of the coal to damp it, and thus regulate the distillation. In the experiments made with this arrangement, the number of smoke marks recorded were greatly diminished, and in some cases not

a single trace of smoke was evolved during the entire duration of the trial.

53. As our knowledge of the proper method of using your coal increased, we found it totally unnecessary to have recourse to this or any other expedient for this purpose.

6. *Clinker.*

54. The formation of clinker on the grates is a serious drawback to the use of nearly every description of coal.

55. The character of the clinker greatly varies, some being dry and others of a pasty consistence. Some are easily removed from the grates when cold, and others are firmly attached.

56. In many cases the clinker is formed at the expense of the grate bars. This difficulty has been overcome, in some cases, by covering the grates with blocks of limestones; but such a plan is unsuited for marine boilers. Coating the bars with fire-clay, burnt into shape, has also been tried with excellent results.

57. We made some experiments on this point, modifying the above experience in the following way: We mixed a small quantity of lime with the coal before throwing it on the grates, in the hope that the lime would form a dry residuum with the ashes of the coal, but the result, although favourable, was not so decided as to justify us in prosecuting the inquiry.

7. *Tubes.*

58. We often had occasion, during the earlier experiments, to examine the working of the fires, the action of the fire-bridges, and the reverberation of the flame in the flame-chamber. This was done by looking through the *sight-holes* in the back and sides of the boiler, which were opened for the purpose.

59. The opinion being very generally entertained that the flame, in passing from the furnace to the smoke-box, escaped through only a portion of the tubes, leaving the other tubes comparatively useless, we tried some experiments in which some of the tubes were plugged.

60. As the lower ranges lie over the fires where the heat is greatest, we thought that, in diverting the flame to the higher rows of tubes, we might effect a better absorption of the heat, and thus improve both the power and speed of the coal.

61. We put our ideas into practice by plugging the lower ranges, as well as other modifications, and carefully watched the results.

62. These results did not satisfy our expectations, and the experiments were discontinued. They, however, prove that the number of tubes may be diminished without lessening the power of the boiler.

YARD COAL.	Power, or Pounds of Wa. at 100° evaporated per Pound of Coal.	Speed, or Cubic feet of Water at 100° evaporated per hour.
Tubes all open, ...	10·897	46·49
Tubes plugged up in alternate rows diagonally, ...	11·039	44·157

IV. STOWAGE.

63. In this respect your coal holds a prominent position among the best steam coal of this country.

The following figures give the weight of a cubic yard of various coals in different conditions:

Name of Coal.	Condition of the Coal.		
	Round.	Broken for use.	Beans.
	c. qr.	c. qr.	c. qr.
Lancashire Coal, .	12 1	12 0	12 1
Newcastle ,, .	12 0	11 3	No beans.
Welsh . ,, .	12 0	11 3	12 1
Lancashire round and Welsh dust mixed, .	...	14 3	...

V. MIXED COALS.

64. It having been suggested that we should try various mixtures of Lancashire coals, we made several experiments, which are recorded in sheets Nos. 30 and 31.

65. Two classes of mixtures were tried, the one being made up of different Lancashire coals, and the other of Lancashire and Welsh coals.

66. The results confirm those obtained in previous experiments, the speed and power of the mixture being about a mean of that of each coal.

67. The value of the Lancashire coals is also shown in the efficiency of a mixture of the dust of Welsh coal with Lancashire coal. The former was so fine that it could not have been burnt alone on the grates. The following experiments are quoted in illustration of this point:—

COAL.	Power, or Pounds of Water Evaporated per Pound of Coal.	Speed, or Cubic Feet of Water Evaporated per Hour.	Smoke Marks.
Lancashire round, . .	11·311	48·220	8
Welsh round, . . .	11·140	47·560	6
Newcastle round, . . .	10·845	52·111	5
Lancashire round and Welsh dust, mixed, . .	10·604	41·384	0

Other Coals.

68. Having employed the inverted fire-bridge in most of our experiments, it was thought desirable to submit Welsh and Newcastle coals to trial under the same conditions.

69. The following are the results — from which it appears that we have obtained rather more work and economy than in previous trials with these coals, which are placed alongside for the purpose of comparison:

	WIGAN EXPERIMENTS.		KEYHAM EXPERIMENTS.	
COALS.	Power, or Pounds of Water Evaporated per Pound of Coal.	Speed, or Cubic Feet of Water Evaporated per Hour.	Power, or Pounds of Water Evaporated per Pound of Coal.	Speed, or Cubic Feet of Water Evaporated per Hour.
Newcastle, .	10·845	52·111	10·71	44·6
Welsh, . .	11·117	49·645	10·14	40·6

70. The small of your coal is itself of superior quality, and we have reported a trial made with yard slack to determine this point, with the following result:—

COAL.	Power, or Pounds of Water Evaporated per Pound of Coal.	Speed, or Cubic Feet of Water Evaporated per Hour.	Smoke Marks.
Yard slack, ...	9·263	34·073	13
Yard round and Welsh dust, mixed,	10·604	41·384	0

71. The value of the small coal, in the case of the Lancashire coals, evidently arises from their physical character.

72. The Lancashire coals are of a hard nature, resist the disintegrating action of the weather, and the small coal produced by attrition is of a rubble character, quite unlike the dust which is produced by the Welsh coal under the same circumstances.

CONCLUSIONS.

73. The great power of this coal, the rapidity of its combustion, its smokeless character when properly used, and the facility with which it is managed by the stoker, places it in the first rank of steam coals.

74. We think that these experiments fully prove the value of Lancashire and Cheshire coals for use on board steamships, both in Her Majesty's navy and in the commercial steam marine.

We have the honour to remain, Gentlemen,
Your obedient Servants,
THOMAS RICHARDSON.
LAVINGTON E. FLETCHER.

32. *Liquid Fuel.*—Under the above title a paper was read before the Society of Arts, London, by Benjamin H. Paul, Esq.:—"The economy of fuel is a subject of so much importance in a variety of aspects, and it affords so much scope for improvement, that any suggestion made with that object is always deserving of full consideration; and, even if such suggestion should be impracticable or erroneous, it is at least worth while to demonstrate clearly the circumstances which may be considered as justifying an adverse opinion. That such a course is appropriate in regard to a project which is expected to involve a reconstruction of our navy and a radical revolution in steam navigation, will, I apprehend, be readily admitted.

The proposal to substitute for the coal now used as fuel in steam vessels some kind of liquid combustible, is an offshoot of the excitement which has prevailed during the last few years in regard to the discovery of vast quantities of petroleum in America; and it was that material which was in the first instance recommended as the substitute for coal. A commission, appointed in America to investigate the subject, reported that petroleum was beyond doubt more than twice as effective as anthracite coal in the production of steam, and that steam could, by the use of this material, be produced in less than half the usual time.

It was an inference by no means unnatural that if this were the case, and if coal could be superseded by this material as the fuel of steam vessels, a very great portion of the space required in merchant steamers for the stowage of coal would be rendered available for more profitable cargo; that steam packets might become independent of coal depôts at various points of their passage; and that vessels of war would be enabled to keep the sea for a very much longer time than they now do with coal. Any prospect of such advantages as these being attainable might reasonably have been expected to justify a more thorough and searching investigation of this subject than it has yet received in this country.

Besides petroleum, several other analogous materials have been proposed as substitutes for coal; for instance, the oil obtained by distilling some kinds of coal, or the shale which occurs in coal formations, and more recently the oil known as 'dead oil,' which is one of the products obtained in rectifying the coal tar of gas-works. All these materials resemble each other closely in being composed chiefly of carbon and hydrogen, which are, in various proportions, the combustible and heat-producing constituents of all kinds of fuel. For the application of these materials, and of liquid fuel generally, various methods have been proposed; but before speaking of them it is desirable to consider what is the evaporative power of these materials respectively, since that is a very important point to determine in regard to the question as to the relative merits of different kinds of fuel.

The heat generated by combustion has been made the subject of the most careful investigation; and since the time of Lavoisier, Laplace, and Rumford, the more precise measurement of the amounts of heat capable of being produced by the combustion of carbon and hydrogen has been repeated by several physicists with results that agree so closely that they may safely be regarded as well established. The names of Dulong, Despretz, Andrews, Favre, and Silbermann, are, moreover, an unquestionable guarantee that these results, and the methods by which they were obtained, are perfectly trustworthy. According to these results, the maximum heat-producing capabilities of carbon and hydrogen are in the ratio of 1 to 4·5. The actual quantities of heat generated by the combustion of a pound of carbon or of hydrogen are as follows:—

Relative Calorific Power.

	lb.	Heat Units.	
Carbon, . .	1	14,500	1·00
Hydrogen, . .	1	62,032	4·28

The heat unit here referred to is the quantity of heat which raises the temperature of 1 lb. of water 1° Fahr. (from 40° to 41°). Therefore the numbers given in the table represent the quantities of water capable of being heated 1° Fahr. by the conversion of 1 lb. of carbon into carbonic acid gas, or of 1 lb. of hydrogen into water. As there are in the Fahrenheit thermometric scale 180° between the freezing point and boiling point of water, those numbers divided by 180 give the corresponding quantity of water capable of being heated from 32° to 212° Fahr. Again, the quantity of heat required to convert 1 lb. of water at 212° Fahr. into steam of the same temperature, is nearly 5½ (more exactly 5·37) times as much as that requisite to heat 1 lb. of water from the freezing point to the boiling point, therefore the quantities of steam capable of being produced from water at 212° Fahr. by the total heat generated in the combustion of 1 lb. of carbon or of hydrogen are of course ascertainable by dividing the number of pounds heated from 32° to 212° Fahr. by 5·37. These several quantities are given in the following table:—

Quantities of water			
Heated,		or converted into steam,	by the heat generated in combustion of
From 40° to 41° F.	From 32° to 212° F.	From water at 212° F.	
Pounds.	Pounds.	Pounds.	Pounds.
14·500	80·55	15·	1 carbon.
62·032	344·62	64·2	1 hydrogen.

These quantities of 15 lb. and 64·2 lb. of water convertible into steam by the total heat generated in the combustion of 1 lb. of carbon or of hydrogen, represent what is termed the 'theoretical evaporative powers' of those substances. By the term theoretical, however, it is not to be understood that these values are in any degree imaginary or assumed; they represent actual facts, which have been established as the results of positive observation, and they are theoretical in reference to the practical application of fuel only in this sense, that these results are not realized in ordinary practice. The reason of this is not the existence of any uncertainty that the total quantities of heat generated by burning 1 lb. of carbon or 1 lb. of hydrogen are respectively capable of converting 15 lb. and 64·2 lb. of water at 212° Fahr. into steam; but it is simply the fact that, under ordinary circumstances, only a portion of the total heat generated in either case is ever available for the production of steam. The statement of the theoretical evaporative power of fuel, or of carbon and hydrogen as constituents of fuel, is, therefore, like the statement of relative calorific power, only an expression of their relative capabilities, and it indicates in this respect a limit which, though it cannot be exceeded in any case, is never fully attained in practice.

In order to ascertain what portion of the heat resulting from the combustion of carbon and hydrogen is available for producing steam, it is necessary to consider what are the conditions under which fuel is usually burnt, and what becomes of the heat generated in the two cases. In making this inquiry it is also necessary to remember that the several substances concerned in the combustion of fuel require different quantities of heat to produce equal increments of temperature in equal weights, as stated in the following table:—

Quantities of Heat.

One pound of	Carbonic acid gas requires	·217	To raise its temperature from T to T+1° F.
	Nitrogen ,,	·245	
	Atmospheric air ,,	·238	
	Steam ,,	·475	
	Water ,,	1·000	
	Water at 212° Fahr. ,,	966·100	for conversion into steam.

It will be seen that water has by far the greatest capacity for heat, both in the state of liquid and vapour, and that a very large quantity of heat is rendered latent in the conversion of water into steam.

In the combustion of carbon, each pound requires for its conversion into carbonic acid gas 2·67 lb. of oxygen, which is derived from atmospheric air, and as this contains only 23 per cent. by weight of oxygen, it is necessary to supply about 12 lb. (more accurately 11·61 lb.) of air for every pound of carbon burnt.

In the combustion of hydrogen, 8 lb. of oxygen are requisite for each pound of hydrogen, and to furnish this about 35 lb. (more accurately 34·78 lb.) of air must be supplied.

But fuel is never burnt for raising steam in such a way that the supply of air is only just sufficient to furnish oxygen for the conversion of its carbon into carbonic acid gas, and of its hydrogen into water vapour. In order to maintain combustion it is necessary to remove the gaseous products from the furnace, as well as to supply fresh air continually; and when this is effected, as usual, by the draught of a chimney, the gaseous combustion products become mixed with the fresh air to some extent. The effect of this intermixture would be to retard the combustion of the fuel, if the amount of burnt air or combustion products in the atmosphere of the furnace exceeded a certain proportion. Consequently, it is necessary to prevent this by supplying more air than would suffice to furnish oxygen for combustion, so as to dilute the combustion products and maintain an excess of oxygen in the atmosphere immediately surrounding the fuel in the furnace. Careful observation has shown that in ordinary boiler furnaces the quantity of air requisite for this purpose amounts to as much as that requisite for effecting the chemical change which takes place in combustion, so that the total supply of air to such a furnace requires to be at the rate of about 24 lb. per pound of carbon burnt, and about 70 lb. per pound of hydrogen burnt.

Under ordinary circumstances the relation between the quantities of these substances burnt as fuel, the total heat generated, the air supply requisite for supporting combustion, and the furnace gas resulting from it will be as follows:—

Fuel.	Quantity Burnt.	Air Supply.	Total Heat Generated.	Furnace Gas.
	lb.	lb.	Heat units.	lb.
Carbon, . .	1	23·22	14·500	24·22
Hydrogen, .	1	69·56	62·032	70·56

The heat generated in either case is, at the moment of combustion, transferred to the gaseous combustion product, and raises its temperature. In the combustion of carbon, the whole of the heat is effective in this way; but in the combustion of hydrogen, a portion of the heat generated is consumed in determining the vaporous condition of the water produced, in the proportion of 9 lb. for each pound of hydrogen burnt. As 1 lb. of water at 212° Fahr. requires 966·1 heat units to convert it into steam of the same temperature, the quantity of heat which becomes latent in this way amounts to 8694·9 heat units (9 × 966·1) per pound of hydrogen burnt, or 14 per cent. of the total heat of combustion. That portion of the heat is ineffective, either for increasing the temperature of the combustion product, or for producing steam in the boiler, and it must therefore be deducted from the total heat generated, in order to ascertain the amount of heat available, which is as follows, compared with that generated by the combustion of carbon:—

	Quantity Burnt.	Total Heat generated.	Latent Heat of Water Vapour produced.	Available Heat.	Equivalent Evaporation of Water at 212° Fahr.
	lb.	heat unit.	heat unit.	heat unit.	lb.
Carbon, .	1	14,500	...	14,500	15
Hydrogen. .	1	62,032 =	8,695 =	53,337	55

In the combustion of carbon under the conditions above mentioned, the products constituting the furnace gas amount to nearly 25 lb. per pound of carbon burnt, and they require the following quantities of heat to raise their temperature 1° of Fahrenheit's scale :—

			SPECIFIC HEAT.		
	lb.		Heat units.		Heat units.
Carbonic acid gas, .	3·67	×	·217	=	·79639
Nitrogen, . .	8·94	×	·245	=	2·19030
Surplus air, . .	11·61	×	·238	=	2·76318
	24·22				5·74987

The increase of temperature resulting from the combustion of carbon is therefore found by dividing the number of heat units, representing the total quantity of heat generated, by the number of heat units requisite to raise the temperature of these combustion products, &c., 1°, and it amounts to

$$2522^\circ \text{ Fahr.} = \frac{14\cdot500}{5\cdot75}.$$

In the combustion of hydrogen, under the same conditions, the products constituting the furnace gas amount to about 70 lb. per pound of hydrogen burnt, and they require the following quantities of heat to raise their temperature 1° of Fahrenheit's scale :—

			SPECIFIC HEAT.		
	lb.		Heat units.		Heat units.
Water vapour, . .	9	×	·475	=	4·27500
Nitrogen gas, . .	26·78	×	·245	=	6·56110
Surplus air, . .	34·78	×	·238	=	8·27764
	70·76				19·11374

Consequently, the increase of temperature resulting from the combustion of hydrogen is :

$$2{,}791^\circ \text{ Fahr.} = \frac{62{,}032-8{,}695}{19\cdot114}.$$

So far, therefore, as relates to increase of temperature the effect produced by the combustion of hydrogen under these conditions is not much greater than that produced by the combustion of an equal weight of carbon, notwithstanding the great difference in the actual quantities of heat generated, as shown below :

		Total Heat Generated.	Available Heat.	Increase of Temperature.
	lb.	Heat units.	Heat units.	
Carbon, . . .	1	14,500	14,500	2,522° Fahr.
Hydrogen, . .	1	62,032	52,337	2,791° Fahr.

We have now to consider what portions of the available heat are, under ordinary conditions, effective in producing steam. The heated furnace gas, resulting from the combustion of the carbon or the hydrogen of fuel, is the medium by which the heat generated is transferred to the water in the boiler; and if it could be managed that between the moment of combustion and the time when the furnace gas resulting from it is discharged into the chimney, the whole of the available heat could be communicated to the water in the boiler, the evaporative effect realized might then be equal, or nearly equal, to the theoretical evaporative power of the fuel burnt. But this is never the case in ordinary practice.

The extent to which the available heat could, in any case, become effective in producing steam by direct transmission to the boiler, must, of course, be limited by the temperature corresponding to the pressure at which steam is to be raised. If that were 50 lb. per square inch, the furnace gas could not be cooled down below 360° Fahr. before being discharged from the heating surface of the boiler into the chimney. The quantities of heat which would in such a case pass away in the furnace gas without being directly effective in producing steam in the boiler would amount to 12 per cent. in the combustion of carbon, and to 15 per cent. in the combustion of hydrogen, as follows:

	Quantity Burnt.	Furnace Gas.	Quantity of Heat requisite to produce increase of Temperature.	Equivalent Evaporation of Water at 212° Fahr.
	lb.	lb.	Heat units.	lb.
Carbon, .	1	25	300° × 5·750 = 1,725	1·8
Hydrogen, .	1	70	300° × 19·114 = 5,734	5·9

These quantities of heat would therefore be wasted as regards production of steam, except in so far as they might be applied in heating the feed water supplied to the boiler.

But when, as in ordinary practice, the supply of air for supporting combustion is maintained by the draught of a chimney, the temperature of the furnace gas cannot in any way be reduced below about 660° Fahr. without interfering with the draught of the chimney, and thus a considerably larger waste of heat is occasioned. In the case of furnace gas, discharged at 600° Fahr. above the temperature of the air supplied to the furnace, this waste amounts to 24 per cent. of the available heat resulting from the combustion of carbon, and to 22 per cent. of that resulting from the combustion of hydrogen, these amounts being equivalent to the evaporation of 3·6 lb. of water at 212° Fahr. per pound of carbon burnt, and to 11·9 lb. of water at 212° Fahr. per pound of hydrogen burnt. In many instances the furnace gas is discharged into the chimney very much more than 600° Fahr. above the temperature of the external air, and then the waste of heat is, of course, still greater in proportion as the temperature is higher.

From these considerations it will be evident that in the combustion of fuels, under ordinary conditions, there is always a great waste of heat. But though the total waste is considerably greater in the combustion of hydrogen than it is in the combustion of carbon, amounting in the one case to 32·6 per cent., and in the other to 24 per cent. of the total heat of combustion, the evaporative efficacy of hydrogen is nearly four times as great as that of carbon. This comparison does not take into account those sources of waste which are due to imperfect combustion, but applies only to such portions of the carbon and hydrogen of fuel as are actually burnt in the furnace. In this case the comparative efficiency of these constituents of fuel in producing steam is as follows:

Combustion of Carbon.

Quantity Burnt, 1 lb.		Equivalent Evaporation of Water.	
		At 212°.	At 60°.
	Heat units.	lb.	lb.
Total heat of combustion, . .	14,500	15	...
Available heat, . . .	14,500	...	...
Waste heat of furnace gas, . .	3,480	3·6	...
Effective heat, . . .	11,020	11·4	9·8

Combustion of Hydrogen.

Quantity Burnt, 1 lb.		Equivalent Evaporation of Water.	
		At 212°.	At 60°.
	Heat units.	lb.	lb.
Total heat of combustion, . .	62,032	64·2	...
Latent heat of water vapour, .	8,695	...	...
Available heat, . . .	53,337	...	...
Waste heat of furnace gas, .	11,520	11·4	...
Effective heat, . . .	41,817	43·3	3·8

Thus the maximum evaporative efficacy of carbon and of hydrogen is, for each pound burnt, respectively equal to the conversion of about eleven and a-half pounds and forty-three and a-half pounds of water at 212° Fahr. into steam of the same temperature and under the ordinary atmospheric pressure. The extent to which this efficacy is realized in the ordinary application of fuel for producing steam will depend upon the relative facilities afforded by the rate of combustion and by the construction of the boiler, for the full absorption of the effective heat from the combustion products during their passage along the flues or tubes of the boiler before being discharged into the chimney. But whatever may be the influence of these conditions in regard to evaporative effect produced, they do not in any degree affect the foregoing considerations as to the maximum evaporative capabilities of the carbon and hydrogen of fuel when burnt in the manner stated, with a supply of air just twice as great as the quantity requisite for their conversion into carbonic acid gas and water vapour.

In the combustion of hydrocarbons under these conditions, whether they be solid, liquid, or gaseous, the total amount of heat generated will be determined by the relative proportions of the carbon and hydrogen they contain. The amount of hydrogen in such substances generally ranges from one-seventh to one-fourth by weight, and for such limits the corresponding amount of heat generated by their combustion and their theoretical evaporative power would be as follows:

Hydrocarbon Burnt.	Carbon.	Hydrogen.	Total Heat of Combustion.	Equivalent Evaporation of Water at 212° Fahr.
lb.	lb.		Heat units.	lb.
1	·86		× 14,500 = 12,470	
		·14	× 62,032 = 8,684	
			21,154	21·9
1	·75		× 14,500 = 10,775	
		·25	× 62,032 = 15,508	
			26,283	27·1

The difference between the theoretical evaporative power of hydrocarbons comprised within these limits of composition and their evaporative efficacy, will also be determined by the relative proportions of carbon and hydrogen they contain, just in the same manner as shown already, so far as relates merely to the mode in which the heat generated is disposed of amongst the combustion products constituting the furnace gas resulting from their combustion. And it is here necessary to notice another circumstance of considerable importance as regards the advantageous application of hydrocarbon fuel.

The following tabular statement will show the manner in which the heat that is consumed in producing a chimney draught is distributed among the combustion products constituting the furnace gas :

Combustion of Carbon.

	Furnace Gas from 1 lb. Carbon.	Quantities of Heat in Furnace Gas.	Equivalent Evaporation of Water at 212° Fahr.
	lb.	Heat units.	lb.
Carbonic acid gas,	3·67	600° × ·8 = 480	·5
Nitrogen gas,	8·94	600° × 2·2 = 1,320	1·4
Surplus air, .	11·61	600° × 2·8 = 1,680	1·7
	24·22	3,480	3·6

It will be seen from this Table that while the total waste of heat in the furnace gas from the combustion of 1 lb. of carbon is equivalent to 3·6 lb. of steam, more than one-half of that heat is consumed in raising the temperature of the surplus air supplied for diluting the combustion product in the furnace. Consequently, any arrangement by which the surplus supply of air could be dispensed with, and combustion maintained at the same rate, would effect a reduction of the waste heat to the extent of 50 per cent., and an economy of the heat generated by the carbon of the fuel, amounting to nearly 12 per cent. Herein consists the advantage gained by driving the air into a furnace, instead of drawing it in by means of a chimney; for in that case the supply of air may be reduced to just enough to support combustion, and at the same time the temperature of the furnace gas may be so far reduced, either within the flues or tubes of the boiler, or in a feed-water heater as to render the greater part of the heat contained in it effective for production of steam.

This possibility of economising in this way the heat generated by combustion of carbon is by no means unimportant; but it is of far greater importance as regards the heat generated by combustion of hydrogen; for in this case the total waste of heat arising from the discharge of the furnace gas at 600° Fahr. above the temperature of the air supply is equivalent to about 12 lb. of steam per pound of hydrogen burnt, and nearly one-half of this is consumed in heating the surplus air supply.

Combustion of Hydrogen.

	Furnace Gas from 1 lb. Hydrogen.	Quantities of Heat in Furnace Gas.	Equivalent Evaporation of Water at 212° Fahr.
	lb.	Heat units.	lb.
Carbonic acid gas,	...	...	...
Water vapour, ...	9·00	600° × 4·3 = 2,580	2·7
Nitrogen gas, ...	26·78	600° × 6·6 = 3,960	4·1
Surplus air, ...	34·78	600° × 8·3 = 4,980	5·1
	70·56	11,520	11·9
		Latent heat of water vapour... 8,695	9·0
		20,215	20·9

Therefore by dispensing with this surplus air, and cooling the furnace gas in a feed-water heater, a saving of something like one-fourth of the total available heat might be effected. A further advantage would also result from the increased temperature of combustion; viz., 4692° Fahr. for carbon, and 4922° Fahr. for hydrogen, and the consequent more ready transmission of heat from the combustion product to the water in the boiler.

The combustion of the carbon and hydrogen of fuel presents another point of difference, which is important as regards the extent to which the available heat is, under ordinary conditions, capable of being rendered effective in producing steam. This difference is due to the presence of water vapour in the furnace gas, resulting from the combustion of hydrogen. As a consequence of this circumstance a large amount of heat is absorbed and rendered ineffective for producing steam. From the foregoing Table, representing the disposition of heat amongst the furnace gas, it will be seen that every pound of water vapour in the furnace gas corresponds to a waste of heat sufficient to produce rather more than 1¾ lb. of steam; and hence it will be evident how great is the disadvantage resulting from the presence of water in the furnace gas, whether originating from hydrogen burnt or from damp fuel or otherwise.

The volumes of the air supply and combustion products for the extreme cases of hydrogen and carbon are as follows:

	Air Supply at 60° F.			Combustion Products at 660° F.	
	lb.	lb.	cubic feet.	lb.	cubic feet.
Carbon, . .	1	24	320	25	630
Hydrogen, . .	1	69	960	70	2044

In the combustion of carbon there is no expansion of volume in the combustion product, except that due to the heat generated, which would render the volume at the temperature of combustion (2522° Fahr.) rather more than six times that of the air supplied. By the transfer of heat to the boiler, to such an extent as to reduce the temperature to 660° Fahr., the volume would be reduced again to about 630 cubic feet per pound of carbon burnt.

In the combustion of hydrogen the supply of air required is about three times as large as that required in the combustion of an equal weight of carbon. There is also an expansion of the combustion products, independent of the heat generated, and amounting to one-half the normal volume of the hydrogen burnt. The expansion due to heat is also greater than in the combustion of carbon, on account of the greater amount of heat generated, so that the volume of the furnace gas at the temperature of combustion (2791° Fahr.) would be about six and a half times that of the air supplied, and the volume of gas discharged into the chimney would be about three and a-half times as great as in the combustion of an equal weight of carbon. This larger quantity of gas will, however, contain nearly four times as much effective heat as that resulting from the combustion of an equal weight of carbon, and its temperature will be about 270° higher, so that in this respect the use of fuel containing a large amount of hydrogen, provided it can be perfectly and readily burnt, presents an advantage as compared with fuel consisting almost entirely of carbon. Rather more than one-fourth of a pound of hydrogen would give as much effective heat as 1 lb. of carbon with a somewhat smaller volume of combustion products. The extent to which this advantage affects the value or efficiency of fuel will, of course, depend on the amount of hydrogen it contains. Since no hydrocarbon available as fuel contains more than 15 per cent. of hydrogen, the actual evaporative efficacy of such a material, when used under the ordinary conditions, cannot, at the utmost, be more than about 40 per cent. greater than that of an equal weight of carbon. This, assuming it to be perfectly burnt, and the arrangement of boiler flues or tubes, &c., to be favourable for the transfer of heat, is the maximum effect to be looked for according to the data already given.

The amount of hydrogen in petroleum is probably larger than in any of the other hydrocarbons proposed to be used as fuel, and that contains, on the average, about 13 per cent. In coal and shale oil the amount of hydrogen is less. Consequently the evaporative efficacy of these materials, as compared with carbon, would not reach the above limit of 40 per cent. in excess. The ratio between these materials and ordinarily good coal is much about the same in regard to evaporative efficacy, since the hydrogen contained in coal compensates for the oxygen and ash it contains, unless the amount of these is very considerable.

The following Tables show the relation between the total heat of combustion and the available heat of hydrocarbons, containing respectively 14 and 25 per cent. of hydrogen, as the amounts of heat consumed in the furnace gas, and the mode in which it is disposed of:—

1 lb. of hydrocarbon, containing 14 per cent. of hydrogen, yields about 31 lb. of furnace gas, consisting of—

	Furnace Gas.	Quantities of heat in Furnace Gas.	Equivalent Evaporation of Water.	
			At 212°	At 60°
	lb.	Heat units.	lb.	
Carbonic acid gas, .	3·16	411		
Water vapour, . .	1·26	359		
Nitrogen gas, . .	11·45	1,683		
Sulphur air, . .	14·37	2,124	2·2	
	30·74	4,577	4·8	
Total heat of combustion, . .		21,154		
Latent heat of water vapour, .		1,217	1·3	
Available heat, ...		19,937		
Waste heat of furnace gas, . .		4,577	4·8	
Effective heat, ...		15,360	15·8	
Theoretical evaporative power, .		...	21·9	
Relative evaporative efficacy as compared with carbon or coal, = 1 . .			1·39	

1 lb. of hydrocarbon containing 55 per cent. of hydrogen yields about 36 lb. of furnace gas, containing—

	Quantities of heat in Furnace Gas.	Quantities.	Equivalent Evaporation of Water.	
			At 212°	At 60°
	Heat units.	lb.	lb.	
Carbonic acid gas, .	358	2·75		
Water vapour, . .	641	2·25		
Nitrogen gas, . .	1968	13·39		
Surplus air, . .	2483	15·39	2·6	
	5450	35·78	5·6	
Total heat of combustion, . .		26,283		
Latent heat of vapour, . .		2,174	2·2	
Available heat, ...		24,109		
Waste heat of furnace gas, . .		5,450	5·6	
Effective heat, ...		18,659	19·3	
Theoretical evaporative power, .		...	27·1	
Relative evaporative efficacy as compared with carbon or coal = 1 . .			1·69	

I am not aware of any liquid hydrocarbon applicable as fuel which contains so much as 25 per cent. of hydrogen, so that an evaporative effect of about 16 lb. of steam per pound of hydrocarbon burnt must be regarded as the maximum result to be attained with such material used as fuel. By burning these hydrocarbons with only just enough air for combustion, or half the quantities assumed to be supplied in these estimations, the effect capable of being realised would be from 13 to 14 per cent. greater than in the case stated above, or about 18 lb. of steam per pound of hydrocarbon containing 14 to 15 per cent. of hydrogen.

The plan of using liquid fuel, which, so far as I am aware, has proved the most advantageous, is one which does, to some extent, at any rate, secure the advantage to be gained by forcing air into the furnace. According to this plan, the oil is supplied to the furnace through a small pipe, together with a jet of high-pressure steam, by which it is converted into spray, much in the same manner as in the toy known as the perfume vaporiser a liquid is blown out of a bottle by a current of air. The steam jet at the same time induces a current of air which mixes with the oil spray and supports its combustion. This is the arrangement used by Messrs. Field and Aydon, and it appears to work exceedingly well, and to effect a perfect combustion of the oil. The oil I have seen used in this way was the dead oil, or creosote oil, which is a refuse product in the refining of gas tar. It possesses characters which render it much preferable to pretroleum or the oil obtained by distilling coal at a low heat for use as liquid fuel. In the first place, its density being greater than that of water—the gallon weighing about 12 lb.—it takes less space for stowage than petroleum or coal oil, the gallon of which weighs only from 8 to 8¼ lb. For the same reason it would not be so dangerous as the lighter oils in case of accident; for instead of floating on the surface of water and burning it would sink harmlessly. Again, its very high boiling point, approaching to a red heat, and the great density of its vapour as compared with that of petroleum or coal oil, are great advantages as regards risk of explosion, in consequence of the oil vapour becoming mixed with air and then catching fire. This could hardly take place with the dead oil, except at a very high temperature, while petroleum readily gives off vapour to the air at a moderate degree of heat.

Unfortunately, the quantity of this oil which is available is very small as compared with the requirements of steam navigation, probably not amounting to 100,000 tons a year in the whole country, and therefore its application must be very limited.

In order now to arrive at some estimate of the advantage to be gained in a steam vessel, either in point of weight to be carried, or space occupied by liquid fuel as compared with coal, it is evident that 100 tons of petroleum, or coal oil, would do the work of about 140 tons of good coal. But as coal is rarely burnt in such a way as to be rendered useful to its full capability, and as there is always a considerable waste in the shape of dust and cinders, which would not be the case with liquid fuel, a further allowance must be made for this. Assuming that one-fifth of the coal is wasted in this way, then the equivalent of 100 tons of oil would be 175 tons of coal, for taking the density of the oil as ·850, it would occupy about the same space as an equal weight of coals, or at the rate of about 53 lb. per cubic foot. This difference would enable a vessel capable of carrying coals for 12 days' steaming to carry oil for 21 days. In burning this oil there would be a saving of labour in stoking, and as it would not give any ashes, a great deal of trouble would be saved in that way.

These results differ widely from the statements which have been made in reference to the relative efficiency of oil and coal, according to which it has been represented that one ton of oil was equal to from four to five tons of coal, and that in regard to stowage room the saving was 'more than five-tenths in bulk!' It is true that those who have propounded these views have not arrived at them by a consideration of the data I have above referred to; and, if I may judge from remarks lately made at the meeting of the Institution of Naval Architects, they would appear to deny the applicability of those data for determining the question between coal and oil as fuel. Such a denial, however, would be of little account if it were not supported by adequate evidence of results, such as those which have been so much dwelt upon being really obtainable: and although this subject has now been some years before the public, I am not aware of any such evidence having been brought forward as would call for or justify the abandonment of those well-established principles by which the heating power and efficacy of fuel is determined.

The results of the experiments made at Woolwich, under the superintendence of Mr. Trickett, the Engineer-in-Chief of the Dockyard, gives, as the highest evaporative effect obtained with petroleum, 11·63 lb. of water converted into steam per pound of oil burnt. In this case, however, the combustion was imperfect. But in the most successful trials with coal oil and shale oil, when very little smoke was given off, the evaporative effect was about 18 lb. of steam produced per pound of oil burnt. In this case some deduction required to be made for the steam applied as a blast to the fire, but the amount was not ascertained. This result was also obtained under peculiarly favourable circumstances as regards the proportion of heating surface of the boiler to the rate of evaporation.

In regard to the supply of material capable of being used as liquid fuel, it is necessary to make a few remarks. First, as regards petroleum, I imagine it is now generally acknowledged that this material in its natural state is not well adapted for the purpose. In that state it contains a large amount of very volatile hydrocarbon, which, even at the ordinary temperature, vaporises by contact with air, and the mixture of this vapour with air is explosive. At the temperature of a steam vessel's stoke-hole this vaporisation would take place more readily, and if there were any leakage in the supply pipes or tanks, disastrous consequences might ensue. In order to remove this objection to the use of petroleum as liquid fuel, the more volatile portion of it must be separated from it by distillation, and that operation, when carried far enough to render the oil fit for use with safety, would reduce the quantity to about one-third.

Another objection to petroleum in its natural state is its bulkiness, the gallon weighing only about 8 lb. This is to some extent removed by the distillation, and by the reduction of the quantity to one-third an oil is obtained which weighs about 8½ lb. per gallon.

According to the latest returns, the total production of petroleum in America—which is out of all proportion the most abundant source of this material—amounts to about 360,000 tons a-year. It would be mere speculation to offer any opinion as to whether this rate of production is the maximum which is attainable, or as to the time it may continue; but the prevailing impression is that the sources from which this supply originates are subterranean accumulations, and, therefore, not to be depended on beyond a certain limit. The experience of oil winning in America has confirmed this view, for it has been found that the wells which were at first what are termed 'flowing wells,' *i. e.*, yielding their oil spontaneously, have gradually ceased to flow; and that, after pumping has been resorted to for bringing the oil to the surface, even that means gradually declined in its effect. It would, therefore, be unwise to rely upon the supply of petroleum as affording material for fuel. And then, if we consider the vast consumption of coal for the purpose of steam navigation—amounting, I believe, to not less than 10,000,000 tons a-year in steam vessels belonging to this country alone—it will be seen that the production of petroleum—gigantic as it is in relation to the use to which it has been applied—is insignificant when compared with the requirements of steam navigation for fuel; that, in fact, the total production does not amount to 1 per cent. of the fuel consumed in the steam vessels of this country.

The possibility of obtaining an oil analogous to petroleum by distilling certain kinds of coal and some varieties of bituminous shale, constitutes another source of liquid fuel, and one which I consider to be far more important, for this country at any rate, than petroleum is. The material obtained from this source, and commonly known as crude paraffin oil, requires to be submitted to the same operation as petroleum, in order to remove the more volatile portion, and obtain an oil suitable for use as liquid fuel, but it would have the advantage of yielding rather a larger amount of such oil than petroleum does. To what extent the production of this oil might be developed as a source of supply for steam navigation it would be almost impossible to form any approximative idea at present. But I may state in regard to this point that, owing to the low price at which petroleum is now imported from America, the coal and shale oil works of this country have mostly been stopped because of their inability to manufacture oil for burning at such a price as to compete with the American product. Circumstances which it would be out of place to enter into here induce me to believe that if the use of liquid fuel were introduced to any extent into practice, that it would be a very great advantage to the oil manufacturers of this country, and that it would be a means of enabling them to meet successfully the competition of the American oil used for burning in lamps. I have already spoken of the supply of 'dead oil,' furnished by the rectification of coal tar, and need here only remark again that the quantity is very small. This is certainly the most suitable material for use as liquid fuel which I am acquainted with, and its excellence in this respect induces me to mention another possible source of a similar material, viz., the distillation of 'slack,' or the waste coal dust, which accumulates at the mouth of a coal pit. It is quite possible that by such means a quantity of oil, similar to that resulting from the rectification of gas tar, might be obtained, and at the same time the slack itself converted into a useful fuel.

There is also in the Island of Trinidad a vast deposit of bitumen, which has repeatedly been an object of passing interest on account of attempts to render it in some way useful. Unfortunately, most of those attempts have hitherto failed; but if liquid fuel should become an article in demand, I think there may be good days still in the future for Trinidad bitumen, for it has the peculiarity of yielding by distillation about 30 per cent. of a thick, heavy oil, approximating very closely to the 'dead oil' of the gas tar refiner. This circumstance, which has hitherto been the disadvantage of the Trinidad bitumen, might then become its chief recommendation, and, according to all accounts, there is abundance of it, and the getting of it is not attended with difficulty.

The relative cost of coal and oil is to some extent still an open question. If it should be found advantageous to use oil as fuel for steam vessels it is probable that neither crude petroleum nor paraffin oil as obtained by distilling coal or shale would be the most suitable for the purpose, and that it would be advisable to separate from either of those materials the more volatile portions, which are applicable for burning in lamps. The less volatile portion, both of petroleum and shale oil, amounting in the former to about 30 per cent., and in the latter to about 40 per cent., would be for several reasons best adapted for use as fuel. It is not so much in demand as the oil used for lamps, and being less volatile could be stowed with greater safety. But I doubt much whether this oil could be shipped for less than £5 per ton. If that opinion is correct, and according to the comparative estimate already made between coal and oil, the cost of the latter would be about three times as much as that of coal. There may be circumstances under which the advantages to be gained by the use of oil as fuel would altogether outweigh any considerations as to this, or even a greater rate of cost, it does not require any great penetration to perceive; but it appears to me equally evident that if those advantages are to be attained only at such a cost, the use of oil as fuel for steam vessels must in any case be restricted to exceptional cases, in which cost is comparatively a matter of secondary importance, and that it cannot be regarded as likely either to revolutionise steam navigation in general or to call for a total reconstruction of our navy.

At this point, however, the consideration of the subject reaches a stage where it is more the province of the merchant and of the naval engineer to deal with it, and to determine the balance between the greater efficacy of this material as fuel, and the greater cost which its application would involve. I therefore leave it here for those more competent than myself to discuss these points, with the hope that the attempt I have made to elucidate the subject, so far as I am able, may be found of some utility in its further development.

I cannot, however, conclude this paper without taking the opportunity of expressing my opinion that the mode in which this subject has hitherto been dealt with, illustrates in a most striking manner the want which is now somewhat vaguely felt of what is termed 'technical education,' by which I understand a means not merely of making those whose business is of a practical character better acquainted with the principles of science and the laws of nature than is generally the case in this country, but also of educating the cultivators of science in a knowledge of the requirements of art, and of the conditions under which science can be made serviceable to practice. If such a closer alliance between science and practice were achieved, I believe it would be found of mutual advantage, and then I apprehend we should soon cease to hear anything more of that fancied antagonism between the two which is the most effectual barrier to progress, and deserves only to be regarded as an indication of ignorance or bigotry."

33. On the same subject, the 'Mechanics' Magazine,' under date September 25th, 1868, has the following suggestive remarks:—" Notwithstanding the careful attention which has been given to the question of liquid fuel, with the view of utilizing it as a steam producer in our navy, it does not appear that any advance has been made towards its practical solution since we were obliged, some twelve months ago, to pronounce Mr. Richardson's petroleum furnace, as then arranged, not a sufficient success—the flames being too powerful, and the mechanism of one of the fireplaces failing. As we have watched the development of this question with considerable interest, as being one likely to greatly benefit our navy, we have recorded from time to time the results of trials and experiments as they have taken place. Following out our plan, we purpose now to notice such

plans as have recently come under our observation, together with the results of trials and experiments made with them. The induced current system of Messrs. Wise, Field, & Aydon, is, doubtless, well known to our readers. Some highly satisfactory results were obtained from this system as applied to a Cornish boiler, fitted with field tubes, at some large works in Lambeth, the working of which we witnessed. This system has now been applied to a marine boiler by permission of Government, and a very complete and full trial has lately been made in Woolwich Dockyard. The system was introduced to the notice of the Admiralty by Captain Selwyn, R.N., after giving lectures upon the subject at the United Service Institution, and the Institute of Naval Architects. The gallant officer stated in his lecture that a 35-horse power boiler of the ordinary Cornish form, with Galloway tubes at the back, had been at work night and day without intermission, at Hackney Wick, since Christmas last, doing considerable more duty with 230 gallons of liquid fuel per day than it had previously done with 3 tons of coal. The cost for working this boiler was reduced from 72s. to 53s. per day, and the water evaporated was 23 lb. to every 1 lb. of fuel. The fire-bars, he said, were covered with a thin bed of glowing ashes, which required renewing every twenty-four hours. In another factory, 46 lb. of water were evaporated by 1 lb. of creosote.

With regard to the recent trial at Woolwich, we may first state that through the kindness of the Controller, and without any expense to the patentees, a small boiler was constructed by Mr. Lewis Olrick, at a fair contract price, on board a steel yacht, which had been originally built for Lord Alfred Paget, but which had been purchased by the Admiralty. In this boiler, a trial, prolonged from March 17 to July—twenty-five days in all—has just been concluded, the consumption of oil and the evaporation of the water being carefully observed and measured. Messrs. Wise, in a contemporary, describe the boiler as always being capable of lighting with either wood or coal as preferred; both had been tried, and one raised steam as well as the other. In the present trial the evaporation with coal was 7½ lb. of water to 1 lb. of coal; that with oil 10 lb. only. This amount, however, had to be reduced by a percentage of steam taken from the boiler; it is not known what, and 10 lb. thus not being the average, it was considered that the amount of evaporation obtained from the oil was about the same as that given by the coal—perhaps a little more. The flame acted like a blow-pipe flame; it melted lead in the chimney, and Messrs. Wise state that it melted pumice stone like so much glue, and that the fire-brick grate in the furnace was constantly at a white heat, and sometimes melting at the edges. Notwithstanding all this it did not give sufficient heat to the boiler, the ash was sent away in fine dust, and thin wrought-iron plates, used as baffles in the furnace, remained undestroyed by the flame. A similar plan—that of Mr. S. E. Crow—has been tried by the Admiralty at Sheerness; but all known about it is, that it very soon made the chimney funnel red hot. The conclusion, therefore, is, that a blow-pipe flame, formed with superheated steam at high pressure, must take away the heat too readily, or apply it at a wrong place.

Captain Selwyn stated in his lecture that if the injector used by Messrs. Wise to supply oil to the furnace was not capable of supplying sufficient, two or more could be used to each fireplace. This arrangement, we understand, will be tried in another boiler of 130 horse power, which is now being fitted up for a further trial; but in the boiler supplied by Mr. Olrick it was found that on a full supply of oil being sent in by the injector, smoke was formed, and the rate of evaporation was lowered. The boiler had Field's circulating tubes, and the arrangement of the baffles was made by Captain Selwyn himself, so that perfection ought to have been insured. The great advantages of the system certainly render it specially attractive to the Admiralty; it can be fitted to the present common service boilers at small expense, and either coal or oil can always be used in the same boiler, but the amount of evaporation must be considered. Good shale oil cannot be obtained in England for less than from £4 to £5 per ton. Creosote is obtainable only in such limited quantities as not to be available for general use. With such a price for oil an evaporation twice or twice and a-half that of coal must be obtained to successfully compete with coal. It is only very sanguine inventors, or men of no practical experience, who state such large results as 30 lbs. can be obtained from any fuel we at present have. It is not possible for any kind of fuel to effect a larger amount of evaporation than from 20 lb. to 21 lb. of water per 1 lb. of fuel; this might be got from oil. Coal should give from 13 lb. to 14 lb., but this is never done in practice. The highest amount ever obtained from coal has been 10½ lb., lately at Wigan, and that only by careful experimenting; the usual quantity in practice is 8 lb., and this by very careful firing; it is commonly only 6 lb., and with any other coal than steam coal only 4 lb.

Mr. Olrick has very properly stated that with oil boilers it is not possible in many cases to get such information from the proprietors as would be useful, partly because they do not take sufficient interest in the matter themselves to allow their men to make careful measurements of the fuel consumed and the water evaporated, and partly because they object to have strangers about their place interfering with the daily routine of the work, leaving out entirely the question of expense in adapting the existing fittings to the necessary meters and measuring tanks. When inventors are informed by the stokers attending oil boilers that large evaporations are taking place, the stokers' information is 'eliminated out of their own consciousness,' and it is astonishing how much this is brought well out in the presence of tip. The largest evaporation obtained from shale oil was that of which an account was given in the 'Mechanics' Magazine' of July 13, 1866, with Richardson's boiler at Woolwich, during five days' working at the rate of about ten hours a-day. It was each day respectively 14·70, 14·80, 17·85, 17·40, and 18·02, with moderate smoke, very light, more like vapour; and on February 11, 1867, the same boiler gave 18·91 with—according to the Government engineer's report—'smoke moderate, but very thick and black when the oil was run in too quickly; the tubes moderately foul at end of trial, duration of trial six hours only.' We believe that had the trial been continued longer, even more than 18·91 could have been obtained, as the furnace would have been in better working order. But Mr. Richardson had to supply the oil at his own expense, and he had no more than was sufficient for a six hours' trial—his boiler, together with that of Mr. Bridges Adams, are now idle.

New processes continue to be brought forward with us. Mr.

James Donald of Glasgow has an arrangement which comprises the construction of a furnace space or combustion chambers, which has its bottom and sides lined with firebrick; the furnace is arched or roofed over with firebrick. In the midst of this combustion chamber there is a firebridge contrivance, which may be termed an ignition block or pier. The oil to be burned is admitted by a pipe nozzle, which is placed in such a manner as to direct a jet of the oil towards or against the ignition block. Apertures are provided for the admission of air; the patentee prefers, where a more intense heat is required, a jet of steam to project the oil with considerable force. This appears to us to be a copy of Messrs. Wise, Field, & Aydon's plan. Mr. H. Pinkus, C.E., introduces a new method, first stating that he used hydrocarbons in conjunction with streams of water and vapours so far back as 1830 in large public works in England, and that he holds the first recorded patents in Great Britain and countries abroad therefor. He states that hydrocarbon, when consumed with superheated steam and heated air by his method, is competent to evaporate more than 30 lb. of water per 1 lb. of hydrocarbon, and that, consequently, it is capable of effecting from five to six times the steam power to be obtained from coal; but we require his proof before we can accept his assertion.

The French are paying considerable attention to the subject. M. Verstraët, a chemist, has a plan by which the gases of the oil are conducted to the fireplace by a current of air. This is similar to the plan of Mr. Bridges Adams, which has been tried at Woolwich Dockyard. On the Emperor's late departure for Chalons, the chief feature of the journey was an experiment tried in the locomotive drawing the train from the town to the camp, a distance of twenty-eight kilometres. The Emperor mounted on the engine, and followed with deep interest all the details of the trial, which is the first of the kind, though the question has been under study and consideration for the last eighteen months. Last June, his Majesty had already tried the first steamboat, the 'Puebla,' in which mineral oil was employed as a motive power. In the above locomotive trip, M. Sauvage, manager of the Eastern Company; M. Dieudonné, an engineer who has devoted himself of late to these experiments; and M. Sainte-Claire-Deville, an eminent scientific man, were on the engine with the Emperor, to whom they gave all necessary details and information. The arrangements are as follows :—On a brick slab, behind a vertical grating, is burnt a stream of oil flowing from a tap, by means of which it is perfectly easy to regulate the production of steam and the development of the power. An evaporation of from 12 lb. to 14 lb. might have been obtained; full particulars, however, are not supplied, but the experiment is reported to have been successful. The first plan, tried in Paris, under the auspices of the Government, was in 1854—that of Messrs. Shaw and Linton, of Philadelphia; the boiler evaporated 12 lb., but made the chimney red hot, and the plan was given up.

From the foregoing facts, which we have brought down to the present time, we gather the present position of the liquid fuel question, which is by no means so satisfactory as we could wish to see it. There is no denying that we have not yet practically utilized petroleum for steam purposes afloat, however we may have succeeded in so doing ashore. We have, however, yet to await the results of the 130-horse power boiler as fitted with Messrs. Wise's system on a larger scale. We have also to bear in mind that Mr. Richardson has not been idle. Having obtained the highest rate of evaporation—according to Government report—and having still found his furnace defective in some respects, he has set to work to remedy these defects. That he has succeeded in producing a very perfect furnace we have every reason to believe, although no trials have as yet been made to test his improved arrangement. They are, however, well calculated to give better results in working than he formerly obtained, and we shall look forward to the time when he will have another trial. We are informed that Mr. Richardson is anxious to compete, at his own expense, with Captain Selwyn, but this is not permitted. He should take his process to France, where civilians appear to be treated with more liberality than in some departments of the British Administration."

34. *The Utilization of Waste Fuel.*—From 'Engineering,' of date March 6th, 1868, we take the following highly suggestive article :—" With the progress of civilization and the development of industry in any country or part of the world, the tendency for a rise in the value of fuel is inseparably associated, no matter how favourably that locality may be situated for a natural supply

of combustibles. Economy of fuel, therefore, makes itself felt as one of the principal aims of modern engineering all over the world. There are two different directions in which economy in the utilization of the natural supply of fuel may be effected, viz.: 1, by making a certain quantity of fuel produce the highest effective duty attainable; and, 2, by making the natural stores of combustibles yield the greatest quantity of valuable fuel. The first road of economy is the well-known and beaten track in which science and practice have now been moving on for a long time past, with more or less satisfactory results, yet without creating any striking innovations in our general practice. The second line of progress is one of comparatively recent development, and it seems to offer a far more promising field for improvements of great originality. This mode of economising fuel is best distinguished as the utilization of waste fuel. It commences at the colliery, or in the forest, or the peat bog, and it follows all branches of modern industry everywhere, looking out and gleaning the different fallings from fuel now recklessly wasted, and with the application of science and skill it opens up a field for economy of fuel incomparably wider and richer than that well-known field of economy of fuel in the narrow sense in which we have defined it above. The contents of the British coal measures contain vast stores of fuel different from the coal now drawn from them and utilized. The beds of bituminous shale in Scotland are probably much larger, and will, perhaps, at some time, be more valuable stores of mineral fuel than the coal seams now worked in this country. Fuel of such a kind is contained even in some of the ironstone bands of Scotland and Wales, and has been used for calcining such ironstones as, for instance, the Scotch blackbands, and even for calcining other ores, by the addition of bituminous blackbands instead of other fuel. At a recent date it has been proposed to calcine such blackbands in coking ovens, and to regulate the admission of air so as to form a coke from a part of the bitumen, and utilize the carbon so maintained within the ore for smelting. Experiments are being made with this process in an ironworks in the vicinity of Glasgow, and a patent has been taken out for this mode of coking. We have been informed that a very bituminous blackband, after being coked in this manner, contains a sufficiency of carbon for being smelted in the blast furnace almost without any further addition of fuel. This of course refers to blackbands which hitherto would have been considered as very poor ores on account of their high percentage of bitumen and small percentage of iron, and in some localities this new process may be useful, not only as a means for saving fuel, but also as a method for utilizing iron ores which otherwise would be scarcely fit for economical blast-furnace practice. At the Falkirk Ironworks, near Glasgow, a blackband ironstone has been worked for some time, which contained a sufficiency of mineral oil to make it worth distilling in retorts like shale, and to make paraffin oil from it. This distilling process served the purpose of calcination at the same time, and the ore was smelted after having been used in this manner for the extraction of the hydrocarbons contained in it. Some iron pyrites, which are used for the manufacture of sulphuric acid, contain a sufficient percentage of sulphur to serve as a substitute for other fuel. Mr. W. Henderson has succeeded in utilizing such pyrites as the fuel, by means of which he calcines his copper ores in the manufacture of copper by his patent process. The pyrites, which must be burnt for the purpose of producing the sulphurous acid for the vitriol chambers, are in this manner replacing the coal, as other fuel, upon the grates under the closed calcining kilns used by Mr. Henderson. In coal mining an enormous percentage of dust coal, slack, and 'dross' is made; and according to the nature and character of the coal, this disintegrated material is at present utilized in a more or less satisfactory manner in some localities, while, taking the average of British collieries, this utilization must be considered to be in a most primitive and unsatisfactory state. The dust from coking coal affords a suitable, and, indeed, the only material for the manufacture of coke. It is well known that the whole iron industry of the Cleveland district has been founded for the purpose of utilizing the waste from the Durham coal fields; the Lancashire collieries have followed a similar course, and some of the large ironworks in that district, as, for instance, the Kirkless Hall Ironworks, belonging to the Wigan Coal and Iron Company, have been erected with this same principal point in view, viz., utilization of coal dust. In Wales only a portion of the coal fields yield a coking coal, and from Scotch coal next to no coke is made. In these localities the coal dust has no proper commercial outlet, and it is at present wasted in the most reckless manner. The Siemen's gas furnace, which is most eminently suited for working with coal slack and similar materials, has not as yet been largely introduced in Scotland, and even for the few furnaces of the kind which exist at the Atlas Works, the Govan Ironworks, and in some other places, it is scarcely worth the trouble to separate coal waste from the shale and other earthy impurities generally mixed with it, instead of using good coal at the very low prices which still exist in the Scotch coal district. Still it is a mere question of time at what particular moment it will pay to wash the incombustible minerals out of the Scotch coal dust and make valuable fuel from it, and we believe that there are sufficient indications at present to show that that time cannot be very far distant. The most promising mode of utilizing coal dust is the manufacture of 'patent fuel,' or agglomerated fuel, as it is more properly called. On the Continent, where the market price of fuel is generally higher than is the case in this country, the manufacture of such artificial fuel has been in practice for a long time past, and we have before this given an account of some of the different processes there in use. In England there are principally three patents which have been practically introduced. The first is the employment of coal tar, or a similar mineral hydrocarbon, as a cement. It has been used in Wales with moderate success for a long time past, but the price of these mineral hydrocarbons is rising gradually, and they can be better employed for other purposes than the manufacture of fuel bricks. There is, moreover, a serious objection to the use of tar as a cement for coal, viz., the fact that the cement melts in the furnace, and the coal dust disintegrates upon the grate. This causes a great deal of inconvenience and loss. The next process in chronological order of the respective inventions is Barker's patent. The cement used in this process is starch freed from gluten, an expensive material which, moreover, is mixed with mineral salts for preventing decomposition, thereby introducing incombustible matter, which increases the percentage of ashes. The fuel bricks produced with this cement undergo a special process of preparing their surface and making them waterproof, precautions which are obviously taken against the decomposition of the cement by the influence of the atmosphere. These fuel bricks are good, but their mode of manufacture is too expensive to make the process commercially successful. Another cement for making fuel bricks is that patented by Messrs. Bird and Co. This is pure gluten, and the percentage of this substance required for cementing the coal is so small as to make the present prices of gluten come sufficiently low. Gluten, however, is a material which acts unfavourably upon the combustion of the agglomerated material. The coal dust is compressed in the gluten process, and the interstices are filled with the cement, which is not porous, and almost impervious to air. The combustion of those bricks, particularly if made of the qualities of coal for which this process is principally required, is necessarily slow and less perfect than the application of a porous cement will make it. Such a porous cement has also been produced and recently patented in this country, and some very fine fuel bricks have been made by its application. The process is about to be introduced on a large scale at one of the greatest collieries in England, and we intend to give full details of its mode of working as soon as the specification has been published at the Patent Office. We believe that this new cement combines all the advantages of the tar, the starch, and the gluten, without having the disadvantages of either of the above substances just explained. There is another very original method of utilizing coal dust, which has been experimented with at the Ironworks, Boulogne-le-Haut, in France (Haute-Marne). It consists in blowing very fine coal dust into a blast furnace through the tuyeres. The blast ignites the coal dust while passing into the hearth, and a fresh supply of heat is thereby gained. Although this process was declared to work successfully now more than twenty years ago, it has not been continued. There is, apparently, a great danger in the application of large masses of coal dust in a blast furnace, since all the dust which escapes immediate combustion at the mouth of the tuyere is carried into the burthen and deposited there in the interspaces of the coke and ironstone, where it may eventually effect a choking or 'gabbing' of the furnace, *i. e.*, prevent the penetration of the blast. At a very recent date, Messrs. Whelpley & Storer of Boston, U.S., have used such fine coal powder for firing boilers, and, as it appears, with very satisfactory results. The fine coal dust is injected in the case by the action of a forced current of air passing through the flues and carrying the powdered coal along with the blast. The combustion takes place throughout a considerable space within the flues, and with proper means and care for regulating the quantities of air and coal and the speed of the current, this invention seems to be likely to give good practical results. The practical question will, of course, turn upon the point of expenditure for reducing the coal to a state of fine powder, and upon the question of management of such self-feeding furnaces.

In the process of coking, another opportunity arises for economising waste products. The gases evolved by the coal are combustible matter, and they, moreover, contain a number of volatile products, which, if condensed, are the sources for the supply of some of the most valuable materials. We have repeatedly drawn the attention of our readers to the great value of the gaseous products of the coking process, and we have given descriptions of some of the methods employed on the Continent for utilizing these products. It may be inconvenient in some localities to find a suitable use for all those compounds which are permanent gases; but that portion which can be condensed and collected in the liquid state should be utilized under all circumstances. Even in the crude state the liquid hydrocarbons are suitable to be used as fuel, and their application for that purpose is a mere question of price. At the present moment, when the price of mineral oil is very low, crude pitch-oil and similar substances are very frequently used as fuel for firing boilers. One of the most successful modes of burning pitch-oil we have recently seen in operation at the works of Messrs. Miller & Co., in Glasgow. The pitch-oil is injected into the furnace by means of a steam jet, and impinged against an inclined plane formed by a solid piece of firebrick masonry occupying the position of the grate in ordinary furnaces. One jet of steam, about 1-16 in. in diameter, injecting a single jet of oil supplied in a stream of about $\frac{1}{8}$ in. diameter, is sufficient for firing a Cornish boiler of 7 ft. diameter and 25 ft. length. The extreme simplicity of the whole arrangement is the principal advantage of this mode of firing boilers. There are no pipes nor burners, no layers of coke or asbestos; in fact, there are no mechanical provisions whatever in the interior of the furnace, and a steam pipe, fitted with an injector nozzle, surrounded by the petroleum, which is fed from a reservoir overhead, forms the complete feeding apparatus for the liquid fuel. The practical experience of about three months' working assigns to the crude pitch-oil burnt at Messrs. Millers' works the value of 1½ times its weight of best coal, *i. e.*, two tons of pitch-oil would be equal in steam-generating power to 3 tons of coal. At the present moment such oil is valued no higher than 1d. per gallon, or about 14s. per ton, and this would be equal to coal at 9s. or 10s. per ton, considering the relative effects; but even at the highest prices which this material was formerly sold at, viz., 2½ per ton, its use would not be dearer than coal at 25s. per ton, a price which is below the market value of coal in many localities. The collection of such materials from the coking ovens would pay at prices which will allow our steamers to use liquid fuel in preference to coal, and the increasing carrying powers of the ship, together with the saving of manual labour in stoking, will amply repay even a small excess in the price of petroleum over that of coal.

The application of the waste gases from blast furnaces for firing boilers, heating stoves, and calcining kilns, we have sufficiently noticed on previous occasions. Attempts have been made to use such gases instead of those of a Siemen's gas-producer for working puddling furnaces. This has not been successful, since the temperatures allowed by the combustion of such gases is not sufficient, as a rule, to raise a welding heat in an ordinary puddling furnace. In the forge the waste heat is best utilized by raising steam for the hammers and engines; but, as a rule, the demand for steam is not sufficient for all the steam-generating power of the different furnaces in a large ironworks. The choice, then, remains between the regenerative principle of the Siemen's furnace and some of those arrangements for saving fuel which embody the same abstract idea without the application of the same means for carrying it out in practice. Of the latter kind of methods for utilizing waste fuel and waste heat, we have given an interesting specimen in our description of the new puddling furnace recently introduced at the works of Messrs. Fox, Head, & Co., at Middlesborough. We would in all cases of choice, however, give preference to the Siemen's gas furnace as the most effective, most economical, and, in spite of all prejudice, as the *simplest* form of furnace for the economical production of high temperatures."

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DIVISION FIFTH.

SMOKE PREVENTION.

35. *Economy of Fuel and Prevention of Smoke.* — "Some three years since," says the 'Mechanics' Magazine,' "we informed our readers of the inauguration of an extensive series of experimental trials on the evaporative power of various descriptions of coal and forms of boiler at Wigan. As this bears upon the important question of economy of fuel and prevention of smoke, which is one of considerable interest to our readers, we append the valuable report of these experiments, which has been forwarded to us by Mr. L. E. Fletcher, Chief Engineer of the Manchester Boiler Association. The object of these trials has been twofold,—firstly, to establish the evaporative efficiency of the South Lancashire and Cheshire coals; and secondly, to ascertain how they could be burnt to the greatest advantage in ordinary mill boilers without the production of smoke, as well as to decide upon the best form of boiler, so that the steam user might learn how to save coal and prevent smoke.

These trials were brought to a conclusion on the 24th ult., being finished off with three general field days, so as to afford steam users an opportunity of seeing the results obtained. On Wednesday, the 22d ult., William Fairbairn, Esq., C.E., president of the above association, with other gentlemen of the executive committee, met the members of the South Lancashire and Cheshire Coal Association, who had been at the expense of these experiments, and visited with them the trial shed in order to satisfy themselves as to the success of the trials. In preparation for this all the boilers were in full work. These are of various construction, one of them being of the marine multitubular type, and another of the patent conical water tube, while a third is an ordinary Lancashire mill boiler with steel furnace tubes, and the fourth a similar one with iron tubes. All of them were fired under different conditions, one of them mechanically by Messrs. Vicar's patent self-feeding firegrate, and all the others by hand. Slack coal was used in the furnaces of two of the boilers, including the one to which the self-feeding firegrate was attached, and round coal in the others, while the length of the firegrate in one of the mill boilers was 4 feet, and in the other 6 feet. All the boilers were in full work and heavily fired, yet without producing any smoke beyond a slight trace of a faint colour now and then. After witnessing the experiments with the testing apparatus, and the mode of firing adopted, the company—having satisfied themselves as to the absence of smoke—adjourned to a luncheon, provided by the Association for the Prevention of Steam Boiler Explosions, in an adjoining room, kindly lent for the occasion by the Wigan Coal and Iron Company, when a brief report upon the progress and results of the trials was read, and the importance of the prevention of smoke and economy of fuel spoken to by several of the gentlemen present.

On Thursday and Friday, the 23d and 24th ult., the trial shed was thrown open to as many members of the Association as wished to be present or to send a representative. A considerable number availed themselves of this opportunity, and the boilers were shown to them in full operation, as on the previous day, heavily fired, without producing any smoke, and it appeared to excite surprise in the minds of many that the results could be attained by such simple means as were then adopted.

On the first series of trials a detailed report (see Division Fourth, par. 31) has already been presented to the Coal Association, and thinking that there was much information with regard to these trials which would prove of general interest, Mr. Fletcher, with the permission of the Coal Association, prepared condensed tables of the results obtained, as well as a brief account of the mode of conducting the trials.

MR. FLETCHER'S REPORT.

It may naturally be expected that I should lay before you on the present occasion a statement of the origin of these trials, with the objects proposed and the results attained. In complying with this I have put my remarks in writing, in order to give you the more information, and occupy less of your time. It is necessary, in the first place, to make brief reference to what are termed the 'Admiralty Coal trials.' Some years ago, at a series of coal trials made by Sir Henry De La Beche and Dr. Lyon Playfair, all the bituminous and gaseous coals, those of South Lancashire and Cheshire included, were very much under-rated; and the Welsh coals, which are more or less of the anthracite class, placed very incorrectly at a much higher rank for evaporative value than the bituminous ones. The reason of this was that in these trials the coals of this district, and of the North Country, which are of the same character, were not properly burnt, and thus they did not evaporate a fair share of water. For some years after, all bituminous coals stood at a disadvantage, till, in the year 1855, the North Country coal owners instituted a series of experiments on the evaporative power of their coals, under the superintendence of Sir W. G. Armstrong, the late Dr. Richardson, and Mr. James A. Longridge, C.E., of Westminster. These experiments showed that the Newcastle coal would not only evaporate as much water as the Welsh, and as rapidly, but also, that if properly fired, it could be burnt without smoke, and the Newcastle coals were subsequently placed on the Admiralty List.

The coal proprietors of this district, however, were still left out in the cold shade, and believing that their coal did not fear competition either with the Newcastle or Welsh, resolved to institute a similar set of trials to those previously conducted at Newcastle, and requested Dr. Richardson, of Newcastle, and myself to undertake their superintendence. For this purpose the marine boiler now standing in the trial shed was specially made, which is a precise counterpart of the boiler employed for testing purposes at H. M. Dockyard, Keyham. These trials, which occupied about two years, showed that the coals of this district had a high economic value, and were able to evaporate 11·28 lb. of water at 100 deg. to 1 lb. of coal, without making any smoke beyond a slight trace of a faint colour now and then. This result is quite equal to that obtained either by the North Country or Welsh coals, and was verified by the Admiralty officers who were sent down to inspect a repetition of the trials and report thereon. This report has since been published, and speaks strongly in favour of the high character of the South Lancashire and Cheshire coals.

Out of these Admiralty coal trials sprung, through the suggestion of Mr. Lancaster, the second series, which you have been invited to witness to-day, and hence the foregoing allusion to them. It was thought it might be well to extend the trials to ordinary mill boilers as well as the marine, with a two-fold object, viz., to ascertain, in the first place, how the coals of this district could be burnt with the greatest advantage in the ordinary mill boilers, and, in the second, the best form of boiler in which to burn the coals, and thus to assist the steam user in economising fuel and preventing smoke. These are most important considerations. The question is frequently put, Which is the most economical form of boiler ? while every one has its strong partizans who advocate it as superior to every other. The circumstances, however, are so various, under which different boilers are worked at different mills, that it is by no means easy to get at reliable data, and therefore the importance of a careful comparative test.

With this view, boiler-makers were invited to co-operate with the coal owners, the one party finding the boilers, the other being at the expense of setting them to work, providing the coal, and conducting the experiments. In answer to this invitation, Messrs. Hick and Hargreaves, of Bolton, supplied a two-flued boiler with steel tubes; Messrs. Clayton, of Preston, a two-flued boiler with iron tubes; and Mr. Green, of Wakefield, one of his patent water-heaters, or economisers. Messrs. Petrie, of Rochdale, were desirous of sending one of their patent boilers fitted with pockets in the flue-tubes, and arranged to do so, but the time proving too limited, the carrying out of their intention was prevented. Further, as it was thought very important to try the evaporative power of a conical water-tube boiler as compared with those of two-flued construction, one was purchased second-hand, and set down along side of the others. It is to be regretted that a still greater variety could not be obtained. The three boilers supplied hardly furnished the full means of settling the very vexed question as to which is the best form of boiler, and it may be that we are but yet on the threshold of this important inquiry. I will, however, give you the results obtained with the means in my possession, and trust they may prove a step in the right direction, and shall be glad if they are the means of leading to a yet further and more exhaustive series of investigations.

In describing the mode in which these experiments have been conducted, it is hardly necessary for me to explain the testing apparatus, since you have this day seen the large tank in which the water was measured, and the diagrams by which the smoke was estimated. Suffice it to say that the water evaporated was carefully measured and the coal weighed, while the smoke was observed and registered throughout every minute of each experiment.

In attempting to ascertain which of the three boilers gave the best results, it was clearly necessary to learn, in the first place, the best mode of firing them, and then to compare the highest result of each boiler with the others. In doing this three modes of firing were adopted—No. 1, 'spreading' firing; No. 2, 'coking' firing; No. 3, 'alternate side' firing. 'Spreading' firing is that usually adopted, and which makes so much smoke. In this system the coal is scattered evenly over the whole fire, beginning at the bridge and then gradually working forwards to the fire-door. In 'coking' firing the coal is heaped on to the dead-plate at the front of the furnace, and after lying there till coked through, the crest is pushed backwards towards the fire-bridge, and a fresh charge of raw coal thrown on to the front of the furnace in its place. By this means the gases are gradually evolved instead of being set free almost instantaneously in a cloud, as in the 'spreading' system, while a bright fire is maintained at the back of the furnace over which the gases pass. 'Alternate side' firing was introduced, I believe, by the late C. Wye Williams. On this plan the coal, instead of being spread across the whole width of the furnace, is cast to one side only, so that one side of the fire is black while the other is bright, when, as soon as the fires are burnt through, the other side of the furnace is charged, and so on.

Each of the three systems was applied to the Lancashire boilers, when it was found on the whole that with round coal the highest amount of duty was obtained by the 'coking' firing, and at the same time the least amount of smoke, though the adoption of 'side' firing appeared of advantage with 'slack,' and probably both systems might be had recourse to with success according to circumstances. Fires also of various thicknesses were tried, viz., 6 in., 9 in., and 12 in., when it was found that the thickness of 9 in. gave a better result than 6 in., and 12 in. than 9 in., so that the thickness would have been increased still further had the size of the furnace permitted it. Added to this, firegrates of various lengths were tried, when it was found that one of 4 ft. gave a more economical result than one of 6 ft., though it scarcely generated so much steam. It has been a very vexed question which is the best part of the furnace for the admission of air above the bars to complete the combustion of the gases, some advocating its admission at the door, others at the bridge. Both these plans were therefore submitted to test, and, without troubling you with precise figures, it was found that there was little or no practical difference between the two plans, and that a slight admission of air for a minute or so after charging on the 'coking' principle, whether at the firedoor or bridge, was successful in preventing smoke.

These preliminaries being settled, the standard fire adopted for testing the relative merits of the three boilers was one 12 in. thick, made of round coal, and fed on the 'coking' system, the combustion being assisted by the admission of a little air through the firedoor for a minute or so after charging, by which means the smoke was practically prevented. This mode of firing was adopted on two lengths of firegrate, one 4 ft. and the other 6 ft., when it was found that with a firegrate 4 ft. in length nearly 10 lb. of water could be evaporated by 1 lb. of coal, and 150 I.H.P. per hour realized by the boiler. When the 6 ft. firegrate was adopted, 9¼ lb. of water were evaporated from 1 lb. of fuel, and about 170 I.H.P. obtained from the boiler per hour. These results are without the assistance of a feed water heater.

The next step is to compare the results obtained from each of the three boilers, and, on considering the whole of the trials, the following appears to be the result:—The patent conical water tube boiler is not practically superior to the plain two-flued, as regards either evaporative economy, speed, or the prevention of smoke; nor is the plain two-flued practically superior to the patent conical water tube boiler. With regard to the steel-flued boiler as compared with the iron one, the steel appeared to have no advantage over the iron, nor the iron over the steel; so that as far as regards economy and speed of evaporation, as well as the prevention of smoke, either one of the three boilers seems practically as good as the other. These conclusions were based on trials made with the boilers set up with external flues in the ordinary way, but it was thought it would be of interest to check the results, by altering the course of the flame so as to allow it to pass directly to the chimney on escaping from the furnace tubes, instead of passing round the boiler through the external flues. This trial corroborated the previous ones, and the results from the patent conical water tube boiler were found to be practically on a par with those of the plain two-flued. This experiment is interesting in other ways. The fuel did not evaporate so much water per pound, but the boiler developed nearly as high an I.H.P. per hour without the external flues as with them.

There is another question of interest with regard to the construction of boilers, viz., whether the introduction of water tubes into the flues of Cornish or Lancashire boilers is of advantage or not. To assist in determining this question, Mr. Clayton, of Preston, went to the expense of fixing four water tubes in each of the flues of the boiler previously supplied by him, so that the same boiler was tried with and without the tubes.

The result of the trials with the tubes certainly showed that, as a rule, some advantage, though slight, was gained, both in economy and speed by the addition of the tubes, but it would require a little further investigation before I could see my way clearly to recommend them as worth their outlay for general practice. In certain cases, where boilers are distressed by heavy firing, they might be found serviceable as an expedient; but where boilers are placed under favourable circumstances, it does not appear that much advantage would be gained from them, and it is questionable whether they would repay the outlay of fixing them in the first instance, and keeping them in repair in the second, as well as atone for the complication they introduce into the boiler.

There is another point of importance in connection with ordinary mill boilers, and that is heating the feed water. It has already been stated that Messrs. Green, of Wakefield, supplied one of their patent economisers, fitted with self-acting scrapers, and the results of experiments with this apparatus clearly showed that it was a decided gain, not only in promoting economy, but also in raising more steam in a given time, so that while the coal bill is reduced, the power of the boiler is increased. The feed water heater is also of material advantage to the boiler, irrespective of the question of fuel, inasmuch as it maintains it at a more equable temperature throughout, and thus promotes its longevity. Although we succeeded in preventing the smoke without any special apparatus, and simply with the proper use of the shovel, coupled with the admission of a little air above the bars, yet it was thought desirable to try the effect of other means, and, therefore, Mr. D. K. Clark's patent steam jets were applied. This apparatus, though very successful in preventing smoke, did not realize a higher economy or speed with round coal than simple hand firing, but when 'slack' was used, it was somewhat superior in economy, but more so in speed.

I must not omit to allude to the subject of mechanical firing, which is one of considerable importance. All present will be more or less familiar with the self-feeding furnace introduced years ago by Mr. Juckes; this, however, as yet, has been principally applied to externally-fired boilers only; but attempts have recently been made to introduce it to those fired internally, and negotiations were entered into for its application to one of the trial boilers. It was thought, however, by the patentees that the furnaces were too small, and, consequently, its application was reluctantly abandoned. Messrs. Vicars, of Liverpool, have brought out a self-feeding fire-grate, which is applicable to boilers whether fired externally or internally, and one of these grates was applied and tested. It proved very successful in the prevention of smoke, as well as in speed and economy of evaporation; but when fired with round coal, it had no superiority over hand firing in any one of those points. When fired with slack, however, it was certainly superior to hand firing both in economy and speed, and equally successful in the prevention of smoke. The constant movement of the bars seems to communicate an agitation to the mass of fuel, which keeps it alive and promotes the passage of the air through it, and thus quickens the combustion, which gives this self-feeding fire-grate an advantage in this respect over hand-firing.

In testing the comparative merits of the various boilers, round coal was adopted as being more equable and reliable in its results, and also as affording a standard of comparison with the prior series of Admiralty trials in which round coal had been used throughout. After the earlier questions had, however, been settled, attention was directed to burning 'slack,' when it was found that smoke could be prevented in burning slack coal as well as round, but that it was more difficult of management as regards speed of evaporation. With slack coal, the coking system proved rather slow in its action, and side firing, though somewhat faster, is yet slower than the spreading; so that although an economical result can be obtained, and smoke prevented, yet the same amount of steam cannot be raised in the same time as with spreading firing. We have found a loss of as much as 30 I.H.P. in one boiler per hour when firing with slack in the speed of coking firing as compared with spreading. From this it appears that when slack coal is burnt, and fired by hand, either speed must be sacrificed or smoke made. This may be met by ample boiler power, but will I fear prove a difficulty in those cases where boilers are fully tasked. In these cases the self-feeding firegrate, previously referred to, as well as the steam jet system, promise to be of service.

From the foregoing it will be seen that in this series of trials we have taken into consideration the best mode of firing, whether with round coal or slack, with thick fires or thin, with long bars or short, the best point for the admission of the air, as well as the comparative advantages of mechanical and hand firing, also the result of forcibly injecting air amongst the gases by the steam jets. We have also endeavoured to arrive at the comparative evaporative efficiency of the conical water tube boiler, and the plain two-flued, as well as the merits of iron and steel furnace tubes, with the value of introducing water tubes into the two-flued boiler. I can scarcely consider this, however, as an exhaustive series of investigations, and there are other trials which it would have been satisfactory to have made. There is the Juckes's furnace applied to boilers externally, which has its strong advocates; also, there are several recently patented boilers, with deflecting flue-tubes, which are stated to realize highly economical results; also, there is the multitubular boiler as adapted for mill purposes. All of these boilers it would be of interest to submit to a careful comparative test. In addition to this there is the gas system, which is an enlargement of the plan of coking firing already described. Much is yet left for other investigators, but I trust that these trials will prove of service to steam users, while I wish every success to those who are willing to push them further.

Though these trials may not be exhaustive, it has been found that smoke may be prevented, whether fired mechanically or by hand, without any special appliance, or when the combustion of the gases is assisted by driving in currents of air by jets of steam, and I think these trials fairly establish the conclusion that the smoke nuisance admits in all cases of considerable abatement, and in most of total removal. As already stated, the only difficulty is in those cases where boilers are overtasked, and these, it would appear, could be assisted by mechanical feeding, or the use of the steam jet apparatus, while in many of them the difficulty could be met by resetting the boilers, or renewing the chimney, so as to improve the draught, or, at all events, by additional boiler power. With sufficient boiler power the smoke question is settled.

With regard to the form of boilers it has been found that those of the plain, two-flued construction, aided by a water heater, are able to develop a very high result. We have evaporated as much as 10½ lb. of water at 100° by 1 lb. of coal on a firegrate 4 ft. in length, and 10¼ lb. on a firegrate 6 ft. in length. In both cases this has been done without smoke, and while evaporating as much as 100 cubic feet of water from the boiler in the course of the hour with the 6 ft. firegrate, and 80 cubic feet with the 4 ft. grate, which is sufficient to develop, with a good engine, about 200 I.H.P. per hour in the first case, and 160 I.H.P. per hour in the second.

I cannot conclude these remarks without calling attention to the great influence of careful stoking simply, on smoke prevention. These trials have proved how very much depends on the proper use of the shovel. George Weekes, the stoker, who has fired the boilers throughout this series of experiments, as well as the previous one with the Admiralty boiler, takes an interest in his work, and considers stoking as his profession. In this way I think it should be viewed. Firing is an art and should be treated as such, and not as a slap-dash random process which any untaught labourer can accomplish. To a great extent our smoke producers are the stokers. Educate the stokers in their art and smoke will be prevented. They should be instructed, in the first instance, how to fire without producing smoke, and be stimulated to constant care by a fine on failure, and a premium on success. If steam users were united in the movement, the question would soon be settled. A stoker would then require a diploma of competence as a 'smoke preventer' before obtaining a post, and his livelihood would depend upon his skill. The question, after all, is not one entirely of science. As soon as the public become sufficiently educated on the subject to demand the suppression of the nuisance, and stokers are placed in their proper position, smoke will be abolished. The question is as much a social as a scientific one, and to exhaust it fully, one must travel into other fields than those of material science only. But this I leave to other hands, though I cannot help expressing the hope that the meeting of this day, by drawing attention to the importance of the subject, will prove a step towards suppressing the smoke nuisance, and thus of promoting a most important sanitary and social reform.

LAVINGTON E. FLETCHER."

36. *Smoke Prevention at Hanley.*—"The *modus operandi* of those clauses of the Sanitary Act of 1866," says the 'Engineer,' under date September 4th, 1868, "which have reference to the prevention or consumption of smoke is at the present time being elucidated at Hanley, the principal town of the Staffordshire Potteries, and some particulars of what is there taking place will no doubt interest many of our readers. The Sanitary Act came into force on the first of August, 1866; but the difficulties incident to the prevention of the smoke nuisance in manufacturing districts induced the Legislature to extend to the local authorities charged with carrying out the provisions of the Act a year's grace as far as the smoke prevention clauses were concerned. On and after the 1st August, 1867, no option was left to the 'nuisance authority,' who was required to summon all contumacious smoke producers, who rendered themselves liable to penalties in the event of their failing to prove that they consumed their smoke, 'as far as practicable.' Recognising the force of this obligation, the town council of Hanley, on the 26th of September, 1866, issued a circular to the manufacturers of the borough, informing them 'that it would be incumbent on the council rigidly to en-

force the Act after the first of August, 1867.' They also sent delegates to a conference of the local governing bodies of the Potteries, held in October, 1867, at which conference the following resolution was adopted:—'That, with regard to furnaces and fire-places, all the schemes then known but partially attained the desired object, and that no plan had been discovered which they could recommend to manufacturers as capable of consuming smoke to the extent required by the Sanitary Act, 1866; but, by way of getting as much done as possible, be it resolved that notices shall be immediately given to the owners of the said engine-furnaces, slip-kilns, and other such chimneys, that the provisions of the Smoke Clauses Sanitary Act, 1866, will be put in force; and also that, as no scheme for the consumption of smoke arising from potters' ovens and the calcining of ironstone has been discovered, the attention of the Chamber of Commerce and the Local and Ironmasters' Association be directed to the Smoke Consumption Clauses of the Sanitary Act, 1866, with a view to experiments being made to ascertain the best means to achieve the desired object.'

On the 21st of the following month the town council published this notice in the local papers:—'In consequence of the time allowed by the Sanitary Act, 1866, for the consumption of smoke as far as practicable, arising from the combustibles used in furnaces attached to steam engines, boilers, slip-kilns, and other such chimneys, having expired, the nuisance authorities of this borough feel it a duty effectively to call the attention of all proprietors of such furnaces to the fact that they are now exposed to penalties for further neglect of the provisions of the said Act.'

From this time forward the council shelved the subject, their indifference being, on all hands, attributed to the circumstance that just one-half of their number were smoke producers coming within the operation of the Act. For severel months this deliberate avoidance of a public duty was patiently endured by the non-manufacturing portion of the inhabitants, but at length—that is to say, in April last—upwards of 200 of the most influential residents, including nearly every professional man in the borough, memorialised the Home Secretary, praying him to send an inspector into the district for the purpose of putting the Act into force under the powers conferred by the 49th section. The memorialists alleged that notwithstanding the attention of the council had been repeatedly called to the duty which the Act imposed upon them, they had made no attempt to prevent the continuance of the smoke nuisance.

To these allegations the council replied in a voluminous document, in which they stated the notices already referred to had led many of the manufacturers to adopt the best known means for consuming smoke, that a smoke inspector had been apointed to carry the Act into force, and that they had not proceeded against any parties for non-consumption of smoke for these reasons:—1st, Because of the unusual difficulties presented by the staple trades of the borough; 2d, because the council felt its own inability to construct works which would consume smoke permanently, even to a practical extent; 3d, because the manufacturers were to a very large and reasonable extent carrying out the best known plans; 4th, believing that so soon as methods or plans were discovered which would to a practicable extent consume smoke, the manufacturers would readily adopt them.

They also joined issue with the memorialists in respect to the rapid increase of the smoke nuisance and the unhealthiness of the borough, stating that although there was a population of 40,000 souls, with no system of sewerage, on account of the difficulty of providing an outfall, the death-rate was lower than other equally large manufacturing towns. Finally, they urged that, having regard to the short time during which the Act had been in full force, and the efforts which were being made to abate the nuisance, 'the council had, to a fair and reasonable extent—due regard being had to the difficulties of the case—carried out the Sanitary Act, 1866.'

The memorialists having made their rejoinder, the Home Secretary at once, and for the first time under the Act, commissioned Mr. R. Rawlinson, C.E., to hold an inquiry on the spot, and for that purpose Mr. Rawlinson sat at the Town Hall, Hanley, on the 28th of July last. The council was represented by Mr. McMahon of the Oxford Circuit, and the memorialists and the Potteries Chamber of Commerce by local advocates. The commissioner's initiatory statement was to the effect that the Sanitary Act was either a dead letter or a living letter, and although he knew from former experience something of the independent spirit of the people of the Potteries, he trusted they would honestly and earnestly address themselves to the enforcement of the Act, in order that the Government might have no excuse for interfering in the management of their affairs. 'He spoke from his own experience when he said that nine-tenths of the black smoke now poured forth from manufactories and engines was sheer waste, and might be prevented. It would not do for him to bolster up any particular patent, of which there were scores, for it was not so much a matter of patents. It was a matter, in the first instance, of proper boiler construction and of plenty of boiler room, but the most important feature of the question was proper stoking. It began and ended with stoking. Hitherto it had been thought that any sort of thickhead would do for a stoker—that any one who could lift a shovelful of coal, and who was content with very low wages, was good enough. Now, that idea had to be unlearnt, for it was necessary that a stoker should be a comparatively educated man. He must know his business and must be well paid. That was where the pinch would lie. If the stoker knew his duty, and did it properly, he (the commissioner) would undertake that the smoke nuisance would be cured without the introduction of patents. What the Town Council had to do was to show the Secretary of State they were honestly doing their best to put down the smoke nuisance. They must know that there were careful men and negligent men in every community, and it would be their duty to compel the careless men to comply with the Act. To use a simile, he had never rightly understood that passage of Scripture, "By faith ye shall remove mountains," until he came to be embroiled in the smoke question. Then he found that whenever a manufacturer said he had tried every possible expedient and could not prevent smoke, and was sure he should never be able, he did not succeed because he had no faith. But when they came to converse with a man who had informed himself upon the subject, and who had faith that the problem could be solved, he almost always succeeded. The subject really lay in a nutshell, but if the majority of the Town Council were obstinately determined to believe that the thing could not be done, it would not be done until some superior force had been brought to bear. They would have to educate themselves, and to imbibe an amount of faith which, if they put their shoulders to the wheel, would remove all difficulties.'

Mr. McMahon said he was prepared to prove that the council had done all that could be done for the trade of the town, but they were prepared to adopt any suggestions which the commissioner might be pleased to make. The commissioner replied, 'that the most practical thing for the Council to do would be to appoint an efficient inspector. The Legislature had never insisted that all smoke should be consumed, but was satisfied if the smoke produced was only 'Parliamentary smoke' —that was to say, smoke which could be seen through.' The commissioner having intimated that the Home Secretary would assuredly comply with the prayer of the memorialists, and saddle the borough with the expense of a Government inspector if they any longer evaded their duty, the inquiry was adjourned for a month to give the council an opportunity of retrieving their reputation.

This they were not slow to do, for on the commissioner taking his seat in court, Mr. McMahon was enabled to inform him that three days after the first sitting the Council appointed 'an efficient smoke inspector'—the previous appointment of a smoke inspector referred to in the reply to the memorial appears to have been an hallucination—who had divided the borough into districts, had reported to the Nuisance Removal Committee the most flagrant offenders—such as those who made forty-five minutes of dense black smoke out of the hour — and had instituted proceedings against Earl Granville and five other leading manufacturers of the borough. On learning that the Council was acting in this vigorous manner, the commissioner, whose remarks at the first sitting were characterized by some severity of tone, said he was quite prepared to admit that time must be allowed to the Council, and that he had the greatest confidence in the integrity and ability of Mr. Davis, the learned stipendiary magistrate for the Potteries, before whom the summonses will be heard on Monday next. It is due to the Council to say that Mr. McMahon showed conclusively that the notice they had issued had induced a considerable number of the principal manufacturers to spend large sums of money in the introduction of various patents for the prevention of smoke, and that much of the delay of which the memorialists complained was due to the sudden death of the borough surveyor in January last. Mr. John Strick, Earl Granville's colliery manager, said nearly £3,000 had been spent on his lordship's extensive works, including £2,000 laid out in covering the tops of the Etruria blast furnaces and utilizing the gas generated."

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DIVISION SIXTH.

STATIONARY STEAM ENGINES AND PRIME MOVERS.

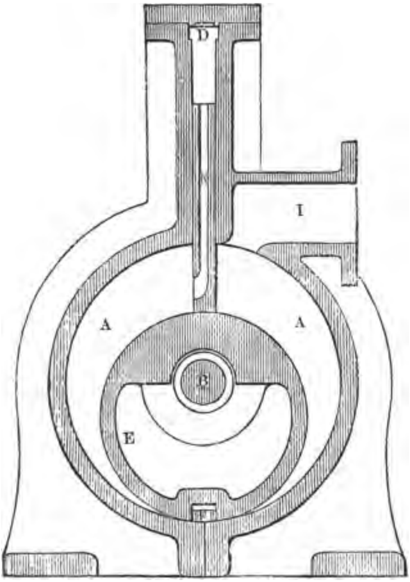
37. *Bailey's Steam Engine.*—The essential requisites in a steam engine in order to excel in the present advanced stage of its improvement, are lightness, strength, compactness, and simplicity, so that it can be easily transported, occupy but little space, be readily put up and operated by engineers of ordinary capacity and limited experience. The working parts should be few and durable, and protected from the injurious effects of dust and dirt. In this engine the elements above mentioned seem to be combined in an eminent degree. The crank of this engine, with its connecting-rod, &c., is enclosed in a steam-tight head, so arranged as to form an extension from one end of the cylinder in which the piston works, and to this piston the connecting-rod is directly pivoted, and the opposite end actuating the fly-wheel. To close the communication between the cylinder and the hollow head, a transverse slide is fitted with a rocking block, through which the connecting-rod passes, the combined action of which provides for the free motion of the connecting-rod, and, at the same time, forming a sufficiently steam-tight division between the cylinder and head.

Upon the standards is secured a cylinder with its attached head, and they support the valves, &c., necessary for the action of the engine. A piston is fitted to the cylinder, and is made of sufficient length to form in itself a guide in its reciprocating motion. One end of this piston is hollowed out to receive one end of the connecting-rod, which is pivoted to it, the opposite end of the rod being attached to the wrist-pin of the disc, which is keyed to the shaft of the fly-wheel. This disc is enclosed in the extension of the cylinder, and the form of this extension is such as to correspond to the travel of the connecting-rod. This arrangement of parts not only dispenses with a piston-rod, cross-head, &c., but forms a steady-working and compact form of engine, having its crank and connecting-rod concealed from view and injury. To close the communication between the forward end of the cylinder and the head so as to exclude the steam which would otherwise fill it, and would consequently be exhausted with every stroke of the cylinder, proving a loss, a slide is fitted in a case, so that a free vertical motion is given to the slide by the motion of the connecting-rod. Through a central opening of this slide the connecting-rod passes; and to form a steam-tight joint the rod passes through a rocking-block, which has a curved form of face to correspond with a similar curvature made in the slide.

By the motion induced by the connecting-rod the slide works up and down, and the block works in its seat in an oscillating manner, presenting no impediment to the operation of the rod, and by the combined action of the slide and rocking-block the connecting-rod has free passage and play in a sufficient steam-tight manner without the aid of a stuffing-box; but inasmuch as the head forms a steam-tight inclosure, it is by no means necessary that the slide or the block be otherwise than a good working fit, and packing may be dispensed with. It will be observed that the steam-tight extension of the cylinder encloses all the principal working parts, which serves to keep them well lubricated, and prevents the ingress of dust, dirt, or other foreign substances. This makes it especially applicable to the American street cars, and we understand that one is now being introduced into a car in New York. The 'American Gaslight Journal,' to which paper we are indebted for all particulars, states that this engine was patented in March last year, and is on sale at 42, Day-street, New York, where it appears likely to be in good demand.—*Mechanics' Magazine.*

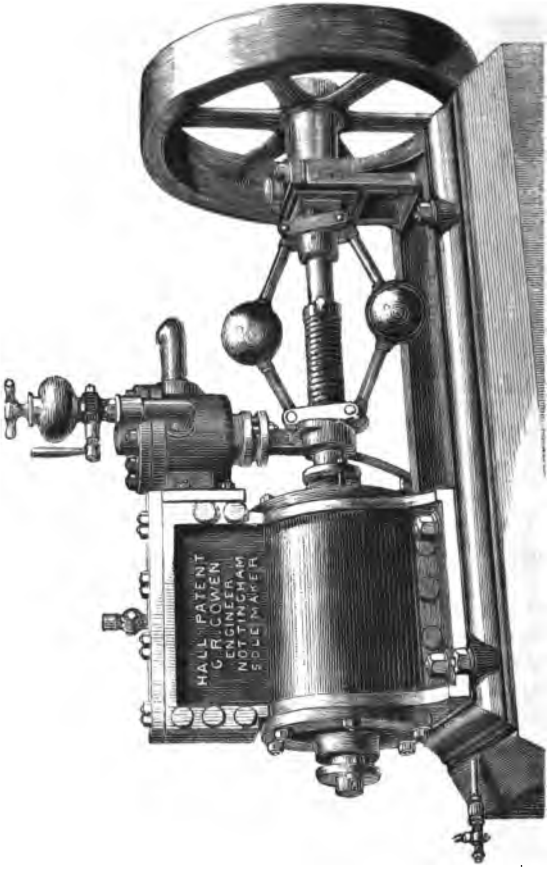
38. *Hall's Rotary Engine.*—The following is a description and illustration of this engine as made by Mr. Cowen of Nottingham:—"A, fig. 47, is the cylinder truly bored, faced, and fitted with covers, which are also faced, and through which the main

Fig. 47.



shaft B works. This shaft is supported at each end in conical bearings, which are arranged so that they can be adjusted for wear. The revolving eccentric piston, E, is keyed on the shaft B, and is kept in perfectly steam-tight contact with the circumference of the cylinder by means of the metallic packing F held out by springs as in an ordinary piston; whilst it is kept tight endways by means of the metallic rings G G, also held up by springs against the faced surface of the covers D D. H is the steam inlet, and I the exhaust outlet, whilst K is an equilibrium cut-off valve worked direct from the cam L, which slides on the shaft B, as controlled by the patent horizontal governor, as shown in the elevation. The admission of steam is thus regulated by this valve in direct proportion to the load on the engine, thus maintaining an uniform speed under variable loads; M is the abutment slide, which follows the piston during its revolution in the cylinder. The steam in the steam chest O pressing on the top of the slide M, tends to keep it in contact with the piston during the first half of the revolution, after which the bottom edge of the slide is exposed on the up stroke to the same pressure as the top, this counter pressure being maintained till it reaches its highest position, when the pressure of steam on the

Fig. 48.



top forces the slide against the piston again for the next revolution.

"We have," says 'Engineering,' "by us diagrams taken by a Richards indicator from one of these engines; these diagrams showing a very good distribution of the steam. Two pairs of the diagrams are off the same engine, and show the action of the cut-off valve under varying loads. The engine in question has a cylinder 18 in. long by 14 in. diameter, and a piston 14 in. in diameter. The boiler pressure was 42 lb., and the diagrams were taken when the engine was running at 150 revolutions per minute. We have also in our possession diagrams taken from a larger engine, which has been indicated up to 37 horse power.

The engines we have described are arranged to run, if required, at great speeds, and the speed can be easily altered by tightening up the governor spring on the main shaft. A surface speed of the piston of 900 ft. per minute is the regular working speed, and small engines have been run with ease up to 1,500 revolutions per minute." Fig. 48 is a perspective view of this engine.

39. *Rotary and reciprocating Engines.*—"We are in receipt of several communications upon the relative value of rotary and reciprocating engines, and the supposed waste of power by the use of the crank while passing the centre. In one instance we are asked to compute the precise 'diameter of a rotary engine, that will equal in efficiency a reciprocating engine having an equal piston area, and a crank of given length.' This question of loss of power by the crank is constantly recurring in one form or another, and we have so often discussed it in our columns that we think our views upon it should be well understood by those who have been for any considerable time readers of our paper. The attempt to substitute any other method than the crank for changing a reciprocating motion into a rotary one, where any heavy work is to be done, has always resulted in a demonstration of the superiority of the crank. The latter is at the same time one of the most simple as well as one of the most beautiful of all mechanical movements. The notion that it wastes power is not founded upon fact, and we think we can make this perfectly plain to our correspondents.

Steam under a given pressure possesses a fixed amount of mechanical power for every unit of volume. The application of the pressure and expansive force of a given amount of steam through the entire revolution of a crank, provided it might be so applied, would not increase its working efficiency. The same amount applied to a portion of the revolution so that its entire efficiency should be used would produce the same result. Suppose a windlass to have a fly-wheel attached of sufficient weight to store up and to impart considerable more power than is required to raise the weight attached to it. Suppose further, that a power of 4 lb. applied to the winch through its entire circuit is sufficient to raise the required weight. Then will a force of 16 lbs. applied successively through ¼ its revolution continuously raise the weight. In this case 12 lbs. of force are taken up by the fly-wheel and gradually expended in raising the weight through the three-fourths of the revolution to which the power is not directly applied. In reciprocating engines the steam is applied only through a partial revolution, but enough is applied so that the surplus force absorbed by the fly-wheel, expended during the remainder of the semi-revolution through which the crank must pass, is sufficient to keep up the speed at the required rate. Therefore there is no loss of power, provided the parts of the engine are properly adjusted, and the steam is cut off at such a portion of the stroke that the full force of its expansion is realized. The steam in a reciprocating engine is applied while the connecting-rod is nearly at a right angle with the crank; the fly-wheel transmits its store of force in a direction always at right angles with the crank; hence it is absurd to suppose that other devices having for their object the application of the steam in a direction uniformly at right angles with it, can possibly possess any great superiority over the crank and fly-wheel which does so very nearly the same thing.

Now a word in regard to rotary engines. If steam is applied to them only through the same fraction of a revolution that it is applied to reciprocating engines, we think there is no one who would suppose them superior to reciprocating engines. But if steam were applied only through one-fourth of a revolution, twice during each revolution, it will take twice as much steam to supply it during the entire revolution. In the latter case more power would be obtained, but it would be at the expense of more steam. Hence we assert that a rotary steam engine, having the same piston area as a reciprocating engine, properly constructed and manipulated, and its semi-diameter equal to the length of the crank, can never do more work in proportion to the steam used (leaving out of the question the slight disadvantage in the application of the power above alluded to), while on account of the imperfect use of the expansive force of the steam, it is less efficient. The account summed up would leave a balance in the favour of the latter."—*Scientific American.*

40. *The Allen* (*High Speed*) *Engine.*—In the numbers of 'Engineering' for Feb. 7th, Feb. 14th, Feb. 21st, Feb. 28th, and March 6th, 1868, the reader will find five elaborate articles on this engine, which is at present attracting so much attention amongst practical men. From the length to which these papers extend, and from the number and size of the illustrations, we are prevented from giving more than a few extracts, as follows:—"The fundamental idea upon which this engine, in common with the Corliss and many others, is designed, is that of variable expansion. Engines of this class have no regulating-valve, but the full boiler pressure is maintained in the valve-chest, and is admitted to the cylinder at the commencement of each stroke, and the governor adjusts the force to the varying resistance by changing the point of cut-off. The action of the regulating-valve raises or lowers the steam-line on the diagram, while that of the variable cut-off lengthens or shortens it, as the load on the engine is increased or diminished.

The object of working steam expansively is, to obtain a high mean pressure through the stroke with a low terminal pressure, on the assumption that, while the former represents the work done, the latter represents the quantity of steam expended in doing it. How far this assumption is found correct in practice we will inquire by and by: upon its approximate truth all expansive working depends. It is readily demonstrated, and is abundantly proved in practice, that the greatest difference between the mean pressure in the cylinder through the stroke and at the end of the stroke, or at the point of release, is obtained by admitting the highest attainable pressure at the very commencement of the stroke, maintaining it up to the point of cut-off, cutting off early and sharply, and permitting the confined steam to exert its expansive force to the end of the stroke. Theoretically, the earlier the cut-off, and the further expansion is carried, the better; but this is greatly modified by various practical considerations. While engineers are agreed in employing some degree of expansion, perhaps no two would recommend precisely the same. The last few years have seen interminable discussions on this subject. Mr. Isherwood, the self-constituted American authority, after dogmatically fixing 7-10ths of the stroke as the proper point of cut-off, employed himself, in the celebrated contest between the Winoski and the Algonquin, a much higher grade of expansion, cutting off rather earlier than $\frac{3}{8}$ths of the stroke. Expansion can certainly be overdone. In this engine it is preferred to cut off at from 1-5th to 1-6th of the stroke, which is about the mean between the views of extremists on both sides.

In employing a high grade of expansion, especially with the considerable pressure of steam now usually carried in stationary boilers, two serious practical difficulties are met with. The first arises from the injurious effect of the sudden application of so great a force on the centres, which the beam-engine, indeed, cannot be made to endure; and the second is found in the extreme difference between the pressures at the opposite ends of the stroke, which is such that the crank, instead of being acted upon by a tolerably uniform force, is rotated by a succession of violent punches, and these applied to it when in its most unfavourable position.

The latter of these objections the advocates of variable expansion have never heretofore attempted to grapple with, but have contented themselves with obviating, as far as possible, the bad effects of this unequal action of the steam, by employing heavy fly-wheels.

The first-mentioned difficulty, however, has compelled attention, and perhaps no mechanical problem has ever received more study than this, to cut the steam off sharply, and yet to admit it gradually.

In America, where much attention has been given to this subject, it has been generally supposed that this problem could be solved only by the employment of what is known as the liberating valve-gear. This is a mechanism which releases the valve when wide open, or partially open, as the case may be, and permits it to be closed more suddenly, by the action of gravity, or of a spring, or by the pressure of the atmosphere. The idea of the liberating valve-gear had its origin in the brain of Mr. Frederick E. Sickles, of New York. The apparatus devised by him for its application to the double-beat valves employed on steamboat engines in the Eastern States was singularly ingenious and efficient, and has, for the last twenty-five years or more, been known as the Sickles cut-off. It combined an opening, at first exceedingly gradual, and then accelerated as the motion of the piston is increased, with an almost instantaneous closing of the port.

The reasoning of the advocates of this system was short, and, in their own view, conclusive. It ran as follows:—'Steam, to be expanded to the best advantage, must be cut off sharply. The sucking in of steam into the cylinder through a gradually contracting passage, technically termed "wire-drawing," involves a great loss, and is not to be tolerated in any degree. A valve closed by a return of the opening motion cannot effect a sharp cut-off; but if it could have a motion sufficiently rapid for this purpose, then the opening motion would need to be equally so, and this would admit the steam so suddenly and violently on the centres as soon to destroy the engine. The admission must be gradual; the cut-off must be sudden. The liberating gear only can give to the valve a slow opening and a swift closing movement. *Ergo*, all the world must, sooner or later, come to use the liberating valve-gear.'

The Allen engine also effects these objects among others, but in a very different way. It presents two grand features for consideration, namely, the peculiar system of valves and valve-gear and the high speed. The action of the former effects, by continuous motion, a perfect distribution of the steam in respect of economy; and that of the latter causes all the practical difficulties, as above described, which lie in the way of the successful employment of high grades of expansion combined with high pressure of steam completely to disappear. The crank receives as little pressure on the centres as we please; none at all, if we like; the force is applied to it, as it advances, in a manner more gradual than the advocates of graduated openings and late admission ever dreamed of, and a fair approximation is made to a uniform rotative force through the stroke. . . .

The theory of working by variable expansion requires the following distribution of the steam: — First, the lead of the valves should be constant, or the same for all points of cut-off, admitting the full pressure at the beginning of the stroke; second, the opening should be sufficient to enable this pressure to be maintained in the cylinder up to the point of cut-off, and the cut-off should be so rapid, that the pressure shall not fall during the operation of closing the port; and, third, the exhaust action should not be effected by changes in the point of cut-off, should permit the confined steam to exert its expansive force as nearly as possible to the end of the stroke, and then discharge it without loss of power from back pressure. Thus, every feature of the diagram is invariable, except the point of cut-off, which is moved by the action of the governor, according to the changes occurring in the load. It is not possible to effect all these objects by means of a single valve. The exhaust-valves must differ from the admission-valves, both in their dimensions and in their movements. Each must be adapted to the performance of its own functions, and to this end must be quite independent of the other.

In this engine four valves are employed—one for admitting the steam, and one for releasing it, at each end of the cylinder. There is no separate cut-off valve; but the admission-valves, by closing, effect the cut-off. All these valves derive their motion from a single eccentric.

The system of valves and valve movements which we have described has no necessary connection whatever with high speed. It may be employed with as great advantage at twenty revolutions per minute as at two hundred revolutions; but, on the other hand, it answers as well in every respect at two hundred, or even at five hundred, revolutions per minute as it does at twenty. Its admirable adaptation to the exigencies of high speed does not at all require, but it enables us to employ, such speed to any extent that we may, on other accounts, deem to be desirable. Being, however, convinced, both by theoretical and practical demonstration, that important advantages are to be derived from the employment of high speed, that the popular view, which regards it as an evil without any compensating good, is utterly wrong, and that, on the contrary, it is in every respect in which it can be regarded beneficial and desirable, and believing, moreover, that a high grade of expansion ought not to be employed except in conjunction with high speed, the promoter of this engine, while he does not in any case insist upon it, strongly recommends for general purposes a piston-speed of from 600 ft. to 800 ft. per minute, and is prepared to employ a still greater speed where circumstances may render it desirable. We shall present here briefly the advantages of high speed, and shall then consider the supposed objections to its use and the construction which it requires.

The great and controlling reason for the employment of high speed in these engines, in which a high grade of expansion, with high initial pressure, is employed—a reason compared with which the other advantages which it presents, great as these are, become of secondary consequence—is, that it enables us to avail ourselves of the inertia of the reciprocating parts of the engine to relieve the crank from pressure on the centres to whatever extent we choose, to apply the pressure upon the crank in a gradual manner as it advances, and to equalize the driving pressure during the stroke, so that, in a properly constructed engine, the higher the speed the smoother, and more uniform, and more silent the running will be.

(Here follows an elaborate demonstration of this action of the reciprocating parts in modifying the distribution of the pressure through the stroke while transmitting it to the crank.)

It will be observed how completely the designer has this action of the reciprocating parts under control. He can proportion their speed and weight to the pressure of steam in such a manner as to relieve the crank from the blow on the centre to whatever extent he may wish. The accumulation of pressure upon the crank during the latter half of the stroke is not, in a properly designed engine, in the least degree objectionable, because there is nothing sudden in the mode of its application, but it comes on the crank in a most gradual manner. It will, however, be found that this action of the reciprocating parts cannot be exerted in the degree necessary to produce a really good effect, unless either the piston speed is much greater than we care to employ, or these parts are of very considerable weight.

The notion that the reciprocating parts of high speed engines should be very light is therefore entirely wrong. They should be as heavy as they can be made, the heavier the better. If, for example, in an engine making 120 revolutions per minute, the reciprocating parts weigh 10 cwt., and relieve the crank of the force of the steam when on the centres, to the extent of 25 lb. per square inch of piston; then by increasing their weight to one ton, they will relieve it of 50 lb., and the running of the engine will be materially improved in the respects of smoothness and uniformity. The Allen engine possesses an advantage in this respect, in having the weight of the air-pump ram added to that of the usual reciprocating parts. These remarks do not, of course, apply to locomotive engines, in which the weight of the reciprocating parts is limited by other considerations, and in which the shock of sudden admission at high speed is avoided, and the driving pressure through the stroke is equalised by excessive compression.

We pass now to the secondary advantages of high speed. The most obvious of these is the increased power obtained by means of it. One engine, for example, making 100 revolutions per minute, exerts the same power which would be given by a pair of similar engines making 50 revolutions per minute. We may be informed that coupled engines are employed to give steadiness of motion—an object for which they are in fact still less needed than they are to furnish the power. All that we want is economical, and, above all, uniform and reliable power; and ever since the first steam engine was made the tendency has steadily been, by employing higher pressure and more rapid piston speed, and more recently by the introduction of direct acting forms, to obtain this power from smaller engines.

More important advantages result from the more rapid rotation of the shaft. Foremost among these must be placed the increased efficiency of the fly-wheel, the power of which, to equalise the motion, increases as the square of the number of revolutions. If, then, in place of the coupled engines already supposed, we substitute a single engine of the same dimensions, but making double the number of revolutions, we obtain not only the same power, but also greater uniformity of motion; for the variations of force are not much greater, while the controlling power of the fly-wheel is increased fourfold.

The advantages of more rapid rotation are largely felt in the transmission of power. Engineers understand very well that, theoretically, the prime mover should overrun the resistance, the pinion should drive the larger wheel, motion should be not multiplied but reduced in transmission. This can seldom be attained in practice, but high speed gives the great advantage of an approximation to this theoretical excellence. On the other hand, slow-speed engines work against every disadvantage. To begin with, coupled engines and enormous fly-wheels have to be employed to give a tolerably uniform motion; often great irregularities are endured, or the abominable expedient is resorted to of placing the fly-wheel on the second motion shaft. Then comes the task of getting up the speed, with the ponderous gearing through which motion is communicated in the wrong direction, the enormous strains, and the jagged motion resulting from torsion and back lash, the villanous nature of all which habit prevents us from realising, but cannot make us wholly blind to. Slow motion prevents, also, the use of the belt, immeasurably the preferable means of transmitting power from a prime mover.

A careful study of the forces developed in the running of an engine at high speed will enable us to attain a construction, in which the difficulties ordinarily encountered disappear, as completely as if they had never existed. This is readily illustrated by a revolving wheel. If unbalanced, it will, at quite a moderate speed, begin to vibrate, and on a little further increase of its velocity this action will become violent; and if its journals are in any respect defective the bearings will be hot; and we may conceive a person ignorant of the cause and cure of this, or indifferent to it, pronouncing rapid revolution to be impracticable. But if a wheel is accurately balanced, and its journals are properly made, there is found to be no limit to its practicable velocity, except that fixed by its cohesive strength. At any speed, short of that at which it will fly asunder, it revolves in perfect quiescence, while its journals float cold in their lubricant.

The same apparently magical change may be effected in the steam engine. High speed, it has been truly observed by an eminent engineer, is entirely a question of construction. The general features of the construction which it requires may be summarised as follows: A direct-acting, self-contained form of engine; the avoidance of overhanging strains; rigidity of both the stationary and moving parts; balancing of the revolving parts, and in horizontal engines of the reciprocating parts also, and in all bearings a sufficient extent of hardened surface and truth of form. If these requirements are fully complied with the speed becomes a matter of entire indifference, and even a tolerable observance of them ensures excellent results. The form of engine best adapted to meet all these conditions is the inverted vertical cylinder engine. In this engine the cylinder is supported from the baseplate equally on each side of the centre line, and is free to expand and contract with changes of temperature. Absolute rigidity may be given to the whole construction, while the baseplate is well adapted to carry double crank bearings, the employment of which renders the action exactly central. On these accounts, as well as for other reasons to be mentioned presently, this form of engine seems preferable in cases where the very highest speeds are to be employed, but for ordinary purposes the horizontal will probably be always the favourite style. In this engine, as shown in the illustrations, the only connection between the cylinder and the bearing of the shaft is below the centre line, and, therefore, the driving force has a tendency to deflect the bed vertically. This strain is, however, rendered harmless by giving to the bed great depth, and bringing the centre line close to its surface. Again, a single crank is employed, involving an overhanging action, which tends to deflect the bed horizontally, and also to spring the shaft between its bearings. This action is, however, reduced to a minimum by making the centre line to overhang the bearing as little as possible consistently with the great strength required at that point, and the bed is made of suitable form, and the shaft of sufficient strength to enable them to oppose to it an absolutely rigid resistance. The form of bed and size of shaft required for this purpose are so desirable also on other accounts, that the fact that the action of the engine is resisted on only two sides of the centre line, instead of all sides equally, seems to be practically unobjectionable. It is found, however, that a long stroke is incompatible with rigidity, and for this reason, and also because both rapid reciprocation with heavy reciprocating parts and rapid revolution are, for the reasons already explained, highly conducive to smoothness and uniformity of motion, these engines, especially the larger sizes, are made of shorter stroke than has been usual hitherto in stationary engines.

The cylinder is bolted to the end of the bed, and left free to move by expansion. It thus retains its parallelism, when hot, sufficiently to enable a deep piston to be employed, presenting a large extent of surface. This is made tight by two of Ramsbottom's packing rings. These cylinders wear perfectly smooth; not one is believed ever to have been scratched, and the wear is so insensible, that it is intended to try the experiment of packing the pistons simply by grooves interrupting the passage of the steam, which are expected at high speed, and with expansive working, to prove quite sufficient. The idea, once universal, and still so prevalent, that horizontal cylinders must at high speed be soon destroyed is seen to be quite unfounded. The various causes which produce wear in cylinders, and which are often as active in vertical cylinders as in horizontal ones, need only to be understood and avoided to ensure the highest durability at any speed. In this respect, as in all others, it is not the speed which does the mischief; it is bad construction, the injurious effect of which becomes aggravated at high speed, but which it is perfectly easy to avoid altogether. The piston is fixed on the rod by shrinking merely, this being the most simple and secure mode of attachment. The rod is required to resist a force applied to press it out equal to a pressure of 250 lb. on the square inch of piston when it is considered safe.

So far as the pressure of the steam is exerted *through* the reciprocating parts to overcome any resistance whatever, including that from their own friction, the action and reaction are equal, and the engine works in equilibrium; but the force exerted to overcome the inertia of these parts, considered as moving without resistance, produces a recoil precisely like the recoil of a gun. The force required for this purpose, increasing directly as the weight of these parts, and as the square of their velocity, needs in a horizontal engine, except so far as it is resisted by the weight of the engine and its foundation, to be counterbalanced precisely in the degree in which it has to be exerted, or in which the inertia of these parts operates to modify the distribution of pressure on the crank, as already explained. In a vertical engine no counterweight is required on this account, because the recoil is prevented by the perfect resistance of the earth; but it is necessary to balance the horizontal vibration of the connecting-rod.

In these horizontal engines the counterbalancing weight is placed in the crank disc opposite to the pin. The stability of the engine, when bolted to its foundation, is such, that at the speed of 200 revolutions per minute a counterweight equal to about one-half the weight of the reciprocating parts is found sufficient to prevent vibration. The least amount that will suffice differs with different sizes and speeds, and is best ascertained by experiment. If the recoil was not partially resisted by the weight of the engine and foundation, the counterweight would need to be equal to the total weight of the reciprocating parts, and this weight is actually required at very great speed when the resistance of the engine and foundation becomes of but little account.

Although the counterweight is a revolving mass, its centrifugal force is in counteraction with the force accelerating the reciprocating parts of the engine at every point of the stroke, precisely as if it was being reciprocated in the contrary directions, only its force is exerted also in the same degree vertically, and in these directions it has, in counteraction with it, not only the weight of the large end of the connecting-rod, but it is incapable of producing a disturbing effect in these directions for the same reason that a vertical engine requires no counterbalancing weight at all.

It is sometimes objected to the counterweight that it exerts an injurious effect upon the bearings; but it is obvious, on consideration, that there is nothing in this objection, because, first, the total strain of the counterweight, as employed in these engines, is less than half that exerted by the driving force; and, secondly, its strain is exerted in the horizontal direction mainly to relieve the bearing from pressure, and in the vertical direction is fully one-half neutralised by the vibration of the connecting-rod.

A horizontal engine cannot be perfectly balanced. Since the angular vibration of the connecting-rod occasions the great difference already shown in the velocity of the piston at the opposite ends of the stroke, it follows that the correct counterweight will be insufficient when the crank is on one centre, and excessive when it is on the other. This, however, will not tend to produce vibration, because the excess of force, although given by the counterweight and the reciprocating parts alternately, is constant in one direction, and will, if the engine is unsecured, give to it an uniform motion in the direction opposite to the crank, as has been practically demonstrated.

For the same reason, also, the force required to give motion to the reciprocating parts is much the greater in the end of the cylinder furthest from the crank. In the engine now being described, for example, this force would, if equal at each end, be 57 lb. on the square inch of piston, as already explained, but in fact it is in the one end 67 lb., and in the other end only 47·5 lb. on the square inch, this being the proportion that the decimals ·0001777 and ·0001269, which are the coefficients of the actual motion of the piston for the first 1°, on the opposite strokes, bear respectively to the decimal ·0001523, the versed sine of 1°. In horizontal engines it is difficult to compensate this inequality; but in inverted vertical engines, at high speed, the tendency is to equalize these forces in a very beautiful manner. The greater velocity of the reciprocating parts is at the upper end of the stroke, and their gravity assists both in imparting and arresting this velocity. Their lesser velocity is at the lower end of the stroke, and this the steam imparts against the action of gravity. Thus, by employing a speed at which the initial acceleration on the down stroke, minus the acceleration of gravity, is equal to that on the up stroke, plus the retardation of gravity, the force of the steam required to put the reciprocating parts in motion at the commencement of each stroke will be the same. This will be the case when the speed is such that the mean of the initial accelerations on both strokes bears the same proportion to the acceleration of gravity that the length of the connecting-rod bears to that of the crank."

41. *The Indicator as a Fixture to the Steam Engine.*—"The steam engine indicator has received occasional notices in our columns, in which its construction and operation have been described, and its uses partially enumerated. We have shown that it gives exact information of the working of the valves, the admission, expansion, and pressure of the steam, its action at all parts of the stroke, transferring these points to paper and forming a diagram which is a basis of the calculations to ascertain the force expended and the power exerted.

But there are other offices and uses of the indicator. By it the relative value of the lubricants used can be ascertained, and the best mode of applying them; the amount of steam required to work the attached machinery as compared with the work done, consequently the saving that can be made in changing machinery to do the same work. Another important office of the indicator is to compare the power developed with the amount of fuel used. This is a check upon the carelessness of the fireman or of the engineer; for if it is known that an engine can be run with an expenditure of two and a-half or three pounds of coal per hour for each horse power on one day, there can exist no reason, except carelessness or heedlessness, why, other things being equal, it should not do the same on another day. It also determines the quality of the fuel. Suppose the last invoice of coal gave one horse power for every two and a half pounds consumed per hour. On one day four thousand pounds are used, but on another day, four thousand five hundred pounds. The indicator shows on both days the same amount of power exerted and that the engine is in the same condition. Then the question is narrowed down to the neglect or carelessness of engineer or fireman, or to a difference in the quality of the coal. If, on weighing the ashes and clinkers, it be seen that on one day they exceeded in amount those made on the other day, it would be plain that the difference in results arose from difference in the quality of the fuel. The incombustible portion of anthracite coal varies from six per cent. to thirty per cent. The proof of its quality can be determined in no way so well as by the indicator combined with the scales.

Every engine—all large engines—should have a pair of indicators permanently attached, and an engineer should be employed who can intelligently use them. A pair of diagrams should be taken twice a-day, say at 9 P.M. and 3 P.M. Let every pound of coal be weighed, and also the ashes and clinkers, and a tabular statement of these facts and the results of the indicator diagrams be made out daily on blanks furnished for the purpose, and a balance struck each week. Thus the proprietor will know at a glance the condition of his engine, the efficiency of his machinery, and the value of his fuel—in fact the cost of all his expenditure of power as compared with the work done.

This may be objected to on the ground that few engineers can be found who can use the indicator, and that some firemen cannot read the scale of the weighing machine. The objection refutes itself: if men are not competent to perform these duties they are not competent engineers or firemen. The use of the indicator can be acquired by the study of such elementary books as 'Porter on the Indicator,' 'Paul Stillman's Treatise,' 'King's Notes on Engineering,' 'Bourne's Handbook,' &c. By the aid of these and practice with the implement any intelligent engineer can readily become an adept in the use of the indicator.

Such education will tend to raise the status of mechanical engineers, reduce the cost of power, insure better work, and induce superior mechanics to adopt practical engineering as a vocation."—*Scientific American.*

42. *The best modes of Testing the Power and Economy of Steam Engines.*—The following is the first part of a paper read by Charles E. Emery, late of the U. S. Navy and U. S. Steam Expansion Experiments, before the Polytechnic branch of the American Institute, Oct. 22d, 1868:—"It is unnecessary for us to do more than simply call attention to the extended usefulness of the steam engine. It is the only motor that has successfully competed with or supplanted the changeable and uncertain power derived from animal muscle and the natural forces of wind and water, and its varied adaptations and applications have brought it into general use throughout the civilized world—not only in stupendous water works and manufactories, and in furnishing reliable and rapid communication by land and sea, but also in reducing the physical exertions of both sexes in the less grand but more important operations of the producing community in the forest, field, and farm house.

Surely, then, the steam engine is not an experiment. Years ago it was made a success, and soon became a necessity; and notwithstanding the grand discoveries that have been made in theoretical and practical science, the steam engine has to this day remained unchanged in every important particular. The principal advance has been in the perfection and general adoption of the simple high pressure engine. Many of the so-called improvements were mere variations in form and in the details of construction, which often failed to produce as economical results as older well tried mechanism. Nearly all the true improvements have been in workmanship, and in adaptations and applications to various uses. A few of the general principles which influence the economy of the steam engine have long been known; and our manufacturers have, in very many cases, claimed a superiority for their engines on account of alleged excellence in the details of the valve gear, or other mechanism, designed to secure the results promised by theory—forgetting that theoretical propositions are of little value unless all the conditions assumed are the same as those in practice, which is rarely the case. It therefore often happens that engines which, in the opinion of the educated engineer, possess many of the elements considered necessary for economical working, do not have those elegant moving details which fix the attention of the amateur and delight the eye of the skilful mechanic. Business men seek only to sell, and therefore push into chief importance such points as the purchaser can see and understand. Statements are made also regarding actual performance, but they cannot be considered impartial, because the trials upon which they are founded are made by interested parties, with no competition present. We have therefore to conclude that the purchaser of a steam engine has to base his selection, almost exclusively, upon the excellence of simple mechanical details; and having done this, if the engine works well, and especially if it does better than the old neglected one, with its worn-out boilers, he is entirely self-satisfied, and ready to sign a recommendation to the public of the engine which *he* has selected, thereby benefiting the manufacturer and flattering his own vanity. But little true progress can be made in this way, as each manufacturer and purchaser knows little more than the result of his own experience.

To bring the steam engine to a high standard of efficiency, accurate comparative trials should be publicly made of every different system of construction. This would be most satisfactory, if it could be done in the same place, doing the same work, under the same circumstances. This would require the erection of costly experimental fixtures, which could be done by private enterprise, for expected gains, or by the combination of several wealthy manufacturers; or, better still, by some scientific organization. The majority of cases must, however, be reached, by trying the steam machinery in the actual performance of the duty for which it has been purchased. We desire, then, in our present inquiry, to ascertain methods and means to test the power and economy of the steam engine, in a strictly scientific manner, which shall be above criticism, and also under the practical circumstances of every day use.

We propose, first, to mention some of the terms in general use on the subject: then to discuss the ways and means employed to measure the power and its cost; and afterwards to select proper units of comparison, and point out the manner of their practical application.

A steam engine is simply a heat engine. The heat evolved by the combustion of fuel is imparted in the boiler to water, separating and agitating its molecules, and thus forming steam. The steam exerts pressure, varied according to its density, upon all sides of the vessels in which it is enclosed. This pressure or force is measured in pounds per square inch. The elastic force of the steam acting upon the engine piston produces motion, which is measured in feet. The combined effects of force, acting through distance, produce mechanical work, which is measured in foot pounds. The number of foot pounds which an engine is capable of developing in a given time, expresses the power of the engine. The unit of the power is one-horse power, the value of which is conventionally fixed at 33,000 foot pounds per minute.

In proportioning steam machinery for any particular purpose, the first thing to settle upon is the amount of power required; and this being fixed in all cases within certain limits, the practical question is, to obtain a certain power at the least possible cost.

It has been said the power of an engine depends upon the work done in a given time; and as work implies force and motion, we must ascertain three things before we can calculate the power, namely, the mean force and the distance through which it is exerted, also the time required for the movement. Having these, we first ascertain the distance moved per minute; and this, multiplied by the mean force, gives the number of foot pounds per minute, which, divided by 33.000, gives the horse power. The distance through which the force is exerted is usually calculated from the number of revolutions made per minute by the engine, which can be ascertained approximately by actual count, but better by means of a register. The speed of the engine is varied more or less by every change in the load, or in the pressure of steam, even when a governor is used, for a change in speed must take place before the governor can operate. The variations are small, with sensitive regulators, but in a majority of cases would materially affect the result. The true plan, then, is to attach a register to the engine, the indications of which should be taken once an hour to check mistakes; and in the calculations, the revolutions per minute should be an average for the whole time through which the trial extends. If the power is to be calculated from the pressure on the piston, the piston movement is also used and ascertained by multiplying the revolutions per minute by double the stroke of the engine, when the latter is double acting. When the tension of a belt, or series of springs, is to be used in calculating the power, the movement of each must also be found, and may be calculated from the speed of the engine. It will thus be seen that two elements of the power are easily ascertained, namely, the time and the distance through which the force is exerted. The mean driving force is more difficult to obtain. There are two instruments in use for measuring this, namely, the indicator and dynamometer. These two names are used in this paper in a restricted sense. The first is applied only to the well known steam engine indicator, and the latter to that form of dynamometer which is used to measure the force transmitted by revolving wheels or shafts.

It would be impossible, in the limits of this paper, to give a detailed description of the indicator. We, therefore, will mention only such features as are necessary to explain its mode of operation. The indicator is so constructed and attached that steam from the main cylinder presses upon one side of a small piston in the instrument, the atmospheric pressure being upon the other side. To the indicator piston is attached a spring and a pencil, the latter arranged to mark on paper. The predominating pressure on the indicator piston, whether of the steam or of the atmosphere, extends or compresses the spring in proportion to the intensity of the pressure, and moves the pencil up and down on the paper. The paper is arranged on a drum, which is so connected that it has a side motion corresponding to that of the engine piston. Consequently, as the engine piston moves, the paper is moved sideways, and, as the pressure changes, the pencil is correspondingly moved up and down; so that the figure or diagram traced on the paper is a combination of the two movements, and should show the pressure at each and all points of the stroke. The mean of a number of ordinates on the diagram represents the mean pressure per square inch of piston, which, multiplied by the area of the piston, gives the total force which produces the piston movement, from which the power may be calculated, as has been before explained. The indicator is a beautiful instrument, of such great value to the steam engineer that it may be said to deserve the numerous words that have been spoken in its praise. Still, in many cases where it has hitherto been considered practically perfect, its indications are of the most deceitful and unreliable character. It shows very perfectly whether the valves are adjusted properly; and often, when applied to an engine which is working improperly, a mere glance at the diagram will reveal the difficulty and suggest the remedy. Large leaks in the valves or piston may also be detected in this way. The indicated pressure at the end of the stroke has very often been employed to determine the quantity of steam used by the engine. Calculations founded on such a basis are entirely worthless, as will be explained when treating of the cost of the power. It has often been attempted, also, to calculate the friction from indicator friction diagrams; but the system is practically erroneous, as will be explained hereafter. The indicator is chiefly employed, however, to determine the power of an engine, it being supposed that the diagram shows correctly the pressure at all parts of the stroke. Even this it fails to do under certain circumstances. The moving parts of the instrument must have weight and friction, and some force is necessarily required to overcome the latter, and put the mass in motion. If, therefore, the pressure be ascending, the indicator will show less than it should; and when the pressure is descending, the instrument will show more than it ought. In either case, then, the length of the ordinates is increased during any change of pressure, whence the mean pressure indicated is greater than actually existed in the cylinder. Until quite recently we supposed that these inaccuracies were too small to require serious attention. Experiment has, however, proved the contrary."

43. *Solar Heat—Ericsson's Solar Engine.*—Captain Ericsson,

at the centennial celebration of the University of Lund, in Sweden, last spring, forwarded to that ancient institution essays relating to the sun, showing that perfect uniformity of the rotation of the earth is incompatible with solar influence, and that solar heat may be so employed as to furnish an infinite amount of motive power for practical purposes. As the first part of the essay does not bear directly on the subject under consideration, I will pass over its contents, merely observing that the philosophical faculty of the Swedish University at the centennial celebration alluded to, conferred on Captain Ericsson the degree of Honorary Doctor of Philosophy. Before presenting to the readers of the 'Scientific American' a translation of the latter part of this essay, it will be proper to state that I have witnessed the operation of one of Ericsson's solar engines to be actuated by atmospheric air heated by the direct intervention of concentrated solar heat, and our mechanical readers will be surprised on hearing that the working piston of the model engine makes upwards of 300 strokes per minute.

The simplicity and moderate cost of the means devised to concentrate the solar heat are such that no practical difficulties present themselves to prevent the construction of solar engines of any desirable power. Much might be expected from the versatility of the constructor and his extraordinary mechanical resource; yet the facility with which the radiant heat of the sun may be collected and concentrated from acres of surface by the means contrived, will alike surprise and interest the mechanical and commercial community.

The following translation of the essential part of Captain Ericsson's communication to the philosophical faculty of Lund, cannot fail to interest your readers:—

"I have, of late years, spent much time and considerable means on experiments to ascertain if the radiating heat of the sun can be concentrated in such a manner as to render it available for the production of motive power.

Sir John Herschel's and Mr. Poullet's experiments relating to the radiating heat of the sun, although interesting, are not satisfactory, as they only deal with low temperatures, showing how much ice may be melted, or what elevation of temperature of water under the boiling point may be effected in a given time on a given surface. The purpose of my investigations and experiments, on the other hand, has been to ascertain what amount of heat can be developed at the high temperature obtained by concentrating the solar rays, viz., bringing their power to bear on a reduced surface, and to devise the most efficient means for effecting such a concentration of the radiating heat. Apart from these preparatory experiments, I have also, at the commencement of the present year, constructed three different motors which I term *Solar Engines.* One of these is actuated by steam formed by the concentration of the heat of the solar rays, while the other two are actuated by the expansive force of atmospheric air heated directly by concentrated radiant heat. Time will not permit, nor is it my purpose on the present occasion, to present a description of these solar engines or the means adopted for concentrating the radiant heat in order to obtain the necessary high temperature. I will therefore limit my essay to the consideration of the essential part of the subject, viz., the motive force itself. With regard to this, I have briefly to state that my experiments show that, at the high temperature requisite for steam engines and caloric engines, the heating power of the sun on a surface 10 feet square will, although in *itself* too feeble, evaporate, on an average, 489 cubic inches of water in the hour, by means of my mechanical contrivance for effecting the necessary concentration. The importance of this result cannot be overestimated, when we reflect that such an amount of evaporation demonstrates the presence of sufficient heat to develop a force capable of lifting 35,000 pounds one foot high in a minute, thus exceeding one horse power. As an incontrovertible evidence of the capability of the sun to develop a great amount of heat at high temperatures, this result is probably of greater importance than any other physical truth practically established.

The mean distance from the centre of the sun to the earth being 214·44 times greater than the radius of the former, it will be found by squaring this sum, that *one* superficial foot of the sun's surface must heat 45,984 superficial feet of the earth. In other words, the sun, on an equal surface, throws off 45,984 times more heat than the earth receives. We are therefore enabled, on the strength of the practical result now positively established, to infer that an area of 10 feet square on the sun's surface develops heat enough to actuate a steam engine,—not a *theoretical* one with its small consumption, but a real steam engine of 45,984 horse power, demanding a consumption of more than 100,000 pounds of coal every hour. But this estimate, based on the evaporation effected by the concentrated radiated heat, is far below the actual development of heat by the sun. Fully one half of the heat conveyed by the solar rays is lost during their passage through the atmosphere and through the apparatus by which the temperature is elevated to the necessary high degree. The actual development of heat, on the supposed 10 feet square of the surface of the sun, will therefore equal the amount of heat generated by the consumption of 200,000 pounds of coal per hour. The mind cannot conceive the intensity which must accompany such an inordinate consumption in so small a space. Still less can we form an idea of the nature of the combustibles or their sufficiency, when such an intense heat is perpetually kept up on the entire surface of a globe the diameter of which is more than a hundred times greater than that of the earth. But it is not my intention on this occasion to lay before the philosophical faculty my speculations regarding the properties of this wonderful orb; I have only designed to discuss the question as to the sufficiency of the radiant heat notwithstanding the enormous distance, and the use we can make of it as a mechanical motor. The result of my experiments, as already stated, having established the fact that without an inconvenient extension of the mechanism which I have devised for concentrating the radiant heat, sufficient power can be obtained for practical purposes, it will now be proper to point out what amount of mechanical power may be obtained by occupying a Swedish square mile with solar engines. Assume that one-half of the area is set aside for necessary roads, houses, &c., an available area would remain of 18,000 × 36,000 = 648,000,000 superficial feet on which the radiant heat might be concentrated. My several experiments having shown that the concentration of the solar heat on 100 square feet of surface is more than sufficient to develop a horse power, it follows that 64,800 engines, each of 100 horse power, may be kept in motion by the radiant heat of the sun on a Swedish square mile.

Archimedes enthusiastically exclaimed that his favourite device, the lever, had power enough to heave the earth out of its path.

It may be more truly said, that the concentration of the radiant heat of the sun furnishes sufficient force to stop the earth in its course.

I cannot omit adverting to the insignificance of the dynamic energy which the entire exhaustion of our coal-fields would produce, compared with the incalculable amount of force at our command if we avail ourselves of the concentrated heat of the solar radiation. Already Englishmen have estimated the near approach of the time when the supply of coal will end, although their mines, so to speak, have just been opened. A couple of thousand years, dropt in the ocean of time, will completely exhaust the coal fields of Europe, unless, in the meantime, the heat of the sun be employed. It is true that the solar heat is often prevented from reaching the earth. On the other hand, the skilful engineer knows many ways of laying up a supply when the sky is clear and that great store house is opened where the fuel may be obtained free of cost and transportation. At the same time a great portion of our planet enjoys perpetual sunshine. The field, therefore, awaiting the application of the solar engine is almost beyond computation, while the source of its power is boundless.

Enough, I trust, has been said to enable the philosophical faculty to judge of the importance of the subject ; but who can foresee what influence an inexhaustible motive power will exercise on civilization and the capability of the earth to supply the wants of our race."

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DIVISION SEVENTH.

LOCOMOTIVE ENGINES.

44. *The Bogie System.*—We take the following paper from 'Engineering,' under date April 7th, 1868 :—" Adams, in his 'English Pleasure Carriages,' gives us the history of coaches, which, curiously, appear to have been of Hungarian invention, and he tells us how Walter Rippon, a famous craftsman in his day, made a coach, nearly three hundred years ago, for the Earl of Rutland, and another for Queen Mary. Whether the moving

temple which he constructed for her sanguinary majesty had a fore-lock history sayeth not; but there can be no doubt that this really elegant expedient for facilitating turning and easing traction on sinuous roads is of very respectable antiquity. If our coaches, wagons, omnibuses, and all our other quadrirotal vehicles were made without it, we should soon have, if not a rebellion of horse-flesh, at least an equine protest quite intelligible to the driver, or the 'Jarvey.' Were a Long-acre coach-builder to try the experiment with his customers, he would soon discover evidences of frigid scapula, or in plain English, cold shoulder, in his cash-book.

A railway carriage is not intended to turn as sharp corners as a coach, but the former, in turning, has the disadvantage that its wheels are fixed to its axles. When railways came in, however, there was to be no turning, except upon turn-tables. The lines were laid out practically straight, but 'practically' is one of the most elastic terms in the language, and it covers an amount of mechanical sinning almost beyond belief. Unlike the coach, the railway carriage runs, virtually, in a groove, with an insignificant amount of lateral play, and its wheel base may vary from 9 ft. to 18 ft. or more, and instead of a quarter of a ton on a wheel, some of our engine driving-wheels are loaded to seven, and a few to eight, tons. These we drive round curves of from ten to twenty chains radius—once in a while round curves as short as five chains—and yet we never employ perch-bolts for the carriages, and but seldom for the engines.

William Chapman, of Newcastle, worked a railway wagon, with a bogie at one end, more than fifty years ago, and the late Mr. Robert Stephenson once mentioned to us that he recommended the bogie to a deputation of American railway engineers, Messrs. Macneill, Whistler, and Knight, who visited him at Newcastle, about 1830, with reference to the character of the rolling stock to be employed for the Baltimore and Ohio Railway, a line then laid out with six-chain curves. The Americans adopted the bogie almost immediately afterwards, both for engines and carriages, and there is no doubt that its use has greatly contributed to the successful results which their lines have achieved The little outside-cylinder engines sent from Philadelphia to the Birmingham and Gloucester Railway had bogies, and engines were made at Neath Abbey, in 1838, for the Rhimney Company, in which two groups of coupled bogie wheels, or eight wheels in all, were driven by gearing from the crank shaft. Sir Daniel (then Mr.) Gooch not long afterwards adopted the bogie for the South Devon engines, and it is now found on many of the Great Western and Bristol and Exeter engines. The four pivoting wheels serving in place of the ordinary leading wheels. With its successful use on the North London, Great North of Scotland, Stockton and Darlington, Great Eastern, and Metropolitan Railways, most railway engineers are now familiar. On at least the two first and the last-named lines it is regarded as indispensable. It distributes the weight of its load upon four instead of two wheels, and in the engines of the Metropolitan and North London lines, the weight on the bogie is 12 tons. Were a single pair of leading wheels used, they would require to be placed sufficiently behind the smoke box to clear the cylinders, and would thus bear an even larger proportion of the total weight. The bogie, pivoted under the centre of the smoke box, gives a longer and steadier wheel base, and the freely radiating action of the bogie axles renders this longer base much easier on curves than a shorter but rigidly rectangular group. When our ordinary types of engine and tender were sent to the Grand Trunk Railway of Canada, they could not face the competition of the bogie as fitted to engines, on the same line, built in the States, and so the leading wheels were taken out and bogies put in. Mr. Watkin, M. P., who managed the Grand Trunk for a time, mentioned, in his address to the shareholders in 1862, that the substitution of bogies under the four-wheel and six-wheel tenders on that line had greatly lessened the breaking of rails during the previous winter; and Captain Douglas Galton, in an official report made, nearly twelve years ago, to the Board of Trade, stated that the bogie rolling stock of the American lines would go safely where our own would jump the rails. We lately illustrated the Russian imperial carriage on the Nicolai Railway, a carriage nearly 90 ft. in total length, yet supported only on end bogies with eight wheels in each, or sixteen in all. Six-wheel bogies are extensively employed under long passenger carriages in the States, and a few have been made—and among them one for the Viceroy of Egypt—which had bogies upon bogies, each end of the carriage having a pivoting under frame beneath it, while, in turn, each end of these frames rested upon a pivoting four-wheel bogie, making sixteen wheels in all. This, however, is a heavy complicated arrangement, not to be recommended.

On the American lines every wheel of every carriage, and almost always of every wagon, has its brake-shoe. On the Baltimore and Ohio Railway there are continuous inclines of 1 in 45½ from eight to eleven miles in length, and on these, where the brakes have to be often applied, the bogies work perfectly, and that around nine-chain curves. It has been objected by locomotive engineers who have not had opportunities of observing the practical working of bogies, that they could hardly be steady and safe when, fitted with brakes, these were applied on steep inclines. So far from this, bogie tenders, carriages, and wagons have been safely worked, for periods of from six months to two or three years, on temporary inclines of from 1 in 10 to 1 in 17 in Maryland, Virginia, and Brazil, and that where the brake was applied to every wheel in descending.

The motion of the long bogie carriages is almost like that of sailing. The momentary shock caused by any given inequality directly affects but one-eighth of the whole weight, and before this shock reaches the body of the carriage it is not only softened by the springs, but divided between at least two wheels, so that really the shock which does reach the body of the carriage, even were there no springs, is that due to but one-sixteenth of the total weight, and this again is distributed over a length of framing of perhaps 30 ft. or even 45 ft. Even where the wheel base is 35 ft. or more, the axles radiate almost exactly to ten-chain curves. As to ease of traction, we have had in our own practice the most indubitable proofs that long trains of bogie wagons have run, at slow speeds, with a total resistance not exceeding six pounds per ton. Indeed, they run with less resistance, and thus require less power, than rolling-stock with rigidly rectangular wheel bases, just as an ordinary four-wheel road vehicle with a fore-lock runs lighter than one without it. Even without this advantage, the distribution or greater subdivision of weight, radiation of axles to curves, and the facility which the bogie affords for long steadily running engines and carriages, render it superior, even on practically straight lines, to the ordinary arrangement of running gear.

The indisputable advantages of the bogie would be even better secured by its application, not merely to the leading, but also to the driving wheels of locomotives. This was done, in a rough way, thirty years ago at Neath, and it is worthy of note that an engine of recent and greatly different construction, yet having double bogies of coupled driving wheels, is now working with excellent success, out of Neath, on the Neath and Brecon Railway. We refer to the engine designed by and built for Mr. Fairlie, who has done so much to bring the merits of bogie locomotives before the profession and the managers of railways. The double bogie engine, with a boiler of double length, having its firebox at the middle of its length, and having also four cylinders with their dependent working parts, is somewhat complicated, but its whole weight is utilised for adhesion, and the weight is equally distributed upon eight wheels, or, in other engines upon this plan, upon twelve. The weight upon the rail at any given point is thus kept down to 3, 4, or at most 5 tons, according to the number of wheels and the total weight. The engine is remarkably steady at all speed, Captain Tyler, who has recommended engines of the same class for the Grand Trunk Railway of Canada, having compared its motion, around quick curves, to sailing. Yet the unwillingness of certain locomotive engineers to even examine the working of this engine is remarkable, and almost incredible instances might be cited of the discourtesy of certain of the English jurors, at the Paris Exhibition, who were invited to examine Mr. Fairlie's model there. But for the timely and energetic interposition of M. Flatchat, a gentleman of the highest eminence in the profession in France, the model would have been passed by unnoticed. It is certain that the employment of long engines, which, having bogies each of short-wheel base, are nevertheless very steady, and which weigh but from 3½ to 4½ tons on a wheel, would very greatly lessen the present heavy wear of rails and tires, and this great reform is so much needed, that every locomotive engineer is morally bound, in the best interests of his profession, to give the whole subject the most unprejudiced and dispassionate consideration."

45. *Thompson's Road Steamer.*—The following, from a paper read before the British Association at Norwich by Professor Archer of Edinburgh, describes a new traction engine which is

attracting at present much attention. "This road steamer has wheels made of a material which at first sight does not look a very likely substance to stand the heavy work they are subjected to. The tires are made of bands of vulcanised india-rubber about 12 in. wide, and 5 in. thick. Incredible as it may appear, this soft and elastic substance not only carries the great weight of the road steamer without injury, but they pass over newly broken road metal, broken flints, and all kinds of sharp things, without even leaving a mark on the india-rubber. They do not sink into the road in the least degree. They pass over stones lying on the surface without crushing them. Those soft and elastic tires resemble in some degree the feet of an elephant. Both the camel and elephant have very large soft cushions in hard hoofs, and no other animal can stand so much walking over hard roads as they can accomplish.

The power required to propel the road steamer is very much less than what would be required if the tires were hard and rigid. They do not crush nor sink into the roadway. The machine, as it were, floats along on the india-rubber, and all the power used in crushing and grinding the stones under rigid tires is entirely saved. It might at first sight be supposed that it would take a great deal of power to propel a heavy carriage on soft tires; but if the tires are elastic as well as soft, the power used in compressing the tire in front of the wheel is nearly all given back as the elastic tire expands behind the wheel.

The india-rubber tires require scarcely any more power to propel them over soft bad roads or over loose gravel roads than on the best paved streets. The reason of this is quite obvious; they do not sink into roads, and do not grind down the stones in the least degree.

Trials have been made at Leith by running the road steamer across a soft grass field, in which an ordinary steam carriage would certainly have sunk. The way it ran through the grass, without even leaving a track, was very remarkable; but when it made for a part of the field which had just been covered with loose earth to the depth of one or two feet, and ran straight across, and then back through the deep soft soil, the surprise of those present was great indeed. The weight of the road steamer is between four and five tons; and yet the wheels in passing over the loose earth compressed it so little that a walking-stick could easily be pushed down in the track of the wheels without any exertion. It is quite clear that one of the great difficulties farmers have had to contend with in using steam engines for ploughing is now removed, for the road steamer will run through any field, even when newly ploughed, without any difficulty. After various evolutions, showing the ability of the road steamer to run about where there were no roads, it passed out into the street, and, taking a large omnibus full of passengers in tow, it proceeded up the Bonnington-road to Messrs. Gibson and Walker's mills, where it took a large waggon, weighing with its load of flour about ten tons, up a steep lane full of holes and ruts and rising with a gradient of 1 in 20. It was obvious that the road steamer was able to do a great deal more than it had to do in this trial. The bite on the road is something marvellous, and the easy way in which it floated along on its soft and elastic tires was very curious. When riding on the road steamer the feeling is like what would be experienced in driving over a smooth soft grass lawn. There is absolutely no jarring at all. Thus the machinery is spared the severe trials arising from the blows and jolts to which it is subjected when mounted on common wheels. There is, incredible as it may appear, no appearance of wear on the india-rubber tires. The original surface which the rubber had when it left the manufactory is still visible.

The steamer which was the subject of the experiments had another specialty besides the wheels. It was fitted with a vertical boiler, which is one of the most economical steam generators yet produced. Externally the boiler looks very much like others of vertical construction; but internally it is entirely different. A glance at a sectional drawing of it will make its advantages apparent to practical men. Its powers may be illustrated by giving the result of a series of trials made in contrast with a common locomotive boiler, and an upright boiler of the ordinary kind. The latter evaporated 3·66 lb. of water for each pound of inferior Scotch coal burned; the locomotive boiler 4·13 lb. of water for each pound of coal; and the new boiler 4·68 lb. of water for a like expenditure of fuel. In contrasting the heating surface the new boiler had a still greater superiority. With 63 ft. of heating surface it evaporated 15½ cubic feet of water per hour. The common vertical boiler, with 72 ft. of surface, evaporated 14 cubic feet of water per hour; and the locomotive boiler, with 137 ft. of heating surface, evaporated 15 ft. of water per hour. This shows the new boiler to possess a very decided advantage.

The tractive powers of the machine have surpassed all expectation. It was constructed to drag an omnibus, weighing, with its load of say thirty passengers, about four tons, on a level road, but its powers are so greatly in excess of this task, that no load yet placed behind it has fully tested its power. An opportunity was offered which was confidently expected would show the limits of its capabilities. A huge steam boiler, weighing with its truck between twelve and thirteen tons, had to be dragged up a hill rising 1 in 12. The little road steamer was chained to the truck, and steadily drew the great boiler to the top of the hill, the india-rubber wheels biting the ground in the most perfect manner; there was not the least sign of slipping. The boiler was drawn from the works of Messrs. Hawthorn and Company along the Junction-road, and then up the hilly Bonnington-road, to the flour mills of Messrs. Gibson and Walker. In its progress the road steamer had to draw its great load over all kinds of road. Nothing seemed to affect the bite of the india-rubber tires. The road was so slippery from the frost that horses had the greatest difficulty in keeping on their legs, but no difficulty was found in going over the glazed surface with the india-rubber wheels. India-rubber does not slip even on ice, as may be easily ascertained by trying to slide in a pair of india-rubber goloshes.

A number of trials have just been completed with a powerful road steamer which has been constructed for hauling waggons loaded with coffee over the hilly roads in the island of Ceylon. This road steamer has two cylinders, each 7½ in. diameter by 10 in. stroke, and a vertical "pot" boiler 3 ft. diameter, by 7½ ft. high. The engine is arranged by means of spur gearing to make either six or fifteen revolutions, as may be desired, for each revolution of the driving wheels. This road steamer weighs, with water and coal for two hours' work, about 8½ tons. It was intended to haul twelve tons gross weight up gradients of 1 in 16. It was found on trial that it was capable of doing a great deal more than the stipulated amount of work. It was first tested by going up a very crooked and steep street in Edinburgh, viz., Cockburn-street, with a waggon in tow weighing 2¾ tons. This street rises with a gradient in some places of 1 in 8, but the road steamer went up with the greatest ease.

The next trial was of a very severe kind. Four heavy waggons, constructed to carry 5¼ tons of coals each, were attached to the road steamer. Each waggon weighed when empty 2¾ tons. With this train in tow the road steamer ran from Leith to New Battle Collieries, a distance of about eleven miles. The waggons were then loaded with 5¼ tons of coals each, and the road steamer drew the whole four from New Battle to Leith, over roads with gradients rising 1 in 16 in several places. The total weight of coals was twenty-one tons; if to this the weight of the four waggons is added it makes a gross weight of thirty-two tons, and including the weight of the road steamer the weight of the whole train was upwards of forty tons. With this train of 90 ft. long no difficulty was found in passing through the most crowded streets of Edinburgh and Leith in the middle of the day and in the midst of a great stream of ordinary traffic. The india-rubber tires are durable beyond all conception, and they are not in the least affected by either heat, cold, or moisture."

46. *The Mont Cenis Engines.*—From two elaborate papers in the 'Engineer,' under date September 18th and 25th, 1868, we extract the following:—"The Mont Cenis engines have now been a sufficient time at work to enable a fair comparison to be drawn between their performance and that of ordinary locomotives. The weight of the engine we illustrate, full, is twenty-one tons, and it is capable in regular work of taking a train weighing thirty tons up an average gradient of 1 in 12, and round curves of two chains radius. A load of thirty tons appears at first sight a very small thing, whereas it in reality constitutes a very remarkable performance. The gross load moved, including the engine, is fifty-one tons. The resistance of gravity on a grade of 1 in 12 is 187 lb. per ton. The resistance of such a track as that over Mont Cenis cannot be less than 8 lb. per ton, at eight miles per hour, the usual speed. So that the total resistance to be overcome, neglecting engine friction—which is obviously considerable—must be 9,945 lb. Taking the resistance of an ordinary train on a level at 8 lb. per ton, we find that it must

weigh 1,243 tons, in order that its resistance may equal 9,945 lb. So that the performance of the Mont Cenis engine is equivalent to that of a goods engine of the heaviest class hauling a train of about 1,210 tons on a level. Assuming the engine to carry its own coal and water, as the Mont Cenis engine does, it would weigh about 43 tons, and its load would be 1,200 tons; but no 21-ton engine of the ordinary construction in existence will draw a load of 1,200 tons, even on a dead level, with certainty. The effect of the gradient of 1 in 12 is to bring the resistance up to about twenty-four times as much as that required on a level. For gravity—

$$\frac{187\text{ lb.} + \text{friction } 8\text{ lb. per ton}}{8\text{ lb. resistance on a level}} = 24{\cdot}6,$$

and therefore, by multiplying the loads actually drawn by the Mont Cenis engines by 24·6, we get their true performance as reduced to a level. The net loads, therefore, taken daily by these little 21-ton engines equal about 738 tons on an ordinary road; and when we call to mind the conditions of climate under which these engines work, we believe most of our readers will agree with us that they have so far not been excelled in general efficiency.

We have said that no 21-ton engine, depending on its insistant weight alone for adhesion, will draw 1,200 tons with certainty, and the truth of the proposition is easily demonstrated. 21 tons are 47,040 lbs.; we cannot assume a greater co-efficient of adhesion than one-sixth, and

$$\frac{47{,}040}{6} = 7{,}840\text{lb.},$$

but the resistance of 1,200 tons at 8 lb. per ton is 9,600 lbs., and

$$\frac{47{,}040}{9{,}600} = \frac{1}{4{\cdot}9}\text{th},$$

a co-efficient seldom if ever realized in this or any other country. Thus, we see that by the aid of the mid-rail, a light engine can do the work of one double its weight, because it enables us at all times to realize a co-efficient of more than one-fifth of the weight of the engine. Against this, of course, is to be urged the great complication of the Fell engine, and, as a consequence of this complication, it is unadvisable to adopt the mid-rail system except on very steep gradients. It must not be forgotten, however, that the present Mont Cenis engines are experimental in the fullest sense of the term, and it is not right to suppose that the mid-rail system is incapable of simplification, or that Mr. Fell's engines may not be improved upon; on the contrary, the chances are strong that much of that complexity which now tells so heavily against the mid-rail system will be greatly reduced. Whether it is or not, with Mr. Fell and his staff remains the credit of having proved that railways can not only be carried over the steepest mountains, but worked with success by steam locomotives.

We do not propose here to enter into any minute description of the engines or their mode of working. They are so complicated in some respects, and the motion of the gear driving the horizontal wheels is so peculiar, that pages of letterpress would absolutely fail to render them comprehensible. Little can be learned save from the drawings (see number of the 'Engineer' for September 18th and 25th, 1868), and these are so clear that any engineer accustomed to read and use drawings cannot be at a loss. Nothing short of a model will render the action of the horizontal driving gear comprehensible, and we advise those who feel much interested, or who wish to obtain information respecting a very neat motion, to construct models from our drawings, which may be very easily done. Off the mid-rail the action is not quite perfect, as the force is not communicated with strict regularity from the pistons, but on the mid-rail it leaves nothing to be desired as far as regards smoothness of action. . . .

The first matter claiming our attention is the arrangement for driving the horizontal wheels; about that for driving the vertical wheels there is no room for doubt; it has, we feel certain, been readily understood by all our readers.

The plan of the movement of the horizontal wheels, and the transverse section through the horizontal levers and guides, will, we trust, render the working of the horizontal wheels intelligible. It will be seen that two flat beams pivot to the frames at either side. From the inner ends of these beams connecting-rods proceed to pins fixed in counter cranks as shown. The horizontal wheels at either side of the central rail are coupled by two rods, only one of which is shown in the plan, as the others are hidden by the main connecting-rod from the piston-rod crosshead, or omitted to avoid over-crowding the engraving. It is obvious that if the wheels at one side are caused to revolve, the horizontal beam coupled to these will swing backward and forward. If this beam is connected with its fellow, then the opposite pair of horizontal wheels must move also. If any of our readers are in doubt on the point, we advise them to examine the drawing carefully, and satisfy themselves that it is so before going further. The two levers are coupled by a very neat arrangement, best seen in the transverse section through the levers and guides. A species of box or crosshead slides in guides. Through this box, and between the guides, both levers work one above the other. A large pin is inserted in one end of the box on which two links work, the slotted out end of each one of which embraces one lever, and is secured to it by a pin passing through a suitable gun metal bush. The arc of oscillation of both levers is the same, and the counter cranks are disposed at that angle which ensures a coincidence of dead and live points in the cranks at each side of the mid-rail.

In consequence of the extra weight thrown on the last pair of vertical drivers by the removal of the third pair of wheels—first adopted against the express advice of Mr. Alexander, by whom the engines were designed throughout—it became necessary to provide a second pair of bearings on the shaft. In an engine so small and so crowded with machinery this was a difficult task, accomplished thus: a frame of angle iron was fixed right across the engine, close to the fire-box. Into this two heavy vertical screwed bars were fitted, the lower ends of which support cantilever brackets of solid wrought-iron resting on helical springs supported in turn by the axle-boxes. The arrangement is shown in front sectional elevation just above the transverse section through the horizontal levers and guides, already referred to. Exception may be taken to it on the ground that the line of strain does not pass right through the axis of the vertical pins. Nothing better could be done, however, and it is satisfactory to know that the arrangement answers its intended purpose thoroughly well. The weight carried on each inner bearing is about 55 cwt.

The transverse section of the engine requires no particular description. It speaks for itself. It may be well here to state that a small pipe is introduced into the steam pipe, by which a little water can be injected from the boiler to lubricate the pistons when running down the incline; the arrangement is found to answer very well. In descending, the brake is used. Its construction will be understood at a glance. By causing the partial revolution of the central vertical standard, the brakes at each side of the central rail are made to approach and grip the mid-rail from opposite points. As a rule, these brakes are not much employed except when stopping, as the engine is kept in mid or forward gear when running down backwards, and the consequent compression of the air in the cylinders serves to retard the machine in a way well understood by every one who has driven a locomotive.

It can hardly have failed to strike our readers that the mid-rail may prevent the existence of level crossings, but on such a line as that over Mont Cenis, where accommodation bridges are unknown, it was impossible to dispense with them. The mid-rail stands up some distance above the track, too high to permit the use of any bridging sufficient to allow a cart to cross; a gap might be left at a crossing, but the expedient would prove dangerous, as, in ascending the steepest inclines, it is doubtful if the impetus alone of the train would suffice to carry it over the break. The difficulty has been completely overcome by an arrangement designed by Mr. Barnes, the resident engineer of the line. This arrangement will be readily understood without much description. A section of the mid-rail, as long as the level crossing is wide, is mounted on levers, in such a manner that it rises and falls just as the upper blade of a parallel ruler may be made to rise and fall while the lower blade rests on a table. Counter weights are provided to balance the moving portion of the rail, and the whole is actuated by a lever in the same way, and with as much ease as an ordinary pair of points. The moving rail is cut off square at the down hill end, and tapered at the opposite extremity, so that when raised to its place it buts fairly against the permanent portion of the mid-rail, and is supported by it against the longitudinal strain exerted by the draught of the engine. There are some thirty of these level crossings on the Mont Cenis line, and they work perfectly well, and give no trouble whatever. The moving rail sinks just below the level of the timber platform constituting the level crossing, and so is completely out of the way of carts, mules, or foot passengers, except when a train is passing. . . .

We believe that we have now described every feature of importance connected with the locomotive stock of the Mont Cenis Railway, and it only remains to add a few words as to its working prospects in an engineering, if not a commercial sense. It is obvious that no past experience can enable us to form any idea as to what the cost of locomotive repairs must be; that with such engines they cannot fail to be heavy, no one understands better than Mr. Alexander, by whom they were designed. A year's working will cast much light on this subject, however, and after all the repairs may not prove so costly as has been anticipated. It is much against the engines that they are too few in number for the traffic, and that as a consequence sufficient time is not afforded for thoroughly overhauling them now and then, and making small repairs in time. It does not appear that Messrs. Crampton and Brassey regard the ten standard engines as the best that can be produced, and Mr. Crampton is now designing twelve others of a somewhat different type. In these the mid-rail wheels will be driven by cast steel gearing, four spur and two bevel wheels being used, we believe. We question whether gearing will be found to answer, and we think that most locomotive superintendents would prefer any system of coupling rods, however complex. But it must not be forgotten that we have no experience in the application of gearing to locomotive work, and it may very well be that nothing but prejudice has stood in the way of its adoption in many instances long since. It is, therefore, quite possible that Mr. Crampton may be right in his views and others wrong. Mr. Barnes, the resident engineer and locomotive superintendent, pronounces in favour of Mr. Alexander's engines, and suggests that more of them should be built instead of trying the experiment of introducing a new type; a fact which speaks strongly in favour of Mr. Alexander's design.

Some engineers have asked why a mid-rail should be used at all, pointing out that even on inclines of one in ten ordinary coupled engines can get up with a moderate load. The answer is very simple. No engine of the same weight as the Mont Cenis engines—21 tons—could get up the incline with 30 tons behind it without the mid-rail. We have already shown that it requires a tractive effort equal to 1-4·9 of the weight of the engine to ascend with this load, and such a co-efficient of adhesion could not reasonably be calculated upon even in the finest weather in the case of an ordinary engine, while it is folly to imagine that it would be available in snowy or foggy weather. Whatever an all-coupled engine might do on Mont Cenis in summer, it would certainly be useless in winter, and these facts dismiss, we think, all the objections which have been brought against the mid rail—in this far, that nothing else has been proposed which would enable the line to be worked as it is worked now. Every one connected with the enterprize is conversant with the defects inherent in the system; but the advantages conferred by the mid-rail so far appear to much more than compensate for them.

It remains to be seen whether the best has been made of the mid-rail yet, and it is highly probable that important improvements may be effected in the mode of its application. The whole trouble lies in combining vertical with horizontal wheels, and it may be found possible to dispense with these last. Thus, a wheel somewhat like Fowler's rope-drum in principle, might be mounted on the centre of the crank shaft. Such a wheel would grip only at one point, and would leave the rail after the centre was passed without the grinding inseparable from the grooved wheel so often suggested. Mr. Alexander has proposed and patented the use of two vertical wheels, one at each side of the central rail, gripping it between their faces at a point close to their circumferences; and there is reason to believe that notwithstanding the grinding action that must take place, the simplicity of such an expedient would compensate for its defects.

In conclusion, we may point out that the working of mountain lines affords immense scope for the exercise of that ingenuity which has always distinguished the profession; and young engineers lacking other employment could not do much better than set about improving on the ideas of Mr. Fell and all others who have turned their attention to the surmounting of steep ascents by locomotive steam engines."

DIVISION EIGHTH.

MARINE ENGINES.

47. *Marine Engine Improvement.*—The following suggestive paper is from the pen of the Editor of 'Engineering,' under date Oct. 16, 1868 :—"From the engine maker's point of view, any change in the construction of marine engines may be undesirable; but to the steamship owner, proposing to build new ships, or put new engines into old ships, any improvement is of an importance corresponding to what it may save, whether in first cost, repairs, fuel, or attendance. Such improvement is also of peculiar interest to a numerous and progressive class of engineers, manufacturing and consulting, who like rather to look forward to the future of steam navigation than to rest satisfied with the present. That the machinery of steamships still *needs* improvement, the most conservative of manufacturing engineers will hardly deny. The marine engine in its present most advanced form is a splendid triumph of practical science and mechanical skill; but most middle-aged engineers can remember when, nearly thirty years ago, they thought the same of the clumsy contrivances, now long since obsolete, which then churned through the water, driving ugly hulls at eight knots an hour. The simplest, lightest, and most economical marine engine of A.D. 1868 is still a complicated, heavy, costly affair, which, none can deny, needs a vast deal of improvement, if we can only find the means of improving it. And if there are means it is of immense importance that they be found out. There appears to be no chance of the supercession of steam by any other power unless we go back to sails. So far the hot air engine, although, in theory, it ought to surpass steam in economy of fuel, falls miserably and hopelessly short of it; while, in any case, some new metal, of unheard-of properties, must be discovered before hot air engines can be made of large power and even tolerable weight. The ether engine promises no better, and but few would hazard its use, with all its danger of fire and explosion, even could it compete in economy with steam. The vast force of the tides, upon which all vessels on the open sea are borne, can in no way be taken advantage of any more than that

of the waves in aid of their propulsion. Something has been said of Captain Ericsson's proposed 'solar engine,' to work somehow, by means of the concentrated rays of the sun. We would be the last to assign limits to the realms of discovery, which are, were such a thing possible within the meaning of words, even more than boundless. But it would require a collecting area, for the purpose of concentrating the rays to heat a large marine boiler, immeasurably beyond what any vessel could carry, or perhaps any manufacturing establishment on land maintain. When the sun, too, happened to be engaged on other business, say, in warming the other side of the world every night—our own night—or when he was warming it by the month together between November and April, or when he was evaporating the waters of the sea into moisture, filling hundreds of thousands of cubic miles of space with fogs, the solar engined ship would be compelled to 'lay to.' In other words, when the sun did not shine, 'the thing,' to employ an Americanism, 'wouldn't act.'

In no general election, therefore, under whatever act of mechanical reform, is steam, as the sitting member, in the least likely to be unseated; Mr. Bourne's confident estimate of the result of the poll to the contrary notwithstanding. And like the ecclesiastical tendencies of many now in the enjoyment of the popular suffrage, the tendency of steam is towards high and not low pressure.

The theoretical advantages of high pressure steam, even up to 500 lb. or 1,000 lb. per square inch, and those of extended superheating, and of the utmost permissible degree of expansion, have been explained and insisted upon in innumerable pages of mechanical literature; and, still more ably and urgently by the many apostles of an improved marine engine practice, who have passed or are now passing away. To what we may attain in the future none can now pretend to say, but while it is undeniable that the principles of very high pressure superheated steam, with high piston speed and a high degree of expansion, is right, the cleverest engineers have only approached its advantages at a great distance in practice. No engineer need be told the reasons why, for they are known to all. At sea it would seem that, even with surface condensation, we are never to have pressure much above 50 lb., although it is encouraging to hear so clever and so successful a marine engineer as Mr. John Elder, of Glasgow, who has succeeded with 50 lb., expressing himself confident of attaining, with the same comparative success, a pressure very much greater yet. It is encouraging to find other engineers doing very well at a six-flod rate of expansion of 30 lb. superheated steam, in steam jacketted cylinders; and encouraging to know that Messrs. Penn's, Messrs. Maudsley's, and Messrs. Napier's very largest engines are frequently run, on trial and for some hours together, at a piston speed of from 500 ft. to 600 ft. per minute.

The whole question of high pressure, say 50 lb. or 100 lb. at sea, turns upon that of surface condensation, and it is undeniable, that so far certain difficulties attending the use of surface condensers have rendered it necessary to keep to pressures at which sea water might, upon occasion, be employed in the same boilers, the vacuum being then maintained by means of an injection condenser—although the air pumps which are sufficiently large for a surface condenser are altogether too small to pump out injection water. It is enough to say, that whenever the long known difficulties—such as the furring of the condenser-tubes, the accumulation of oil, acidulated or otherwise, in the boilers, or the corrosion of the boilers themselves—are once and finally overcome, there is nothing to prevent the regular use of 100 lb. or 150 lb. steam pressure at sea, any more than in locomotives upon land.

In the meantime it is as well to keep to boilers suited to pressures of 30 lb. or thereabouts. As compared with ordinary land boilers, the modern marine tubular boiler is a light and compact, if not a remarkably strong structure; and even in respect of strength it is not to be forgotten that but very few marine boilers—or those made for seagoing steamers—have ever blown up. But if we compare it with the locomotive boiler it at once becomes a hulking, clumsy contrivance, to say the very best for it. Its weight, together with the water contained in it, will not fall much short of 5 cwt. for every cubic foot of water evaporated per hour, whereas one-third this weight answers in the locomotive. When we consider how badly a thin and nearly square box—and the shells of nearly all marine boilers are little more than square boxes—is calculated to withstand internal pressure we perceive the first element of weakness and consequent weight. When, again, we perceive what a small proportion of tubular surface is presented in comparison with the extensive but indifferently effective vertical surfaces of half-inch plates, and, besides these, the considerable surfaces under the ashpit—generating little or no steam—there is nothing to wonder at as to weight. Water bottoms were absolutely necessary in wooden ships. Is it certain that they are at all necessary or even desirable in iron ships? Locomotive boilers give a good rate of evaporation without them. Indeed they have been tried on locomotives without the least advantage. And as for dividing the length of a boiler by means of five, six, or seven 'water legs' into four, five, or six separate and distinct furnaces, what is the good of it? Look at the weight of plates, the stay bolts, the angle iron or flanging, the hand holes and the cleaning—and all for what? No doubt the 'legs' unite the furnace crowns with the water bottom, and if not so secured the latter would endeavour, and no doubt successfully, to straighten itself out, like the hollow spring of a Bourdon gauge, into a vertical line with the back of the boiler. But if there was no water bottom there would be no straightening tendency of the kind; and even with a water bottom a water front, as in a locomotive firebox, would most effectually tie it to the crown plate, and, still more, very sensibly diminish the heat in the boiler room. As to a great flat crown plate 15 ft. by 7 ft., more or less, it would be no more difficult to stay than the crown plates 5 ft. by 4½ ft. of broad gauge locomotive fireboxes worked to four times the pressure per square inch. Nor would there be any difficulty in keeping the crown plate clean. The room now taken up by the 'legs,' 6 in. or more each, would be occupied by two additional vertical rows of tubes of hardly one-fourth the thickness, yet presenting much more effective surface. But if the furnaces must be separated like pigeon holes, or little chapels of ease, make the legs a foot through and perforate them with 4 in. tubes. These would give much additional surface of the most valuable kind, and they need not interfere with proper cleaning.

All marine boiler tubes ought to taper, being smallest at the front or smoke-box door; but, unfortunately, if so made, they could not be set in the boiler, as there would be no room to enter them at or withdraw them from the rear end.

Marine boilers made with cast-iron ash-plates instead of water bottoms, and having no divisions between the furnaces, would weigh much less than at present, be much cheaper in first cost, and would present far more of the most effective heating surface, viz., of horizontal plate with the fire beneath it. The grate area would be enlarged, narrower air spaces would suffice, the draught would be better equalized, thinner fires maintained, and the 'combustion chambers,' or space for the mixture of the gases with air, would be very much increased.

It would be worth while to consider also whether some form of furnace like the Wilson furnace could not be adopted in connection with marine boilers. In this case, with boilers fired athwart ship, they could be brought very much closer together, and the boilers on both sides fed simultaneously from a raised stage, on which the men could stand with comfort. If such a furnace were found to answer it would require feeding only through a hopper, and no slicing of the fire, or dragging the grate bars from beneath, inasmuch as there are no bars, and none but absolutely incombustible refuse.

If nature would but kindly increase the conducting power of metal—but she won't—what different and how much lighter boilers we might have. The average evaporation from all the heating surfaces of a marine boiler of the English type is but 2 in. in thickness, or depth of water, over the whole surface, per hour, or $\frac{1}{30}$th in. per minute, or $\frac{1}{1800}$th in. per second. It is not certain that an artificially increased circulation of water would be of any use. As it is already, there must be a lively rattle of water and steam from over the furnaces up among the tubes above them, and the water level must rise in a heaving mass of steaming foam at a point not far from the hind end of the tubes. 'Heat pins' have been tried and abandoned for getting the heat more rapidly and directly into the water. They were in the way of cleaning on both sides of the plate, and if not burning off often occasioned leaks. As it is, nature will not be hurried, and we may as well give her her own time, in the shape of half an acre of heating surface, as Mr. Penn has done in the boilers of the Hercules. In America they would give an acre, the Wampanoag, of but two-thirds the indicated power of the Hercules, having 30,500 square feet. The Wampanoag is one of their newest and best vessels, but let us look at one of a crack lot of frigates, built in 1854, one to which American practice still conforms pretty closely in respect to the machinery of war vessels, the Wabash, whose maximum performance in smooth water is, according to Mr. Isherwood's *Experimental Researches*, only 9·11 knots an hour. She has direct acting screw engines with 72 in. cylinders and 3 ft. stroke. These, with boilers, and water in the boilers, weigh no less than 470 tons, and yet they work to but 1,039 indicated horse power, each horse power being performed by upwards of 9 cwt. of machinery instead of 3 cwt., as in the best practice here! The Wabash has four boilers with twenty furnaces, or as many as the Duke of Wellington, and these furnaces have no less than 338⅓ square feet of grate, while the total heating surface is 11,852 square feet, the most of it in 5,440 little water tubes, each 2 in. in diameter and 3 ft. long. Was ever a ship so boilered to so little profit? With 15 lb. steam, cut off at 11 in. of a 3 ft. stroke, or less than one-third, the revolutions were 49·3 per minute, corresponding to 295·8 ft. of piston. The vacuum must have been something extraordinary, the feed water from the hot well having a temperature of 135°; indeed the back pressure in the cylinders, as measured above zero, was 3½ lb. No wonder that the consumption of best coal was 4,250 lb. per hour, or over 4 lb. per indicated horse power.

Would that we could but have a good rotary engine! Will such a desideratum for ever baffle the practical genius of engineers? There would be the straight, plain, screw shaft, no cranks, no reciprocating parts, the engine, of any size desired, revolving at one end and the screw at the other. All the screw shaft bearings, including the thrust bearing, would be packed like the stern tube with lignum vitæ, and they, with the shaft, would be enclosed in a plate iron trunk filled with water for 2 in. or 3 in. all around the shaft, and thus the bearings might go for months, if not for years, without being once looked at, and without the possibility of heating. Why should the stern bearings have the whole benefit of the wood linings, the invention of which raised the screw engine and screw propeller from the depths of doubtful expediency to the summit of success? Silver linings—even they may be said to have been to the dark cloud which for so many years hung over the cause of screw propulsion. And even with overhead engines, why should not the main bearings and eccentric hoops be wood-lined and work in water; the connecting-rods, too, be of sword section, and fitted either with gun metal 'brasses' or wood blocks? If the latter were found, on trial, to stand well, a conical tank of boiler iron, nearly closed at the top, would nearly, if not entirely, prevent splashing of the water, the cylinder bottom being well protected against cooling. We are convinced that the half of the virtues of wood bearings is not yet known. The cranks, in the case just proposed, would not, of course, be left the ugly lumps they now are, but would be formed as circular discs to cause as little churning of the water as possible. No thump, no hot bearings, no oil, no attendance. The difference in friction, so far from being against wood, might be found to be, after all, altogether in its favour. There should be no more need, when under way, to look at the crank shaft, or the thrust or line bearings, than into the stern tube, or at the screw itself. And will there not be found some cheap method—whether by casting, drilling, or by punching, as in Deakin and Johnson's process — to make a 3 in. central hole right through the length of the screw shaft? How much better it would be for it, and the journals need not be ½ in. larger in diameter in consequence.

If the science of the future can ever accomplish anything for marine engineers, let its first triumphs be these:—first, some mode, other than evaporation, of rapidly precipitating the saline constituents of sea water:—second, some mode of greatly increasing the heat, conducting activity of the metal or metals of which steam boiler furnaces and tubes are formed. But, except by a blind faith, opposed to all that is now known, we cannot hope for either consummation. Although the salt and water which together form sea water, are in mechanical mixture only, it is almost as difficult to separate them as to separate the oxygen and nitrogen of the air, which also is but a mechanical, and not a chemical, compound of these gases. We might almost as well hope to decompose water by an expenditure of power, say one half as great as that which would be derived from the combustion of the resulting hydrogen. Then should we have liquid fuel indeed—a hydrogen field covering one hundred and fifty millions of square miles, or three-fourths of the entire surface of the globe, upon which steam ships could steam everywhere, without coal or stokers. Liquefied hydrogen, from a mile to seven miles deep! Inexhaustible? were it only released from its aqueous bond it would expand into a volume immeasurably greater than that of the entire atmosphere surrounding our planet. And, if that were not enough, it is, like everything else when chemically considered, indestructible, even by combustion with oxygen, whereby it is simply recombined in water, to be again decomposed, the hydrogen again burnt, and so on, *ad infinitum*. A ton of coal once burnt is for ever destroyed as coal, although every atom of its chemical constituents survives in other but unavailable combinations. So let those hope who can. We see no way of attaining to this imperial possession of nature, but neither do we see the limits of human discovery.

But it is time to descend from these lofty flights of chemical fancy. Let us go back to the engines. Could they be run twice as fast they would require to be but half as heavy. Then why not run them faster? Because they would wear out too rapidly; the rubbing surfaces might heat, in spite of all lubrication —seize, and all would go to wreck together. This is exactly what would have been said, twenty years or so ago, of an attempt to run short stroke (4 ft.) screw engines at 60 revolutions per minute, yet Penn's engines of that stroke, in the Bellerophon, have been run at 75 revolutions, and so far from breaking down are as good as new. Mr. Stirling's fine express locomotives, running at 45 miles an hour, measure off 720 ft. of piston per minute by the hour, and give no trouble. And were railways safe at still higher speeds, say 60 miles continuously, these engines would as easily (as they often now do for a few minutes), measure off from 960 ft. to 1,000 ft. per minute, by the hour together. Why should not marine engines do the same? Is it that there is not room for a five ft. stroke, with a 10 ft. connecting-rod, and that 100 revolutions per minute are not required for the screw? If these are not the reasons, what are they? It is certain that when we give up cast-iron pistons, of heaven knows how many tons' weight, when we employ hollow steel piston-rods, when we abandon the ugly round connecting-rods and adopt steel, channelled at the sides, thus **I** (or, if made to work through water, upon wood bearings, as already suggested, they may be made of double-edged sword section), when we adopt steel cross-heads and bore out the axis of the crank-pins and throws, we shall be enabled to run much quicker without jar or danger of heating.

Lightness, good workmanship, and large bearing surfaces are all that is required to permit of the highest speeds.

With injection condensers only a given amount of water is required for condensation, and to give more only needlessly lowers the temperature of the feed water, besides throwing additional work upon the air pump, without obtaining any real improvement of the vacuum. But with a surface condenser the case is very different. With a moderate quantity of cooling water outside the tubes, a relatively large amount of tubular surface is necessary, inasmuch as the temperature of the water rises so rapidly that it soon becomes nearly ineffective for the purposes of condensation, especially if the water be pumped from the Gulf Stream, the Red Sea, or any other warm source of supply. Some engineers maintain that it requires about as much cooling surface to get the heat out of the stream as it required of cooling surface to get it in. The usual proportion of the former to the latter is about as 2 to 3, or 3 to 4. In any case the quantities to be dealt with are large. A pair of engines working to, say, 2,000 indicated horse power, would, in moderately fair practice, require every hour the quantity of steam that would be evaporated from 900 cubic feet of water, or 15 cubic feet per minute. To condense this by injection, with the water at about 60°, would require 350 cubic feet, or 10 tons of water per minute. This would flow in from the sea; but its momentum being extinguished in the rose of the injection pipe, it would require to be lifted out again to the sea level, perhaps 10 ft. or 15 ft., or even more; the work, exclusive of all losses from friction, &c., thus amounting to from 7 to 11 or 12 horse power. Were the same quantity of water pumped through a surface condenser, there would be no loss of power (disregarding that from friction, bends, &c.), beyond that due to the head which would maintain the required rate of flow. If the 350 cubic ft. per minute, or, say, 6 cubic ft. per second, were to be passed through a nett water-way of even 1 square foot, it would move at the rate of but 6 lineal ft. per second, corresponding practically to a head of rather more than 1 foot. But much more than the ordinary amount of injection water is required with surface condensers. Yet on ship board, with the surface condenser 10 ft. or 15 ft. below the water line, ten or fifteen times the ordinary amount of injection water may be sent through without any real loss of power as compared with lifting out the injection water by the air-pump. In dealing with, say, 3,500 cubic ft. of water per minute (100 tons, or nearly 22,000 gallons of sea water), only centrifugal pumps would be reckoned admissible. No such large quantity is required in the case we have supposed, nor could any surface condenser adapted to engines of 2,000 indicated horse power well pass such a quantity unless the water ways between the tubes were needlessly large. Yet it is as well to remember the advantage which a large volume of condensing water affords, viz., that it renders a less extent of condensing surface necessary. The more water the less surface, the less total bulk of condenser, and the less cost.

Marine engineers have not done well, we think, in gearing the centrifugal circulating pump to the screw shaft. There are several reasons, which it would require too much space to point out here, but some of the principal northern firms, among them Messrs. Robert Stephenson & Co., Messrs. Thompson, Boyd, & Co., of Newcastle, Messrs. Lamport & Holt, of Liverpool, and others, are largely adopting Messrs. John and Henry Gwynne's centrifugal pumping engines, by which the water circulated may be always exactly adjusted to the requirements of the main engines as well as to the temperature of the condensing water itself.

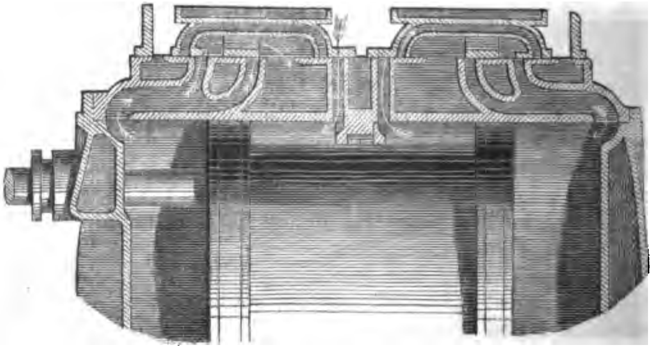
In bringing this lengthy and discursive discourse to an end, we confess we cannot see much hope for steam navigation in the use of 'liquid fuel,' unless it be procurable at far below the present cost, and little in water jet propulsion. But we do see in the future large, light draught, flat-floored ships without sails or masts, such as are so much employed in the American waters, and such ships, steadier and more buoyant than the old type, deserve the most improved engines which the skill, whether of the present or the future, can devise and construct. A lighter draught implies a smaller screw, and it may be that we shall have to adopt twin screws in general use, but for this there is time to wait, and waiting need in no way retard the utmost possible improvement of the marine engine. Z. C."

48. *Description of New Double Expansive Engines for H.M. Ship " Spartan."*—The following paper was read before the Institute of Naval Architects by Edward Ellis Allen, Esq. " I have been invited to contribute a short paper for this year's meet-

ing of the Institution of Naval Architects, descriptive of the engines now in course of construction by Messrs. J. & G. Rennie for H.M. ship *Spartan*. I regret that I cannot enter very fully into the details of their construction, the manufacturers being naturally anxious to complete and subject them to a thorough trial before submitting their details to professional men; the engines in question being the first of their kind of any considerable power, as also the first intended for marine purposes. As, however, a large number of engines of from 6 to 20 horse power have been constructed upon precisely the same principle for pumping, sawing, ploughing, and other purposes, some of which have been constantly at work for upwards of four years, giving great satisfaction, I have no fear as to the results of the engines of the *Spartan*. Assuming, however, that some of the details adopted in these engines are capable of improvement, it is most improbable that any difficulty can arise in making it, the same general plan of construction being capable of being carried out in practice in various ways.

The engines of the *Spartan* are 350 nominal horse power, and are intended, when exerting their full force, to give out 2,100 horse power by indicator, *i. e.*, six times the nominal power, when the expansion is carried to about seven times, the pressure of steam in the boilers being 55 lbs. per square inch above the atmosphere, or about 70 lbs. total pressure. The cylinders are 64

Fig. 49.



inches in diameter, and the stroke 2 ft. 9 in. They are formed as shown in fig. 49, their length being rather more than twice the length of the stroke. Each cylinder is divided into two portions by means of a division cast with it, and furnished with metallic packing similar to that of a piston, but acting inwards instead of outwards. Through this division a trunk works, having a piston at each end packed in the ordinary way. The trunk is made to occupy about three-fourths of the capacity of the cylinder, being in this case 56 in. in diameter, thus allowing an annular space of 4 in.

The steam is admitted from the boiler alternately into the annular spaces formed on each side of the division in the cylinder, being cut off by lap on the valve at about five-eighths of the stroke, or by means of the link motion at any less part of the stroke, and afterwards passes to the respective ends of the cylinder, where it is fully expanded; that is, in the ratio of the areas of the whole cylinder to the area of the annular space. From the ends of the cylinder the steam escapes in the ordinary way to the condenser. The cylinders are steam-jacketed as well as both the covers, and, if necessary, steam may be readily admitted to the trunk; but the large surface of the cylinder being available for keeping up the temperature of the steam during expansion (especially effective as regards the steam contained in the annular space), will probably never render it necessary to admit steam into the trunk for heating purposes.

The boilers of the *Spartan* are six in number, each 9½ feet in diameter, with circular furnaces 3 feet in diameter. Each boiler contains a number of tubes over the furnaces, and a superheater is formed in the uptake.

One surface condenser serves for both engines, and is of the ordinary kind, the steam being made to circulate on the outside of the tubes, cold water supplied by centrifugal pumps being driven through them.

The valves of the cylinders are shown in fig. 49, each valve having double ports for exhausting. The pressure of steam on back of valves is removed in the ordinary way. Both valves are worked by one rod, and are driven by double eccentrics with link motion in the ordinary way.

The engines are placed horizontally, and are of the ordinary double piston-rod construction, with return connecting-rods, their peculiarity alone consisting in the construction of the cylinders and valves. When working with the link motion in full gear the steam will be expanded about seven times, and the expansion can readily be increased to ten or twelve times when required.

The advantages of the arrangement are chiefly its capability of fully expanding steam of considerable pressure; uniformity of action—the high and low pressure steam acting simultaneously; the diminution of the strain thrown on the piston-rods, connecting rods, and guides, in consequence of the steam from the boiler never acting directly upon the large area of the piston, its expansion in the annular space reducing the pressure to nearly half that at which it is first admitted into this space before it passes to the cylinder ends. In the case of the engines already constructed, the trunk is found to be amply supported by the end pistons (each of which may be narrower than an ordinary piston), as well as by the central packing, the cylinders being very equally worn. The steam passages are also very short, and consequently there is little loss in charging them.

In order to avoid any accumulation of pressure by successive changes of the passage through the valves, they are so constructed as to be charged with high steam at each stroke, the edge of the valve passing over its seat. The same object could be accomplished in another way, viz., by exhausting the passages in the valve at each stroke.

It may be well to glance at one or two of the objections which have been made to the form of engine here described: and, first, as to the difficulty of keeping the division and the cylinder steam-tight. In answer to this, I may state, first, that no such difficulty has occurred in any of the engines already constructed; but if a leakage should occur, the steam escaping at once finds its way to the end of the cylinder, increasing the pressure of the expanding steam, the equilibrium ports always being open when the steam is entering the annular space on the opposite side. The loss, therefore, by leakage in this way is really very small, the steam not being lost as if leaking past a piston. Moreover, there is always steam on both sides of the division and the cylinder, there never being a vacuum on one side and steam on the other. The large surface of the cylinder has been thought by some to be objectionable; but, so far as experience goes, it is really one of the good points in the arrangement, affording, as it apparently does, ample heating surface for the expanding steam. Admitting steam to the trunk for the purpose of adding to this heating surface has been objected to, on the ground that it was impossible to make the trunk hotter than the steam. This, of course, is evident; but the question is whether the steam, during expansion, is capable of taking up more heat than the jacket can transmit; if so, good may arise from admitting steam to the trunk.

I may here perhaps shortly describe another use to which the trunk may be put, *i.e.*, in engines worked by steam of a still higher pressure than that to be used in the case of the *Spartan's* engines. The trunk is made cellular, and is bored out so as to receive a piston, which is kept stationary by a rod attached to one or both cylinder covers. The passages for the steam are found all round the trunk, between the outer and inner skins, one-half of them opening out at opposite ends, so rendering the capacity of the trunk available as space for expansion, and adding from 50 to 70 per cent. to it, according to the proportion of the trunk to the whole cylinder. By this arrangement it would be easy to provide for expansion to the extent of twenty times, using steam of 100 lbs., 120 lbs, or even 150 lbs. pressure. The speed of the *Spartan's* engines will be about 100 revolutions per minute, equal to a piston speed of 550 feet.

With regard to the question of economy of fuel from the use of steam of 50 lbs. to 60 lbs. pressure, well expanded and afterwards condensed, it may be difficult to determine; but I have every hope that it will be below 2 lbs. per indicated horsepower, and if the pressure be increased to 120 lbs., as I believe it shortly will, I think we may hope to see 1½ lb. good coal doing the work of an indicated horse power. In the high-pressure engines I am now working on the principle described, I have reduced the consumption of fuel to less than one-half, and in some cases to one-third, that of ordinary engines, cutting off at three-fourths of the stroke, and consuming only one-third of the water, viz., 2½ gallons per dynametrical horse-power. In these engines, which are mostly portable engines, I use mostly 75 lb. steam, expanding it six or seven times, reducing the exhaust steam nearly to zero, and thus avoiding all noise or escape of vapour in a visible form, except in cold weather, or when the air is charged with moisture. One marked advantage of the arrangement for portable engines is the fixed nature of the expansion, such engines very rarely being fitted with expansion link motion, or any other means of working the steam expansively; the link motion, even if fitted, affording no check to the driver working it in full gear, and consequently the steam non-expansively.

I need scarcely remind you that any arrangement calculated to economize steam renders the boilers either proportionately smaller, lighter, and cheaper, or more effective as economical steam generators; the saving from economy of steam being two-fold—first, directly in reducing the quantity of water to be evaporated for a given power; and secondly, in rendering the boilers more economical on account of the relative increase of heating surface.

In suggesting points upon which any discussion may most profitably turn, I would direct attention to the vast importance of economizing fuel in ships of war, more especially those that are armour plated. In many of these it is well know that three or four days' coal is all that can now be carried, *i.e.*, when full steaming. Now, this quantity (whatever the actual amount required may be) must, I think, sooner or later serve for twelve or fifteen days, so as to carry the vessels some 5,000 miles without recoaling. How is this to be accomplished? It seems to me there is only one way, viz., by employing steam of considerable pressure, liberally expanding it in some form of double expansive engine, condensing, of course, by surface, and a moderate amount of superheating, or, as I prefer describing it, using dry steam. In discussing the merits of an engine, therefore, it seems to me one of the most important questions is, whether it is equal to this advanced service to which it must probably soon be put. All our ironclads are terribly defective, as it seems to me, in what we may call the 'wind and pace' of vessels. They neither go far enough nor fast enough, and ere long these points must be attended to, whatever difficulties may be met with in accomplishing the end in view.

With regard to the speed of vessels of war, it has well been said that the speed of a fleet is that of the slowest vessel in it. Now this should be 14 knots, if not 15 knots, an hour, whereas that of our ships is from 9 knots to 14 knots at the best. One requirement seems to have been entirely overlooked, viz., that if any number of vessels are required to move at an uniform steam, they must have what I would call surplus power. This has never been provided for, nor can it ever be, except by the use of high-pressure steam, with ample provision for expansion and adequate cylinder capacity. The variation in speed of vessels, due to the state of the surface below water, indifferent quality of coal, and other causes, cannot be put at less than 2 knots, so that to maintain 15 knots at sea, and at all times (which has been insisted upon by many competent authorities as necessary) provision must be made for 17 knots or 18 knots an hour. This surplus power appears to me as necessary for the ships of a fleet as for the locomotives of a railway; and further, that some such concentration of power is essential in order to meet the requirements of ships in the Royal Navy.

I have during the last fourteen years paid considerable attention to the economy of fuel in steam-ships, and have devised five classes of double expansive engines with this end in view, diagrams of which are exhibited, the engines of the *Spartan* being, I think, the best; but, curiously enough, nothing more than a kind of stereoscopic blending of the 'combined trunk' engines of 1855. In the *Spartan's* engines the two cylinders of this first arrangement are joined together, the one trunk serving for both pistons. This apparently very simple change did not, however, occur to me until seven years after my first production. During the last few years I have had the satisfaction of seeing three of my plans practically adopted in steam vessels; arrangements which are perfectly new to me, and honestly devised, after a careful study of the future requirements of marine engines, being now looked upon as very obvious modifications. Thirteen or fourteen years ago, however, the expansion of steam in marine engines was almost without a single advocate, the supposed necessity of making them as light as possible being considered paramount to every other consideration. In the beginning of 1855 I ventured to suggest that the government should invite tenders for marine engines, in which 'economy of fuel' was the object sought, in the same manner as they had done some time previously when 'economy in space and weight' were the objects proposed. Some years before this suggestion was acted upon in ordering the three vessels—*Octavia*, *Constance*, and *Arethusa*; and these had given rise to the present trial of the engines intended for the *Spartan*, as well as of another form of double expansive engine in course of construction by Messrs. Maudslay. The end-to-end cylinder engine, with trunk connection, designed by me in 1855, has been carried out in the engines of the *Poonah* for the Peninsular and Oriental Company, and for the engines of her Majesty's ships *Pallas*, *Crocodile*, and *Serapis*, while the same arrangement, with double connecting rods, has been in use in the Peninsular and Oriental Company's ships *Delhi* and *Tanjore*. The annular cylinder arrangement has been worked out by a manufacturer for the Swedish government, and I believe with good results. The vast importance of modifying the ordinary construction of engines in which steam of even 50 lbs. pressure is employed, will be seen by considering the strain to which the engines of the *Spartan* would be subjected, if the steam were admitted at once at full pressure upon the whole surface of the piston being not less than 70 tons, while for the large engines of the *Northumberland* class it would not be much short of 300 tons alternately on both sides of each piston, perhaps 120 times a minute. As the pressure of steam increases, so does the necessity become greater for employing double expansive engines. The future progress of marine engineering in the Royal Navy is a question of the greatest possible interest, and I shall be well repaid should the proposed discussion throw any light upon the subject, which it can scarcely fail to do.

"In the discussion which followed," says the 'Practical' Mechanic's Journal, August 1st, 1868, "the chairman remarked it was a very large and important question, and well worthy the consideration of every gentleman who took an interest in marine engineering, and as applied to boiler makers and engine makers. —Mr. Grantham said he thought it was a pity that the paper should go off without some discussion. He would offer two or three remarks which had suggested themselves during the reading of the paper. He thought that gentlemen were apt to lay too much stress on the importance of economy of fuel in the navy. In his opinion it was far more important to the mercantile marine, where there were ten or twenty ships for one in the navy. However important it might be to save fuel in the navy, it was only for the promotion of our self-glorification, and, in some remote measure, to the glory of our country; but in the other it was of importance to the world at large and the whole commercial marine of the country. A large number of engineers had attempted annular engines, and he had seen one that was used in the gunboats of Sweden, in the Exhibition of 1862. He did not wish to disparage the plan now before the meeting, and was sure that everything which would conduce to the employment of high-pressure steam used expansively in our ships was by far the most important direction on the question of economy of fuel. It would be a very narrow view to think that we had arrived at the highest point of perfection; and, although you hear of such economical engines, the great majority of engines were worked at an extravagant expense of fuel. He thought there was some little difficulty as to Mr. Allen's plan, but probably it only arose in his own mind and could be easily explained.—Mr. Allen said, with reference to the engine in the Exhibition, it was his own plan worked out for the Swedish government. The arrangement was that the high-pressure cylinder was in the inside of the low-pressure one, which made a neat arrangement in many respects. The high-pressure steam passages were very long. It worked a good engine, but took up rather more room than some of the other kinds.—Mr. Harland thought it would be desirable for engineers to turn their attention to the boilers best suited to produce steam. The fault had not been the inability of the engineers to produce the steam engines, but the difficulty was that of producing the steam boiler. He would suggest that engineers should consider thoroughly the production of a first class boiler which would stand wear and tear, and be easily repaired."

49. *Marine Engines at the Paris Exhibition of* 1867.—From a paper in the *Scientific American*, we take the following:—"*The Friedland Engines*:—There are three cylinders side by side, acting on cranks placed at angles of 120° with each other. The middle cylinder alone receives its steam directly from the boiler and is unjacketed, while the outer ones are jaketed and receive their steam from the exhaust of the middle cylinder, forming together the equivalent of the low-pressure cylinder in engines on Woolf's plan, so common in Europe. It will be seen that

with this arrangement with three cylinders, it becomes necessary to commence the release of steam from the high-pressure cylinder at about three-quarters the stroke, but it is not necessary on that account to cease admitting fresh steam to the cylinder, since that which passes out of this, acts on the piston of the adjoining cylinder, which is just commencing its stroke, though if a higher degree of expansion is required, the steam may be suppressed at any portion of the stroke. One important point, however, which has been attempted in the construction of these engines has been to make as many of the parts as possible interchangeable, and with this object the valves for all three of the cylinders are made exactly alike, and are set so as to open and close at the same relative point in each case. This latter condition involves the suppression of the steam at about three-fourths the stroke, and introduces some anomalies in the distribution, which do not exist in the ordinary arrangement with two cylinders. Tracing out the distribution of steam to each cylinder, it will be seen that we have first, three-fourths the stroke of the high-pressure cylinder with full boiler pressure steam; then, admission to the second cylinder, and expansion in both till the latter has made three-fourths of this stroke, or the first crank two-thirds of a revolution; then suppression in the second, and at the same time the piston of the first being at about one-fourth of its return stroke, opening of the valve to the third cylinder and expansion between that and the first until the completion of the revolution. The valves are of the D shape, and the steam is admitted beneath and released above them, the valve faces being placed on the top of the cylinders. The valves are worked from cranks in a revolving shaft connected with the main shaft by gearing; and with an arrangement of internal gears by which the advance of this secondary crank shaft may be changed as required for reversing. The exhaust connections are made by means of copper pipes of elliptical section, so made to economise height, and furnished with stay bolts along their shorter axis. The condensers are of the ordinary kind, and the air pumps are placed below and are worked from arms forged on the piston rods. The pumps are of the ordinary double-acting kind, and, as is too frequently the case with this form of pump, the delivery valves being placed at the top of the water chamber and the foot valves at the bottom, all the air contained in the condensed steam has to pass through the body of water in the pump, which it cannot do rapidly, from its finely subdivided state, and accordingly the vacuum obtainable in the pump is very much impaired. The foot valves should be placed at the top of the body of water, the delivery valves being close by, so that the air immediately passes out at the latter without having to percolate through a great mass of water. The shaft of this engine is furnished with a strong universal joint coupling—simply a Hook's joint. The pillow-block brasses are in two pieces, and are set up sideways only, by wedges and nuts above the binders. The framing is very stout, and extends directly across from the cylinders to the condensers on the level of the main shaft. The other pair of engines by the same makers are very similar in general construction of details, but are of the ordinary cylinder type, with valves placed at the sides and worked by a link motion. They are of 265 nominal horse-power, being one of a pair of such engines intended for one of the new French vessels.

The design of the engines built by Messrs. Schneider & Co. appears to be the most common for large power in the French Marine. As already stated, the engine which is in operation, built at the Indret works, is of the same kind, and in addition to this, among the very interesting collection of moving models exhibited by the French Admiralty, the design occurs more than once. It will not be necessary to say much more in reference to the Indret engine therefore, except to mention a few points of difference between it and the one already described. One of the most noticeable of these differences is in the arrangement of the guides for the main crosshead. In the Creusot engine, these consisted of a pair of top and bottom surfaces on each side of the journal of the connecting-rod, and between that and the arms to which the piston rods were attached, as often found in our own engines. The bearing on the crosshead was formed by two blocks of cast-iron encircling the wrought iron crosshead, and secured to each other by feathers on their meeting faces. The wearing faces of these castings are recessed and filled with Babbitt metal. In the Indret engine only a single bearing is used directly beneath the connecting-rod journal, and this is made very wide so as to give ample surface when running a-head, but the lips which form the upper bearing over the sides of the cross-head block have apparently not half the surface, so that the conditions for running backwards are not so favourable, though perhaps there is as much surface as is necessary for the purpose. The condensers are placed at the extreme sides of the engine, outside of the piston rods of the outer cylinders; the space therefore between the three sets of guides and connecting-rods is entirely clear. Beneath the guides are pumps worked in some cases by rods from the steam pistons, and in others by lugs projecting downward from the piston rods. The arrangement of valve gear is the same as in the engines already described. These engines are working regularly every day, but one boiler being fired to supply them with steam, and they appear to run very smoothly, requiring but moderate attention. The appearance they present when operating in this manner, with the blades of the huge screw beating the air and creating a strong current, is novel and imposing. They are so arranged that visitors can walk around every part of them, and examine the working of each portion. In the same annex is Meazeline's three cylinder engine of 450 nominal, or 1,800 actual horse power. It is very similar to those of the same type already mentioned, and is a very creditable job as regards workmanship. Beside it stands another engine of similar size and type, in which the singular and not disadvantageous plan has been adopted, of omitting in the erection, nearly all the main castings and framing, thereby showing all the details of the moving parts—portions which in the usual course are entirely hidden through their construction. The outer packing ring of the pistons is of cast-iron, a single ring, the full width being used. The follower bolts are secured from working loose by portions of a ring of wrought iron, let into a groove turned in the follower just by the side of the square bolt heads. As these rings in their turn are held in by screws, the question is, how much less liable these latter are to work loose than the follower bolts would be with no additional provision. The foot valves are placed at the side of the air pump chamber, but in an inclined position, the valves being on the under side. These consist of long rectangular rubbers, giving a long and narrow opening on each side of the guard, by which arrangement it is supposed they will have stiffness enough to close promptly, notwithstanding their downward inclination, while the upper end of the valve, at which most of the air would escape, being close to the delivery valve, the air would have but a small volume of water to pass through before making its exit from the chamber, a circumstance always favourable to the attainment of a good vacuum.

The engine by Messrs. Escher Wyss & Co., in the Swiss annex, is a very neat job, but presents no particularly striking novelty in its design. There are a pair of inclined cylinders of about 30 in. diameter by 42 in. stroke, placed side by side and connected to the upper frame, containing the main pillow blocks, by the guide bars only in the direction of the strain. These are of wrought iron, and made tolerably heavy to resist flexure, but appear rather light from being unsupported throughout their length. The top casting is, as usual, supported on turned wrought iron bolts resting on the bed plate below, to the further end of which the cylinder castings are also bolted. The air pump is vertical and single acting, placed directly beneath the crank shaft, and worked by a connecting-rod and trunk from a crank in the centre of the shaft. The exhaust from one cylinder passes through a high arched pipe into the exhaust chamber of the other, and thence a horizontal pipe leads along the bed plate to the condenser under the shaft. The valve motion is of the ordinary shifting link kind."

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DIVISION NINTH.

GENERAL MACHINES AND TOOLS.

50. *Steam Hammers.*—We are indebted to *Engineer,* under date March 6th, 1868, for the following article:—"The conditions under which steel or iron is employed in steam hammers are exceedingly trying; and it is no matter for surprise that these machines, unless well made at first and well cared for, should quickly get out of order, and require no small outlay to keep them in repair. They usually fail by the breaking of the hammer-head, or more strictly, of the slide-block to which the hammer head is fixed; the piston-rod, or the piston itself. So long

as the blow is delivered on a mass of iron directly under the piston-rod, the hammer-head is spared any twisting strains, and seldom breaks; but in those hammers specially fitted with large faces, and employed in forging masses of considerable superficial area, the blow is often delivered at a point some distance to the right or left of the centre of the anvil, and a twisting strain is caused which not unfrequently results in the fracture of the hammer-face or slide-block, and for this reason it does not appear that moving cylinder hammers are well adapted for such work. It is not easy to suggest a remedy. The best plan seems to be to resort to the judicious use of ribbing, the ribs being disposed on the slide-block in such a way that the cross strains may be resisted by a cantilever girder; and we need hardly point out the importance of distributing the weight of the head as much as possible, its approximate concentration in one point, which is not that of percussion, being almost certain to induce fracture elsewhere.

The piston-rods appear to give way solely as the result of molecular deterioration. The fracture is invariably crystalline, and the metal brittle. This is just what might be expected according to old theories, and goes far to show that there is more force in these theories than is now willingly admitted. It is, at all events, certain that a perfectly fibrous tough bar of iron may be converted into a crystalline brittle bar by a few months', or even weeks' use as the piston-rod of a steam hammer. In fact, it is impossible to get any rod to stand when the connections of the piston and the hammer-head to it are rigid and direct. The experiment has been frequently tried, and has invariably ended in failure so far as we are aware. Therefore some sort of cushion, intended to arrest vibration, is now always introduced into the striking column which has the piston for a capital and the hammer-head for a base. The best place for the cushion is between the slide-block and the piston-rod, and various modes of applying it will suggest themselves to our readers. The best material is hard wood. In some cases, however, the wood is interposed between the piston and the rod. The rod is made with a flange, to which the piston is bolted, a disc of hard wood being interposed between the two. The breakage of rods, curiously enough, appears to be affected materially by the weight and shape of the piston. Now the piston does not, under any circumstances, weigh nearly as much as the rod. Yet if it is made strong and stiff, the rod, if also stiff, is certain to break after a very short time, whereas if it is made slight, and as light as possible, the rod will last for years. It is clear that the momentum of a heavy piston moving at a high velocity is very considerable, and its sudden arrest must cause considerable strain; but it by no means follows that the piston of a steam hammer can store up work enough to break its rod so long as the latter is tough and fibrous. There is reason to believe that the presence of the piston tends in some way to induce crystallization, and an investigation of the influence of mere form on the progressive deterioration of masses of metal exposed to percussive strains would constitute a very interesting and important inquiry, which we hope to see carried out ere long. As a rule the pistons are forged in one with the rod, and they represent a considerable mass, concentrated, so to speak, at one end of a slender column, at the lower end of which it is to be presumed, vibration commences, proceeding thence to the top. No experiments on the effect of percussion on slender bars under such conditions have ever been carried out.

Pistons give way because their own momentum tends to carry them down after the rod has been brought to rest; the rod, in point of fact, is driven through them. The remedy consists, not in increasing their weight with the intention of making them stronger, but in reducing it as far as possible, and thus imparting a certain amount of elasticity. Instances have been known in which broken and roughly-patched pistons did duty for months, although the new pistons with which they were replaced again and again could not be got to stand. The correct principle of construction is, beyond question, to concentrate all the weight as nearly as possible in the head, and to reduce the weight of the piston and rod to the lowest limit. By adopting this course, and interposing an elastic medium between the head and the rod, breakages may be avoided, and the expense of repairs reduced. Mere increase of dimensions will not impart strength. The deteriorating influences with which the engineer has to deal cannot be combated by brute force. They must be evaded by the skill of the designer, not by the employment of great masses of metal."

The same journal has, under date June 12th, 1868, an illustrative description of a "Six Ton Steam Hammer," by Messrs. Davy of Sheffield.

"It is patent to all engineers," says the writer, "especially to those who use steam hammers extensively, and who therefore know from dearly-bought experience, that the ordinary steam hammer has a voracious appetite. The weight of steam used to the work done bears a greater proportion in this than in any other steam-driven engine, arising from the fact that the piston can seldom, if ever, complete its full stroke in ordinary working, and the stroke must be made long enough for the maximum thickness of the metal to be forged, and the maximum blow to be given. A variety of schemes have from time to time been proposed to remedy this defect, all more or less impracticable, and have therefore never been made available. The object is gained in the hammer which we illustrate in a manner which is both simple and ingenious. It is evident that if the amount of steam exhausted at each stroke be represented by the capacity of that stroke, be it long or short, then it matters not what the length of the cylinder is. for a portion of the steam will be retained in it at the completion of each stroke equal to the difference between the capacity of the stroke produced and the capacity in front of the piston, and will be available for the subsequent stroke. This is the principle of Mr. Davy's invention, which is carried out in the following manner:—The valve establishes a communication between the top and bottom cylinder, and if we imagine the piston to stand in the middle of its stroke when the blow is given, it will be seen that by lifting the valve steam is admitted to lift the hammer. To produce the blow the valve is depressed, and in doing so steam first passes from the bottom to the top of the cylinder, thus filling the vacant space before steam enters from the steam-chest. On the other stroke it will be seen that the same action takes place, producing in this instance a saving of 50 per cent., or one-half of the steam, which would otherwise be wasted.

For working single acting the *modus operandi* is as follows:—The valve will be moved in an upward direction, admitting steam to the underside of the piston, and when it has ascended sufficiently high the valve will be moved in the opposite direction until the equilibrium ports in the valve are opposite the ports in the valve casing; a portion of the steam which has raised the hammer will then pass from the lower to the upper side of the piston, equalizing the pressure on both sides, when the hammer will descend with a velocity due to gravitation, with the addition of the little extra pressure due to the area of the piston-rod. The steam on the under side of the piston at the completion of the stroke will be retained in anticipation of the next stroke, and that on the top side will be exhausted.

To work double acting the valve is first moved as previously explained for single acting, but instead of the valve being reversed after equilibrium is established, its motion in the same direction is continued, thus opening the top steam-port to the steam-chest, and the bottom port to the exhaust. It will thus be seen that a portion of the steam is retained, when double acting—in each end of the cylinder—in anticipation of the subsequent stroke. Mr. Davy patents a variety of valves for the accomplishment of the above-described object.

It will be seen that the hammer which we illustrate is of the ordinary form, but of larger proportions for the weight of the hammer than is usual. The standards are 12 ft. between in the clear; the cylinder is 39 in. diameter, and 5 ft. stroke. The valve, being in equilibrium, is moved with great ease, and the gear for working it is of the simplest description. The piston is of the ordinary construction."

51. *Wrought Iron Cranes.*—"There is no species of construction," says a writer in the 'Mechanics' Magazine,' under date July 10th, 1868, "that has better exemplified the gradual abandonment of timber, and its substitution by its now favoured rival, iron, than the ordinary crane. The old upright post, the square jib, have, except in a few instances, yielded to the new material. Timber was in this instance, as well as in many others, succeeded directly, not by wrought iron, but by its fellow, cast: and the smaller descriptions of cranes, particularly those of a moveable type, are mainly composed of that substance. The nature of the strains induced upon the various parts of a crane are favourable to the employment of cast-iron, and, what is more, allow of its combination with wrought-iron—a union by no means safe to attempt in the majority of instances. Signal failures have attended the combination of cast and wrought

iron, in the case of girders, but they were, perhaps, quite as much owing to the unscientific manner in which the structures were designed as to any inherent fault in the material. At the same time, although engineers understand at the present day the subject of strains much better than they did in the infancy of railroads, yet great care and precaution are necessary in dealing with the two metals together. In a cast-iron crane, the post and jib will manifestly be of a cast metal, and the arm or tie of wrought-iron, and each will therefore be most suitable to resist the particular strain brought upon it. Although there is no example of construction in which it is easier to determine the amount of the strains, and to apportion the metal to resist them, yet at the same time a crane works more within its safe load than girders or pillars. There are so many fortuitous circumstances attending the working of a crane, that a large margin must be left for contingencies. The incessant jerks and violent concussions it is liable to, produce an impactive force that demands special precaution to be safely encountered. It is probably for this reason that the employment of cast-iron has been confined, similar to the case of railway bridges, to the smaller specimens. A material of so well-known treacherous a nature cannot be safely relied upon, where sudden and violent strains may be brought upon it at any moment. Owing to the crystalline instead of fibrous condition of the particles, they are more disposed to separate under the action of an instantaneously-applied momentum, and they are wanting in that elasticity necessary to enable them to resist strains of a tensile character.

Wrought-iron cranes may, similarly to girders, be constructed either upon the lattice or the plate system. In the latter, they in reality belong to the tubular type. The principle of their design is very different from that governing the ordinary examples, and it is no longer a question of apportioning the metal according to the relative duties of jib, tie, and post. Those distinctive features are lost, or, rather, merged in the general framework of the crane, which is made strong enough to withstand their individual as well as joint influence. Mr. Fairbairn was the first engineer to introduce wrought-iron tubular cranes, which, by dispensing with the common arrangement of jib and tie, allowed more headway to the load to be lifted—a great advantage in the shipment of heavy bulky articles. The solid sides are, moreover, well adapted to resist the sudden jerks to which a crane is constantly exposed. At the same time, lattice-sided cranes, or those in which the sides are braced together by open trellis work, have their advocates. They are lighter in appearance and cheaper in construction, but for very heavy cranes intended to lift up to 20 tons, the tubular form is, upon the whole, to be preferred. It becomes difficult to adapt the diagonal bars in the web to the form of the crane without multiplying them to an extent that entrenches considerably upon the plate principle. Moreover, stiffness is one of the most essential qualities belonging to a crane, and although the strength of a structure is not necessarily a function of the stiffness, yet they can be more intimately combined in the solid than in the open web system. Lattice bracing is admirably adapted for resisting strains, of which the amount and direction are accurately determined, but should there exist any confusion and uncertainty with respect to the manner in which they act, or the direction in which their components might be resolved, it is not so safe a medium as its rival. It was for this very reason that plate girders, or, more generally, the solid web system, was the first adopted in girder work, and for a long period prevented the introduction of the other type of construction.

The strains upon the various parts of girders, especially upon the sides or web, were but very imperfectly understood, at the best, in the infancy of railway bridges, and the solid or plate girder offered a solution of the difficulty. Only make the sides thick enough, and stiffen them at intervals by extra strips of metal, and the strains might go in any direction they pleased. It was a matter of no moment to the engineer whether the girder was designed upon scientific principles or not, provided it was strong enough, and the requisite strength was ensured at an enormous sacrifice of material, a corresponding disregard of economy, and in utter defiance of all accurate and mathematical reasoning. The substitution of open diagonal bracing, where each bar acts as the direct channel or medium for resisting one strain, and for resisting one strain only, evidently was the result of the accurate application of theory to practice. To apply it thoroughly and successfully necessitated a minute and scientific investigation into the whole question of the theory of strains and the determination of formula and theoretical rules to guide the designer in truly proportioning his material. In a tubular or box crane, the cross sections made in the direction of the radii of the different curves of which its form is composed, increase in size from the top to the bottom, and are a maximum at the ground line, where the leverage to fracture it is greatest. Equal care and skill is required in apportioning the sectional area of the different sections of a tubular or of a lattice crane, for the time is gone by when the strength of a structure was synonymous with its weight, and size was the only standard of stability."

52. *On the Application of Machinery to Coal Cutting.*—The following is an abstract of a paper on this subject, read by Mr. John Fernie of Leeds, before the Institution of Mechanical Engineers at Leeds:—"The objects to be gained by the application of machinery to coal cutting were stated to be—first, the cheapening of the work; second, the saving of a large quantity of coal, which, in the ordinary process of holing or undergoing by hand labour with the pick, is broken up into slack and dust; thirdly, the removal of the danger attendant upon undergoing by hand labour; fourthly, the getting of a larger quantity of coal out of the pit; and fifthly, in the case of machines worked by compressed air, the collateral advantage of better ventilation and a cooler atmosphere in the mine, owing to the discharge of the compressed air after each stroke of the tool. The difficulties attending the application of machinery to work previously done by hand were said to be greatly increased in the case of coal-cutting machines by their having to work at great depths below ground, and in the very confined passages of a mine. The writer of the paper described two machines driven by compressed air, one having a pick worked by a bell-crank lever, with an action like that of the ordinary pick used in handwork, and the other working a straight-action tool, somewhat in the manner of a horizontal traversing slotting machine. Both of these machines have now been successfully employed in regular work for a length of time in the neighbourhood of Leeds. One of the pick machines does the whole of the undercutting at the West Yorkshire coal and Iron Company's colliery at Tingley, holding a seam 3 ft. 8 in. thick, the compressed air for driving it being

supplied by an air-compressing engine at the surface. In a trial recently made with this machine by the writer, it was found that a pick of 75 lb. weight, cutting a groove to a depth of 24 in. from the face, gave about seventy-four blows per minute. The coal at Tingley is worked by the pillar and stall system, and the time occupied by the machine in undercutting the length of 56 ft., forming one pillar, was twenty-five minutes, including all stoppages. With a pick of 90 lb. to complete the previous cut, to the depth of 3 ft. 9 in. from the face, the blows were about sixty per minute, and the half length of 28 ft. was undercut in seventeen minutes. The time occupied in running the machine back and changing the pick was sixteen minutes. From these trials it appeared that in undercutting to the depth of 24 in. in a single course the work done was at the rate of about thirty square yards per hour, and in undercutting in two courses to the total depth of 3 ft. 9 in., the work was done at the mean rate of about fifteen square yards per hour, including the time required for running the machine back and changing the pick. The other coal-cutting machine—which may be described as on the horizontal traversing slotting principle—is the invention of Mr. Donisthorpe of Leeds. The machine traverses along the working face of the coal, and cuts out a horizontal slot or groove along the bottom of the seam of coal, or along a parting in the thickness of the seam itself. The work regularly done by one of these machines employed at the West Riding Colliery of Messrs. Pope & Pearson, at Normanton, is at the rate of eight to twelve yards per hour, including all stoppages, and undergoing the coal to the average depth of about 3 ft. 4 in. in from the face. At the same colliery the work done by each collier by manual labour is about six yards per day of eight hours, undergoing to a depth of 3 ft. in from the face. The machine, therefore, performs the work of from twelve to eighteen men. Its operation has been found so successful that it was being employed for a very long continuous face of work, and the different parts of the mine are being laid out, as far as possible, for working according to the long-wall system for the purpose of obtaining the greatest advantage from the use of the machine. With great clearness Mr. Fernie showed how the machines to which he referred answered the requirements referred to in the introductory parts of his paper."

53. We take from the 'Scientific American' a number of articles as follows:—(a) *The Hanging and Care of Shafting.*—"We believe there is less care bestowed, and less sound judgment exercised, upon the hanging and after care of shafting than upon any other means used in applying power to manufacturing processes. If the water wheel or the steam engine is in good order, performing its work properly, and the machines driven by it are also in good order, not a thought is bestowed upon the media between the actuating power and its ultimate development, except the necessary attention to the belts and the oiling of the shaft journals. Yet it is frequently the case, when the result is not satisfactory, that neither the driving power nor the machine which furnishes the product is at fault, but, if the result is not adequate to the cause, the reason may be found in the shafting or other intermediate transferrers of the power. Generally, in such a case, the belts are examined, and their condition assumed as a reason for the imperfect transmission of the power from the prime mover. The condition of belts is a very important point in all manufacturing processes where power is used, and attention to them will save many dollars in the course of a year; but there are other as important elements which are not always taken into consideration. One, and the principal one, is the condition of the shafting. A line of shafting running perfectly true, without jumping or jerking, turning smoothly and noiselessly, is a delight to the mechanical eye. The first thing examined by a thorough mechanic when he comes into a manufactory is the shafting. If the line runs true and the pulleys do not 'wabble,' the boxes do not exude oil at their ends, and there is no rattling or grinding, he says at once, 'who ever hung this shafting knew his business.'

A building for the reception of machinery should be erected with a view to its intended use. The walls and their foundations should be strong and rigid, and the timber sound and well seasoned. Fragile frames of imperfect lumber standing on insufficient foundations are costly receptacles for machinery. Shrinking and springing timber and settling walls cannot give the necessary support to the machinery, nor allow the reduction of friction to its minimum. In such rattle-traps a line of shafting will not retain its place twenty-four hours consecutively; a large proportion of the power employed is lost in overcoming unnecessary friction, and the running machinery rapidly deteriorates. When the amount of loss of power by friction exceeds twelve per cent. there must be a 'screw loose' somewhere.

But the reason of unsatisfactory running of shafting is not always its location in an improperly constructed building; sometimes those who hung it did not know, or, at all events, did not do their business. It is one of the most delicate jobs of the millwright, and requires not only experience and skill, but discretion and good judgment. Where the shafting is supported by bracket boxes on posts, a chalk line should be stretched and marked on the posts to represent the top and bottom of the brackets or the centre line of the shaft. The sag of the cord, if the line is long, should be rectified by the eye aided by a water level or similar adjusting instrument. A wooden straight-edge of well-seasoned board, long enough to reach from one box to the next, and of uniform width, is useful for levelling up the boxes. It is to be used on edge, one edge resting in the boxes and the spirit level placed on the other. Some millwrights provide themselves with iron cylindrical pieces of different diameters to fit various sizes of boxes, turned true and having a small hole drilled accurately through the centre. These pieces are about six inches long, and being laid in the box, the cord is passed through the hole and stretched over three or four lengths of shafting. In practice, however, we have preferred the straight-edge, which is rigid, and offers a support to the spirit level. After all, the mechanical eye is the best test of line, although not of level.

When hangers are used the chalk line should mark the centre of each hanger, or a line directly over the centre of the shaft. The flooring beams to which the hangers are to be secured, if of unequal depth or thickness, as is frequently the case, should be dressed to a level. Where shims are necessary they should be of rigid wood, well seasoned. We never found anything equal to rived cedar (not pine) shingles, which are almost as hard as horn. The bolt heads for suspending the hangers ought to be of flattened convex form, upset from the bar, and perfectly sound. A goodly-sized washer should be inserted under the head and recessed into the floor. Where it is necessary to place a hanger directly to the floor planks, there should be a piece of seasoned plank, at least twice as long as the spread of the hanger legs, firmly bolted to the floor, on the under side of course. Some prefer lag screws or coach screws to bolts for securing hangers, and to say the truth, their hold is exceedingly tenacious; we never knew one to draw. The hole for their reception, however, should not exceed in diameter the size of the screw less the thread.

One common fault in hanging shafting is spreading the hangers or brackets too far apart. A length of shafting should not be so insufficiently supported as to sag in the slightest degree; if it does it will spring when in motion, and create a large amount of friction in the boxes. The hangers should also be located with reference to the weight supported on the shaft; a heavy pulley, or one the belt of which sustains a great strain, should be supported by a box or boxes in close proximity. To accomplish this it is of course necessary that the position of every machine should have been determined before the shafting was hung; a competent millwright can do this; one that cannot make a plan and carry out its details is incompetent.

The shafting properly hung and the machinery in operation, the line should be inspected once in every two or three weeks, the hangers or brackets adjusted, if out of line, and every defect remedied. This is necessary with the best hung shafting and in the best building, if the economy of power is worth looking after; for there are so many disturbing causes affecting the integrity of a line that it is impossible to depend upon long continued accuracy unless constant attention is given to the condition of the shafting. A box slightly out of line or level will absorb a large amount of oil yet be continually hot, waste power by unnecessary friction, and grind and cut the shaft. Attention to these matters will be found to pay at the end of the year."

(*b*) *Shafting and Belts—Absorption and Transmission of Power.*—" The renting of power for driving machinery is in many parts of the country as common as the renting of habitations and places of business; but while the value of the yearly amount to be paid for the latter can be easily ascertained and fixed, from the known cost of the premises, this or other sufficient data are wanting in regard to the amount of power used. Where that power is ample and cheap, as in a constant and sufficient water privilege, the amount of rent paid may be of little consequence; but where all the power must be generated from fuel and transmitted by the steam engine, it becomes a matter of great consequence to the proprietor. Only the crudest means are at present available to ascertain the amount of power transmitted by pulleys and belts. So many conditions are to be considered that the construction of a set of rules for calculating the amount of power, in all cases, is simply impossible. Not only the width of the belts, the diameter of the pulleys, and the relative position of the shafts, but the condition of the belts and the velocity of the shafts, must be taken into consideration, together with the peculiar circumstances which every separate case presents.

It is well known that the closest mathematical calculations, based on the style of engine, diameter of cylinder, length of stroke, velocity of piston, pressure of steam, and other points of a steam engine, fail to give accurately the amount of power the machine may develop. The actual trial by means of the indicator in the hands of a skilful manipulator is the only reliable test. From one of the best—if not the best—masters of the indicator in this country, we learn that engines calculated by their builders to give a certain amount of power often so signally fail of achieving the result desired, that in one recent instance an engine calculated for sixty-horse power had run for months yielding less than twenty-six horse power! The indicator showed the fact, and the experience of the operator detected the fault and pointed out the remedy.

Now if in a machine constructed with such care and skill as the steam engine such a wide difference should be found between the calculated and indicated horse power, what difference should we not expect, when the test is applied to a case presenting so many points of possible variations between the intended and real amount of power as that of belt transmission? And it is the fact that in very many cases the proprietor of steam power, knowing the actual power of his engine, finds that letting for hire what he deems is one-half of that power, his tenants are absorbing nearly the whole available power. The rough method of calculating the amount of power delivered or transmitted by the width of driven belt—a plan which was common enough a few years ago, and may be so now—is as ridiculous and as far from the truth as the formula of the astronomical instructor who taught his pupils, in estimating the distance of the fixed stars from our planet, to 'guess at the distance and multiply by four;' or as accurate as the man who took the measure of a door opening in a house he was building by measuring it with his outstretched hands, and rushed to the door maker with his hands held in position. Scarcely less nonsensical and foolish is the plan of charging for power to drive a wood-turning establishment, with its lathes revolving at the rate of thousands of revolutions per minute, at the same price per machine as the machine shop with its equal number of lathes and plainers revolving at a very low rate of speed. Yet we have seen, very lately too, a case of this character, where the owner of an establishment actually rented power for a wood worker—sawyer and turner—at a lower price per machine than he charged a machinist, and then wondered how the power of his engine could be so absorbed. 'Wood,' he said, 'was easily worked; it must require more power to drive a lathe turning iron than one turning wood.' In this statement he plainly showed his want of knowledge of the simplest principles of mechanics. Velocity is a great absorbent of power, and where a shaft is run at a rapid rate the very friction of the shaft is a serious drawback to the amount of power it will transmit compared with the amount received. To get the best results from belts they should not be driven more than thirty feet per second or eighteen hundred feet per minute; yet they are often driven at a much higher rate. There is a limit to the effective cohesion of belts to pulley faces, a fact, we are sorry to notice, some of our best mechanics are slow to acknowledge, or, at least, to put in practice.

A belt running horizontally—not crossed—will, without excessive tension, deliver more power than one of the same width and weight running vertically. This every mechanic knows. It will also run easier. So with belts in other positions and under varying circumstances. It is evident, therefore, that calculations of the power transmitted by belts, based exclusively on their width, will not be reliable under all circumstances.

From a letter before us we learn that by the trial of a dynamometer, already patented and now in process of repeated and extended trial, the results of its trial have surprised and disgusted the hirers and users. In a trial where it was tested by the most elaborate and exact experiments, in one case it was found that it showed a difference of one hundred and twenty-five per cent. between the amount of power used and that actually paid for, in favour of the proprietor. 'Few,' he says, after many trials, 'imagine the amount of power absorbed by rapidly-driven shafts.' We hope his endeavours to construct a dynamometer, which may be applied under all circumstances, and give reliable results, may be successful. It is much needed."

(*c.*) *Adhesion of Leather Belts to Cast Iron Pulleys.*—"In the January and February numbers of the *Journal of the Franklin Institute* are two articles on the above subject which present some facts of value to mechanics and others who employ belts in the transmission of power. The facts given are the result of numerous experiments made by Mr. H. R. Towne, at the suggestion of Mr. Robert Briggs, and although begun and conducted without a knowledge of those made by Gen. Morin and MM. Poncelet and Prony, the results of which appear as a translation in Bennett's *Morin's Mechanics*, it adds to their value to know that the results of these independently conducted experiments are virtually the same. The fact that not only the butts in which the lacing holes are punched, but even the splices are the weakest portions of the belt will surprise many who regard the latter, when properly made, as the strongest parts. From the manner, however, in which the experiments were conducted it would seem useless to attempt a dissent from the results as presented.

The report says: The experiments were made with leather belts of three and six inches width and of the usual thickness—about $\frac{5}{16}$ths of an inch. The pulleys used were respectively of 12, 23$\frac{3}{8}$, and 41 inches diameter, and were in each case fast upon their shafts. They were the ordinary cast iron pulleys, turned on the face, and, having already been in use for some years, were fair representatives of the pulleys usually found in practice.

Experiments were made first with a perfectly new belt, then with one partially used and in the best working condition, and, finally, with an old one, which had been so long in use as to have deteriorated considerably, although not yet entirely worn out. The adhesion of the belts to the pulleys was not in any way influenced by the use of unguents or by wetting them—the new ones when used were just in the condition in which they were purchased—the others in the usual working condition of belts as found in machine shops and factories—that is, they had been well greased and were soft and pliable.

The manner in which the experiments were made was as follows:—The belt being suspended over the pulley, in the middle of its length, weights were attached to *one* side of the belt, and increased until the latter slipped freely over the pulley; the final, or *slipping* weight, was then recorded. Next, 5 lbs. were suspended on *each* side of the belt, and the additional weight required upon *one* side to produce slipping ascertained as before, and recorded. This operation was repeated with 10, 20, 30, 40, and 50 lbs., successively, suspended upon both sides of the belt. In the tables these weights, *plus* half the total weight of the belt, are given as the 'equalizing weights' (T_2 in the formulæ), and the *additional* weight required upon one side to produce slipping, is given under the head of 'unbalanced weights;' this latter, *plus* the equalizing weight, gives the total tension on the loaded side of the belt (T_1 in the formulæ).

The belt, in slipping over the pulley, moved at the rate of about 200 feet per minute, and with a constant, rather than increasing, velocity; or, in other words, the final weight was such as to cause the belt to slip smoothly over the pulley, but not sufficient to entirely overcome the friction tending to keep the belt in a state of rest. In this case (*i. e.*, with an excessive weight) the velocity of the belt would have approximated to that of a falling body, while in the experiments its velocity was much slower, and was nearly constant, the friction acting precisely as a brake. By being careful that the final weight was such as to produce about the same velocity of the slipping belt in all of the experiments, reliable results were obtained.

It became necessary to make use of a weight such as would produce the positive motion of the belt described above, as it was found impossible to obtain any uniformity in the results when the attempt was made to ascertain the minimum weight which would cause the belt to slip. With much smaller weights *some* slipping took place, but it was almost inappreciable, and could only be noticed after the weight had hung for some minutes, and was due very probably to the imperceptible jarring of the building. After essaying for some time to conduct the experiments in this way, and obtaining only conflicting and unsatisfactory results, the attempt was abandoned, and the experiments made as first described.

In this way, as may be seen, results were obtained which compare together very favourably, and which contain only such discrepancies as will always be manifest in experiments of the kind. It is only by making a great number of trials and averaging their results, that reliable data can be obtained.

The value of the co-efficient of friction which we deduce from our experiments, is the mean of no less than one hundred and sixty-eight distinct trials.

It will be noticed, however, that the co-efficient employed in the formulæ is but *six-tenths* of the full value of that deduced from the experiments, the latter being 0·5853 and the former 0·4229. This reduction was made, after careful consideration, to compensate for the excess of weight employed in the experiments over that which would just produce slipping of the belt, and may be regarded as safe and reliable in practice.

A note is made, over the record of each trial, as to the condition of the weather at the time of making it—whether dry, damp, or wet,—and it will be noticed that the adhesion of the belts to the pulleys was much affected by the amount of moisture in the atmosphere. It is to he regretted that this contingency was not provided for, and a careful record of the condition of the atmosphere kept by means of a hygrometer. The experiments indicate clearly, however, that the adhesion of the old and the partially used belts was much increased in damp weather, and that they were then in their maximum state of efficiency. With the new belts the indications are not so positive; but their efficiency seems to have been greatest when the atmosphere was in a dry condition.

Experiments were also made upon the tensile strength of belts, with the following results:—The weakest parts of an ordinary belt are the ends through which the lacing holes are punched, and the belt is usually weaker here than the lacing itself. The next weakest points are the *splices* of the several pieces of leather which compose the belt, and which are here perforated by the holes for the copper rivets. The strengths of the new and the partially used belts were found to be almost identical. The average of the trials is as follows:—

Three-inch belts broke through the lace holes with	...... 629 lbs.
,, ,, ,, ,, rivet ,,	......1,146 ,,
,, ,, ,, ,, solid part ,,	......2,025 ,,

These give as the strength *per inch of width*:

When the rupture is through the lace holes	.... 210 lbs.
,, ,, ,, rivet ,,	.... 382 ,,
,, ,, ,, solid part	.... 675 ,,

The thickness being $\frac{7}{32}$ inch (=·219), we have as the tensile strength of the leather 3,086 lbs. per square inch.

From the above we see, that 200 lbs. per inch of width is the ultimate resistance to tearing that we can expect from ordinary belts.

The experiments herein described are strikingly corroborative of those already on record, and this gives increased assurance of their reliability; and, although there is nothing novel either in them or in their results, it is hoped that they will prove of interest, and that an examination of them will lead to confidence in the formulæ which are based upon them."

(*d*) *The Diamond Point Tool.*—"No apology is deemed necessary for offering an article on this important tool. When properly made there is no tool more satisfactory, but in practice it is quite exceptional to find a good one. Hence it is to be inferred that the principles of its action are not completely understood by all turners and tool dressers.

To begin at the beginning, the tool should have the proper inclination forward for the lathe, and the work on which it is to be used, a tool for a light lathe and for small work requiring more inclination than one for a heavy lathe and large work, and a plainer tool but little inclination. These points, however, are commonly observed.

The next thing is to put the cutting side in its proper angular position. Fig. 50 is a horizontal section near the point of a good tool in cutting position, and fig. 51 likewise of a bad one. The tools are supposed to be for feeding to the left, in the ordinary way. The corner 1, is the leading corner; 2, is the cutting corner; 3, the following corner; and 4, the back corner. 1, 2, is the cutting side.

Fig. 50.

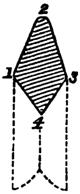
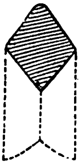


Fig. 51.



Now in forging the tool the cutting side should be made to stand at a small angle with a horizontal line in the direction of the crossfeed, as in fig. 50, not a large one as in fig. 51. In other words, its position must be a little removed from that of the edge of a straight side tool, but there must be some angle, otherwise the tool ceases to be a diamond point, and becomes a half diamond, and must be inclined to the left to give it clearance. A true diamond point should not be so inclined, but only forward. Thus, it appears that the cross section of the part drawn out to form the tool should be a rhombus or diamond, and not a rectangle or square, in order that the cutting side may not form too great an angle with the transverse line.

The reason why a small instead of a great angle is required, becomes obvious thus: In setting the tool, the point must be elevated to such a height as will give it the proper clearance. The clearance of the pointed and the clearance of the cutting side are two things, and the tool must be so formed that the cutting side will have its proper clearance when the point is elevated to the right height.

The shape must be such that the clearance of side and point will coincide in one position. When the angle of the cutting side is too great, the elevation of the tool affects too much the clearance of the cutting side. If it was made with no angle, but straight like a side tool, it is plain the elevation would not affect the clearance of the side at all, but only that of the point. The final adjustment is made by turning the tool in the tool-post to the right or left from a straight position.

The tool being forged it must be properly ground. The diamond point is a wedge for separating two portions of metal. Of course a thin wedge operates easier than a thick or blunt one.

There is less disturbance of the molecules of the metal removed in the chip, consequently less heat, and the tool is not thereby burned away. It is not uncommon for a good tool to stand a whole day in turning wrought iron with a heavy chip and fast speed, without sharpening, except with an oil stone, in position, and making continuous spiral chips to the last.

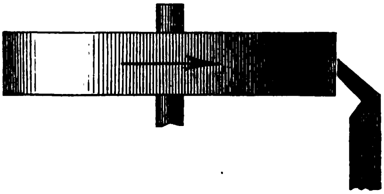
As this wedge is a powerful one, there is a tendency of the tool to move forward in the direction of the feed, which is performed with little power, so that the tool is liable, with improper management, to spring into the work and break. This is what frightens many workmen from using thin tools, but if properly made and handled, there is no danger in using very thin tools. Some men, in attempting to grind a tool thin, grind the back corner low, but this does not make a tool thin, at least, not thin to any useful purpose. It makes the point slender and weak, so that it breaks off; then they are disgusted.

It is the following corner (marked 3 in the cut) which must be ground low to make a good thin tool.

In a plainer tool, the back corner, and necessarily the leading corner, should be left high compared with the cutting corner, to prevent the tool springing down into the work, and also to strengthen the point. In a lathe tool the leading and back corners may be ground somewhat lower. If left sufficiently high, the tool will make left hand spiral chips. It is best to grind these corners low enough to make straight or right hand spiral chips. In all cases the following corner should be ground low.

To grind a diamond point properly and easily, it is well to know the best place on the grindstone to apply it. The place recommended for grinding a tool according to these principles is shown by the cut. This is for a right hand tool, or one to

Fig. 52.



feed to the left. The tool is to be held in nearly a horizontal position. To grind the back corner higher, of course the back end of the tool is held more to the right. I think any one who tries it will agree that this part of the grindstone peculiarly facilitates giving the form to the tool which has been recommended. The ugliest ground tool is here speedily brought into comely form."

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DIVISION TENTH.

METALS—IRON—STEEL—ALLOYS.

54. *Notices of Recent Improvements in Iron and Iron Making.* — "Professor Tunner," says the editor of the 'Practical Mechanic's Journal' of October, 1868, "states in a Report upon improvements made in the production of pig iron 'as evidenced at the late Exhibition at Paris of 1867,' that he could not find in the Exhibition much technical progress. The enlargement of the blast furnaces in their height and diameter appears to be still the object of trials on a large scale in England. A furnace above 80 feet high has been erected in the last year in the Cleveland district in England (Messrs. Morrison's, we believe), and the results obtained, as regards the consumption of fuel, have been much praised; but such hard coke and such coarse aggregates of ironstones as are worked in that district are not to be found again soon, nor everywhere. These results can, therefore, perhaps only be considered as very important locally. The diameter of the furnaces at the bottom appears to have reached in round furnace cavities to 7 feet diameter as its present limit, although that again widens itself during the working of the furnace, and yet is found still safe and right for use up to 8 or 9 ft. diameter. A diameter of 6 feet at the bottom is the general measure for the larger furnaces, and especially for those which are used for the lower numbers of pig iron. An acknowledged progress has been made, and is still becoming extended in application, in the heating of the blast to the highest possible degree. Even the coke-consuming furnaces, which are

supplied with a cast-iron blast-heating apparatus, blow with air heated to 300° or 360° C.; but the blast-heating apparatus constructed upon the principle of Siemens' regenerator, of which there is also one in use at Friedrich Wilhelmshütte, near Siegburg in Westphalia, affords a still higher temperature, and would be more generally employed if their maintenance had not been found so far subject to so many interruptions and repairs, arising mainly from the interior lodgments of dust upon the brick heaters. With the high temperature of the blast is not only connected an enlargement of the furnace at the bottom, but at the same time a narrowing of the furnace mouth, and also with the complete disappearance of the boshes, whence has been attained the further advantage of a regular descent of the charge in work. The English and Scotch furnaces distinguish themselves in that way before all other ones. Models of blast furnaces were exhibited in the French, Prussian, and Swedish departments. In the former ones was more particularly shown the methods adopted in France for catching and utilizing the gases. The methods used for the charging were also shown, without, however, according to Tunner, representing any innovation worth imitation. One rather complex, but ingenious and probably effective method, for constructing the furnace top so that the charge should be fed in with perfect uniformity all round, and that at no moment should any feeding aperture permit the escape of gases, exhibited by France, does appear to us to merit somewhat warmer praise. The furnace model of the brothers Büttgenbach, in Neuss (Rhenish Prussia), Tunner deems the most instructive one; very original is the distribution of the gas, which appears to be effected through five hollow cast-iron columns, which carry also the broad circular crown beam upon which the brickwork above the furnace mouth rests, and which is only strengthened by iron hooping instead of by a mantle of boiler plate. The furnaces built during these last years on the Continent are generally constructed after a Scottish pattern, that of the so-called boiler-plate mantle-furnace (*Blechmantelofen*), or 'cupola' as frequently called by us; but as regards the cost, Tunner considers there is nothing saved by that. In the country of Siegen (Westphalia), where most of the new furnaces are also constructed thus, as many are also in Cleveland (Yorkshire) and in Cumberland, for a rather large furnace, the plate mantle, with the ironwork at the furnace mouth, requires about 400 centners of plates (20 tons, nearly, English), the price of which, including the fitting-up, will be about 6½ thalers (19s.) per centner. The cast-iron cill plates upon which the mantle rests, and the supporting columns, weigh between 700 and 800 centners, costing 3 thalers (9s.) per centner. The outlay for one of these mantles will be, therefore (without the brickwork for the foundation), nearly 8,000 florins (£800) a price for which almost in all localities a brick-built mantle could be obtained. A plate-iron mantle or cupola furnace is, perhaps, under certain circumstances, more desirable, but it is questionable whether it is free from influence in producing loss of heat by radiation and evection. If a furnace, therefore, is to be erected for permanence, and if, especially, the price for the fuel to be employed is very high, a brick-built shaft is, in Professor Tunner's opinion, to be preferred before the plate mantle or cupola furnace.

Raschette's furnaces, which appeared before the public some years ago at the London Exhibition of 1862, have only been exhibited in the Russian and Prussian departments. The model in the latter one from the Hartz forest was destined only for lead-smelting. It appears, therefore, that Raschette's furnaces for the production of pig iron have not been adopted in practice except in Russia, for which the principal reason may be their alleged failure on trial at Aubel's works near Muhlhausen. Tunner, however, has been assured by a Russian engineer, that these furnaces give in Russia good results when worked for the production of white or mottled pig irons, though not for producing gray pig iron. Assuming the correctness of this statement, Tunner finds a reason for it, mainly, in the small height of the furnace. It is right to add, however, that the editor of the *Berg-geist* states that in Russia a series of furnaces after Raschette's system (he enumerates ten of them) are at present worked with perfect success, not only for gray, but also for white and mottled pig irons. The above-mentioned trial by Aubel, he states, had not taken place at Muhlhausen; but a furnace arrangement which had been executed in all its parts at Muhlheim, near Cologne on the Rhine, and upon the design of the Raschette furnace, was erected there, and had not failed as a furnace, for a great number of engineers, amongst whom have been some of the first furnace-men of our time, had approved its working as good, and had remarked the most satisfactory products of metal from it; but certainly the limited liability *company* who owned the furnace had failed after the time that their engineer Aubel, who was the representant of General Raschette, and who built the whole of the works, had been removed from the management. Aubel's trials at Muhlheim, therefore, cannot be considered at all in any technical relation, nor as proving anything disadvantageous to the Raschette furnace, as to which we may add that very little is so far accurately known in this country.

The following recent statistics as to iron making in France are not devoid of interest, as showing the shifts to which iron masters there are driven by scarcity and dearness of fuel, and yet how ably and well they meet this deficiency:—

The total production of charcoal-made pig iron for 1867 in France is estimated at 177,300 tons;, of pig made with two combustibles, 78,700 tons; and of pig made with mineral combustible, 886,800 tons; showing a total of about 1,142,800 tons, of the value of £4,805,800. In 1866 the production of charcoal-made pig attained a total of 213,000 tons, while that of pig made with two descriptions of combustible was 89,900 tons, and that of coke-made pig 950,200 tons, showing a total of 1,253,100 tons. The decline in the production of pig in France this year is thus estimated at 110,300 tons. The French production of charcoal-made iron this year is estimated at 41,700 tons; of iron made with two combustibles, 23,400 tons; and of coke-made iron, 735,900 tons; showing a total of 801,000 tons, of the value of £7,393,880. If we compare these results with those for 1866, we find a diminution of 8,700 tons in the quantity of charcoal-made iron, a diminution of 4,700 tons in the quantity of iron made with two combustibles, and an increase of 2,500 tons in that of coke-made iron.

The result goes to show, on the whole, an increase in the supply of good coal fuel and coke, and to support the long-known increased and still increasing scarcity of charcoal. This view is further supported, perhaps, by the falling off for the last three years in the importation of English coal into France. The general diminution in the make of French iron is to be accounted for by fiscal causes, in which we in England have still more severely participated.—ED."

55. *Iron-Making in* 1867 *and* 1868.—From a detailed paper in the 'Engineer,' under date January 10th, 1868, we extract the following paragraphs:—"The manufacture of pig iron has undergone considerable change in its localization within the last ten years, and the process of change has been going on in a marked manner during the last year. The older districts have been reducing their make of pigs, finding themselves unable to compete with the newer centres in the production of cheap iron. Thus, we find that in Scotland, South Staffordshire, and South Wales, a large number of blast furnaces have been blown out. On the contrary, in Cleveland, and in Lancashire and Cumberland, there has been an increase of producing power. The number of blast furnaces has been extended, and in addition to this many of the smaller furnaces have been replaced by others of much greater dimensions, and capable of making large quantities of iron.

It is noticeable that a gradual improvement has taken place in the general nature of the operations connected with the manufacture of pig-iron. In Staffordshire increased attention is being devoted to the utilization of the waste gases. Calcining kilns are in places superseding the open mounds until recently universally adopted. Locomotives are being more extensively introduced for the haulage of materials about blast furnaces; and the consequence is that the average production of even the small and inconvenient furnaces of the older districts is being considerably increased. In certain districts manufacturers still persist in adhering to their old wasteful methods of manufacture; but it is clear that if they expect to compete at all successfully with the newer furnaces, they must adopt all the improvements that can be made applicable to their plants.

There is not much improvement to report in blowing engines. Several modifications have been introduced by different engineers, but many manufacturers have a strong preference for the old-fashioned beam engine, which generally does its work very satisfactorily. There is no reserve power, however, as a rule, and hence stoppages occur when anything interferes with the working of a single engine. By using smaller engines with quicker motion it is easy to have one always in reserve, without increasing the engine room or expense very much. The new engines at the Teeside Ironworks are very compact, and work smoothly and well. Great attention continues to be devoted by blast furnace engineers to the heating stoves for raising the temperature of the blast. At the present time the temperature of the blast is generally from 1,000° to 1,200°; but a greater heat even than this is obtained from Whitwell's 'hot-blast' stove, the main features of which are its regenerative character, the ease with which the flues are cleaned out, and the high temperature obtained. Mr. Player in his stove first burns the gas in a separate combustion chamber before allowing it to come in contact with the pipes through which the blast is conveyed.

It is well known that sulphur and phosphorus are most deleterious ingredients in pig-iron, and effectually preclude its conversion into Bessemer steel. The varieties of iron made from the ironstones of the coal measures or secondary rocks generally contain a rather high percentage of phosphorus, derived from organic remains. The high price which iron suitable for the Bessemer steel manufacture commands has caused great attention to be devoted to the purification of iron from the above-named elements. It has been proposed to effect this by the admixture of certain mineral substances with the ordinary blast furnace charge; but this has been found an expensive process, and has not been successful. There have been also several propositions made for the purification of pig-iron by means of certain chemical substances, chiefly alkaline nitrates, which are so placed as to come in contact with molten iron in a suitable converting vessel; and the deleterious ingredients are more or less completely removed by the action of the gases liberated by the decomposed nitrates. Some experiments made at Langley Mill, Nottingham, gave promising indications, and the plan is now being still further perfected by a Lancashire firm. It would, however, be quite possible to prevent a large quantity of the phosphorus and other impurities from finding its way into the blast furnace at all, as the fossils and iron pyrites are generally found in certain layers of ironstone, and these parts could be easily thrown aside. Great improvements in the quality of pig-iron have been made in several instances simply by 'pickling' the ore. The use of mill cinder is also very objectionable, and where adopted should always be confined to furnaces specially set aside for the purpose, as by employing this material the phosphorus eliminated in the manufacturing process is all transferred to pig-iron again. A good quality of pig-iron will never be produced from the common iron ores unless the greatest precautions are taken to remove impurities from the materials supplied to the blast furnace.

Great attention continues to be devoted to the economical manufacture of superior iron or steel from ordinary pig-iron. The expensive nature of the Bessemer operation, the great waste incurred where the pig-iron is not almost perfectly pure, and the heavy royalties which are levied on their manufactures, naturally induce practical iron makers to discover a readier method of producing somewhat similar results to those obtained by the Bessemer process. The Richardson process has been a good deal discussed of late, and at Glasgow very satisfactory results are said to have been obtained. The novelty consists in blowing in air to molten iron through a hollow 'rabble' terminating in a number of points, and moved about in the same manner as in ordinary puddling. A saving of time is effected, and a superior quality of iron is said to be produced. The experiments of Mr. Menelaus, of Dowlais, on the rotating puddling machine, were laid before the Mechanical Engineers at their last annual meeting; but the discouraging feature was the failure of the apparatus owing to the impossibility of finding a material capable of withstanding the great heat generated in the converters. If this difficulty could only be surmounted, it seems probable that the machine in question would lead to a great saving of labour. Other puddling machines have been brought under public notice during the past year. Of these the plans of Griffiths and Morgan deserve notice; in the former a rabble is made to work backwards and forwards through the molten iron very nearly in the same manner as by hand manipulation; in the latter a rotary motion is given to a couple of arms attached to a vertical shaft which passes through the roof of the puddling furnace. In another direction also great attention has been devoted to the economical manufacture of iron by more fully utilizing the fuel employed in generating the necessary heat. Wilson's furnaces, now in operation in several ironworks, appear to give excellent results; the consumption of fuel is complete, there is no smoke, and the quantity of fuel used per ton of puddled iron produced is much below the average by the ordinary process. A new kind of furnace has recently been introduced by Mr. Leigh, the principle of which plan is to volatilize the fuel by making it fall upon a mass of molten pig-iron covered with a thin layer of slag, and occupying the position of the fire-grate in an ordinary heating furnace. It is asserted that the heat generated in this furnace is very intense, and the patent is now being put in operation in several ironworks with a view to test its merits. There can be no doubt of the vast importance of introducing improvements into the results of the puddling process as long as this stage is necessary in the manufacture of wrought iron. It is mainly upon the success of this process that the quality of the finished iron depends. Continental makers exercise far more care in keeping the produce of each man separate, and in selecting the puddled iron to be used in making the finished bars. By this means the bad work of an inferior puddler is not made to destroy the results obtained by the superior man. It would be unjust to omit to mention the gradual introduction of Siemens' regenerative gas furnaces to the manufacture of iron. Several works have such furnaces in operation, and at the extensive Creusot works no less than sixty of these furnaces are being fitted up.

It will thus be seen that, on the whole, a great amount of attention is now being devoted to the economical manufacture of iron, especially in the transition stage from pig to best malleable iron. But it must not be concealed that there is here room for vast improvement still. The operations connected with puddling are as yet exceedingly rude, and the inventions we have named are only very partially known or appreciated by the trade. It is evident, however, that English iron manufacturers are now becoming more fully alive to the absolute necessity of conducting their operations in a more systematic and scientific manner. At present one great difficulty to be contended against is the prejudice which the workmen have against anything new and untried. This prejudice is almost equally strong on the part of the mill or forge managers, on whom a manufacturer has to depend for the practical carrying out of his ideas. A consideration of this matter would raise up the whole question of technical education; but it seems certain that English ironmasters will have to introduce many sweeping changes and improvements if they are to continue to hold a foremost place amongst the iron manufacturers of the world.

Passing on to improvements which have been made in the finishing department of the iron manufacture, we find that some changes of minor importance have been introduced. The universal mill for rolling double T-iron for girders, and mills with vertical as well as horizontal rolls for plate mills, by which the waste in shearing is reduced, deserve notice; but on the whole there is not much to dwell upon in this department.

In making a brief review of the iron trade for the past year, it is scarcely possible to define accurately the improvements which belong exclusively to so short a period. It is only by very gradual changes that the modern changes in blast furnaces have been brought about, and even now there is a somewhat primitive aspect about too many of the works in the older districts; but, on the other hand, some of the boldest achievements in this department of manufacture have been successfully accomplished during the past year. Comparing the results obtained by one of the old-fashioned blast furnaces, making on an average only a little above 100 tons of iron per week, with the behaviour of a first-class modern furnace, making 300 tons of iron per week on a consumption of coke averaging less than a ton per ton of iron produced, and with the completeness of the various arrangements, the economical results of the latter system are easily appreciated, and lead to the conclusion that continued attention and experiment will still be well repaid if directed in this branch of engineering. We have already alluded to a few points more particularly demanding attention. What the future aspect of blast furnaces will be it is difficult to estimate. It would seem, however, that the extreme limit as to size has already been reached, but if the results obtained from the gigantic furnaces before mentioned are only realized, and the consumption of coke per ton of iron is brought down to 16 cwt. or 17 cwt., the extra outlay will yield a handsome interest, and no doubt when new plant has to be erected large furnaces will be in much favour. The general opinion of the Cleveland iron trade is still against furnaces more than from 70 ft. to 80 ft. in height, and from 20 ft. to 30 ft. in width at the boshes, and taking into consideration the original cost and the expense of working, it seems that these dimensions represent something like the most economical scale on which blast furnaces may be constructed in districts where the ironstone and fuel admit of large furnaces being worked. At this time the problem of mechanical puddling is the most knotty point requiring solution in connection with the manufacture of iron. Nothing at present devised effects more than a partial improvement; and in all cases there is not much present prospect of the various schemes proposed being extensively adopted. They are not sufficiently easy of application, and the results to be obtained are so doubtful that practical men have considerable hesitation in making expensive alterations unless some more tangible results could be guaranteed. In mill-work there is still unfortunately much room for improvement. The loss of fuel, of time, and hence of money, owing to the 'rule-of-thumb' manner in which mill 'piles' are made, is alone a serious item. Generally speaking, in rails for instance, the piles are made so large that frequently a long length has to be sawn off. It seems evident that it could be quite possible to calculate the length which a pile of any size would run, and that were greater precision adopted in this matter, a vast improvement would be the result. This is only one instance out of many that might be adduced, showing the necessity there is at the present day of increased attention to a more scientific method of conducting the preliminary details in finishing mills. On the whole, we may say that although there are many matters still requiring the most careful attention on the part of members of the trade, yet it is a subject for considerable congratulation to find that important additions were last year made to our stock of information with reference to the manufacture of iron."

56. *On Some Points Affecting the Economical Manufacture of Iron.*—The following paper was read before the British Association by Mr. John Jones, F.G.S., Secretary of the North of England Iron Trade:—"The object of the following paper is to consider briefly the merits of certain methods which have been recently proposed for cheapening the cost of manufacturing iron.

It is almost impossible to overrate the importance of this question. A distinguished member of this Association has raised a warning voice against the reckless manner in which our resources of coal are being exhausted, but since that time no great changes have been devised for producing a more economical application of fuel on a national scale. The supremacy of the British iron trade depends upon the comparative abundance of fuel in close proximity to the ironstone; and in proportion as the mineral treasures of coal and ironstone are exhausted, so will the position of this national industry decline, for the importation of the raw material is quite out of the question. Therefore, the economical use of the minerals we still possess is a subject of great importance. This country is now making about 4,500,000 tons of pig iron per annum, and is capable of producing at least 3,000,000 tons of finished iron. Speaking approximately, it may be said that the iron manufacture alone consumes about 15,000,000 tons of coal per annum, or rather more than one-seventh of the total quantity raised from the various coalfields. These facts are adduced to show the immense issues involved in certain changes in the mode of manufacturing iron, to which special attention will presently be invited.

These improvements will be considered under two heads. (1.) The economical application of fuel. (2.) Simplification of manufacturing processes.

The first subject naturally leads us to examine critically the whole process of manufacturing iron from the ironstone to the finished plate or rail. In smelting operations large quantities of fuel are consumed, and it must be admitted that in many cases large quantities are also wasted. Still, in the newer ironfields, where the smelting works have been recently constructed, no such waste is allowed. The greatest possible care is taken to utilize the products of combustion, and to make the gas from the furnace tops available for raising the temperature of the blast and for generating steam. The attention of blast furnace engineers has, indeed, of late years been mainly directed to the full utilization of the fuel employed. There can be no question as to the great saving that has resulted from the elaborate arrangements now in operation at the principal smelting works of modern construction; but these plans do not admit of being readily adapted to the older type of blast furnace. In many districts the mineral resources have been so far exhausted as to preclude capitalists from making changes that would involve a large expenditure without the prospect of a satisfactory return. All that can be expected in such cases is a partial adoption of the economical arrangements alluded to above, and it is satisfactory to find that a gradual change is taking place in this respect. The older plant is, in fact, being assimilated to that of the newer iron smelting districts, as far as special circumstances will allow. It seems, then, that the economical use of fuel is fully understood and acted upon in the manufacture of pig iron, at all events in the modern class of works. There it has been found practicable to make pig iron with about 20 cwt. of coke to the ton of iron produced, including heating, blast, and raising steam. It is thought, also, that even more gratifying results may yet be obtained, but at this figure it is not easy to understand how any radical change for the more economical use of fuel can be brought about. The only waste of heat-producing elements appears to be during the conversion of coal into coke, when a considerable quantity of combustible material is driven off, and is completely lost, but it is by no means certain that the conversion of the coal into an intensely hard mass does not more than compensate for the loss, unless the volatile hydrocarbons given off in coking could be made available in the furnace. It may be said, however, speaking generally, that we have now arrived at a point in the smelting of iron that is approaching theoretical perfection very closely, and what now mainly remains to be done is to bring the older blast furnaces as nearly as may be up to the modern standard, as far as the use of fuel is concerned.

When, however, we follow up the finished iron a stage further, we come to processes where there is a marked lack of economy in the appliances used, as well as great want of skill in the agents using them. To begin with, there is first a heavy loss of fuel incurred in melting the cold pig iron charged into the puddling furnace. There would, doubtless, be difficulties in running off the iron direct from the blast furnace in all cases, but there are many places where the proper mixture of pig iron might be made in the blast furnace, and where such regularity of working might be ensured as would allow of the molten cast-iron being charged direct into the puddling furnace, or at all events, the pig iron might be economically melted down in large quantities and supplied to the puddlers in the fluid state. But this suggests a more radical change in manufacturing operations than need be discussed at present. However sound such a proposal may be theoretically, it has not yet had any extensive application, though it has been practised in several ironworks.

But, taking the ordinary puddling operations, it is evident that a great waste of fuel occurs here. Large quantities of carbon are driven off in an unconsumed form in dense clouds of smoke, whilst another mass of partially consumed coal goes away as ashes and cinders. The same kind of waste is also characteristic of the various heating furnaces. The precise amount of fuel used in producing a ton of puddled iron differs in almost every ironwork, but it may be safely asserted that 25 cwt. of fuel to the ton of puddled iron is under the average the country through. The question arises, whether it is practicable to so modify the construction of the existing puddling furnaces as will ensure more economical results, and at the same time afford proper facilities to the workmen. Is it possible, in fact, to make the whole of the fuel used effective in producing heat in the furnace? because, if this can be accomplished, the quantity of coal required in the puddling process will be very considerably reduced. This problem has more recently occupied the attention of many minds, for numerous patents have been taken out dealing with it in one way or another, and it has now been to a great extent solved in a satisfactory manner, so that we appear to be getting near a means of using fuel as economically in the puddling as is already done in the blast furnace.

The Wilson modification of the firegrate, as perfected by Messrs. W. Whitwell & Co. of Stockton, has received a good deal of attention amongst iron manufacturers, and it is gradually being adapted to the peculiarities of fuel in the various districts, and its construction is being reduced to its simplest elements. This furnace may be described in a few words, the principle having to be modified a little according to special circumstances. The fuel in this furnace is made to burn on a sloping solid fire-brick bottom, the coal being introduced at the top, and made to pass gradually down to the part where there is an incandescent mass; the hydrocarbons, which in ordinary furnaces form smoke, and thus pass off without doing any economical work, are turned into an intense flame in the furnace, and no smoke is made, when a sufficient quantity of atmospheric air is admitted. Underneath the combustion chamber is a closed ash-pit, into which a blast of air is forced by means of a steam jet three-sixteenths of an inch in diameter. The air causes a reduction of the cinders and clinkers usually formed in ordinary furnaces; and at the same time the steam passing through the red hot cinders is decomposed, carbonic oxide and hydrogen being produced. The air for combustion is mainly introduced by means of a pipe which passes through the flue bridge, round the furnace back, through the flame bridge, into an upper chamber above the sloping generator, whence it descends in thin streams through the perforated bricks into the furnace. The air is thus supplied in a highly heated condition. This furnace gives off no smoke, and the materials are perfectly consumed, the formation of ashes and cinders being also prevented. Without going into details, it has been practically demonstrated from results obtained by working these furnaces a considerable length of time, that the quantity of fuel required per ton of puddled iron is from 20 per cent. to 25 per cent. less than in the ordinary furnace, the consumption of coal ranging between 17 cwt. and 18 cwt. The principle of the Wilson furnace is the complete combustion of the fuel before it comes to the furnace chamber, but a certain amount of heat is assumed to pass from the furnaces without being utilised, though this can be as easily made available for generating steam as can the waste heat from puddling furnaces of ordinary construction. The subject, however, admits of being approached in another way, by devoting increased attention to the utilisation of the heat, and by making the waste heat available again in the furnace. The Newport furnace, patented by Jones, Howson, and Gjers, and in operation at the Newport Ironworks, Middlesborough, is constructed on this principle. A chamber is built in the ordinary chimney stack, and in this are placed two cast-iron upright pipes, with a partition reaching nearly to the top of each. The waste gases from the furnace are diverted into the chamber by means of a damper, and raise the temperature of the iron pipes to a high degree. Through these pipes the air required for combustion of the fuel is drawn by means of a steam jet; the mixed air and steam being conveyed to the furnace bridge, and delivered there by a series of tuyeres; also a portion of the air is sent in lower down, underneath the bars of the grate, the ashpit being closed so that no air can reach the furnace, except that which has been heated to a temperature of about 500° by the waste gases. By this means a regenerative action is set up, and it is found in practice that the combustion of the fuel is nearly complete, the only smoke produced being at the time when heavy firing is going on. The actual results arrived at by the use of these appliances are the saving of from 25 per cent. to 30 per cent. of fuel as compared with the operation of the furnaces of ordinary construction. In the working of several of these furnaces with grey forge iron, six heats per day, the quantity of coal used in producing a ton of puddled iron has been reduced to 16 cwt. and less; ordinary furnaces, working under similar conditions, using from 22 cwt. to 23 cwt. to produce similar results. In proportion as refined iron or lower qualities of pig iron are introduced, the proportion of fuel required decreases considerably.

The structural modifications required in adapting existing puddling furnaces to the more economical types here alluded to, are so slight, compared with the saving to be effected, that the whole outlay would quickly recoup itself; for assuming even that each furnace would cost £50 in alterations, and would thus be made to save 25 per cent. in fuel, each furnace would more than clear itself in a single year. The modifications, also, are such that in each case the workmen would require no special training to enable them to use the new furnaces.

Though prominence is here given to only two varieties of improved puddling furnaces, I am aware that other modifications exist, each of which has its special advantages, but in this notice I wish to disregard any particular allusion to plans that would involve a large expenditure before they could be got into successful operation, and where a more highly-trained class of workmen than is yet available would be required in order to ensure success. The above remarks are, however, made without prejudice to other methods proposed to effect the economical use of fuel in the manufacture of finished iron. But I wish to insist upon the fact demonstrated from the working of the two types of furnace alluded to, that with proper care and an average amount of skill on the part of the workman, a saving of at least 25 per cent. in the fuel commonly used in puddling may be made without in any degree injuring the quality of the iron produced, and without the expenditure of a large sum of money in altering existing arrangements. Now what does this mean in the aggregate? We have previously assumed that 6,000,000 tons of coals are annually consumed in the production of the whole quantity of finished iron which this country could make—that is, allowing 9,000,000 tons of coal for the production of pig iron. A saving of 25 per cent. upon this represents close upon 1,500,000 tons of coal. If, then, it be possible to effect an economy of this marked character by means so comparatively simple, this subject undoubtedly becomes one of vast importance to the iron trade of the country, and, indeed, is entitled to rank as a national question.

If the results indicated in the above remarks could be secured for the whole iron trade of the country, this industry would be at once placed in a much more favourable position with respect to foreign competition, about which so much has been written of late. We are asked, however, to go a step further than this. We are invited to relinquish certain prejudices which most practical iron makers and engineers have as to the proper mode of manufacturing iron rails, plates, or bars—a mode that has been in existence for a very long period. In following up the process for making, say an ordinary railway bar or plate, we soon arrive at a complicated series of operations. The puddled iron has to be rolled into rough bars, which, after being straightened and weighed, and allowed to get quite cold, are cut up into short lengths, made into piles, conveyed to heating furnaces, heated and hammered or rolled down, are then a second time heated, and finally rolled off into finished bars. Even when the second heating is not required, the ordinary process of manufacture contains several objectionable features. The iron is allowed to cool down in the intermediate stage of puddled bars. The piles can never be made perfectly homogeneous, lines of lamination remain in the finished iron, and these cause serious defects when the material is exposed to heavy wear, as in common rail. Now, theoretically, it would seem a more rational plan to carry on the various stages in the manufacturing process more rapidly, and without the many complications which now encumber it. In what is termed the Radcliffe process an attempt is made to carry out this principle, the puddled iron being passed through the necessary stages so rapidly that it reaches the point of finished iron in little more than half an hour after leaving the puddling furnace. The plan is described in a few words. There is no peculiarity about the iron used, the puddling, or the fettling employed. Good workmen are required, and the best fettling is allowed. The puddled iron is brought out 'young,' and the furnaces are made to work in such a manner that five or a greater number of balls may be brought out practically at the same time. These are treated under a heavy steam hammer, having a quick action; and by the aid of mechanical appliances a large bloom is easily formed, according to the size of the plate or rail to be manufactured. The bloom is passed through a heating furnace, to recover the heat lost in the shingling process; and, after being exposed to a mellow flame for a short time, it is at once rolled into the finished article.

In this system we find the various stages reduced to the simplest form, whilst the quality of iron produced by this method speaks for itself. A perfectly homogeneous structure is secured, no lamination occurring under this mode of treatment. This process has been extensively practised, especially in the production of plate, at the Consett Ironworks; and therefore its value has been fully tested. It has the further merit of requiring very little modification in existing ironworks to enable the plan to be put into operation, an immense advantage in these days, when even more direct means of producing finished iron are thought to be not far distant improvements, and when plans requiring an extensive outlay have comparatively a poor chance of being adopted.

The method here sketched out leads to a great economy in labour, fuel, puddled iron, stores, repairs, and in many other ways, and, besides, the productive power of the machinery is so far increased, that the dead charges—a very important item in the cost of making iron—are distributed over a greatly increased make of finished iron. On the face of it, it must be evident that this process far more nearly fulfils the conditions required in a scientific plan for manufacturing iron than does the cumbrous one generally adopted. If new works had to be constructed to carry out the system, still more satisfactory results would doubtless be obtained, just as has been the case with the modern improvements in blast furnaces. There is, it must be admitted, much prejudice to be removed from the minds of managers, and even higher authorities; there are mechanical and other difficulties to be overcome before complete success can be ensured, under the various circumstances characteristic of the finished iron trade. But what I wish to dwell upon is, that the principle of the proposed method of manufacture is theoretically correct, is calculated to effect a great reduction in the cost of producing iron, and promises to enable iron manufacturers to make the most of our national resources, by allowing of the production of the finished iron with the least possible expenditure of fuel and of labour.

Taken in connection with the first consideration, that of effecting greater economy in the use of fuel, it would seem that there is a possibility of saving, say 25 per cent. of coal, even upon the ordinary mode of working, and also of dispensing with processes that at present use from 10 cwt. to 15 cwt. of fuel. In other words, this subject, looked at in a national point of view, means a possible saving of about 3,000,000 tons of coal per annum, including the two principles of economy mentioned in this paper, besides which there are other equally tangible points where a material saving could be effected, but which do not admit of being expressed in common terms, as is the case with the fuel.

It may be mentioned, however, that the rapidity of the process prevents the waste by oxidation of the iron under treatment, and, under ordinary circumstances, we are informed there is a saving of from 3½ cwt. to 4 cwt. of puddled iron in every ton of finished rails or plates produced. This iron is simply lost in the usual mode of procedure. If this heavy loss could be even partially prevented, a vast saving would be made, and no extra expense would be incurred in obtaining such a result.

The metallurgy of iron is such a wide subject, there are now so many workers in it, and the whole subject is of so much national importance, that I venture to think the points to which I invite attention are deserving of general notice by all who are practically interested in the iron manufacture, or in the use of iron for engineering purposes. It is high time that the manufacture of iron were placed upon a more truly scientific basis. Our mineral treasures have been so readily available, and we have, until quite recently, enjoyed such an extensive monopoly in the iron trade, that our position seemed unassailable. We have found, however, that the application of science has enabled our continental neighbours to overcome natural disadvantages, and to place themselves on a level with ourselves as far as cheapness of production is concerned. It is for us to apply to our manufacturing operations those principles which have proved successful in their case, and there is no doubt we may be able to effect such a sweeping economy in our cost of manufacture, that we shall soon obtain the full benefit which we ought to derive from our abundant supplies of coal, and the vast quantities of ironstone lying within reach of the fuel required to smelt it."

57. *Purification of Iron Ores.*—"The question of removing," says a leading article in 'Engineering,' under date Sept. 11th, 1868, "sulphur and phosphorus from iron still stands before the practical world as an important, well known, yet unsolved problem. It is the bridge with which we expect some day to connect the metallurgical practice of the present day to a future far more advanced, and a scientific system of metallurgy to be arrived at by the gradual yet constant advancement and development of science and knowledge. We have recorded many attempts to remove phosphorus and sulphur from pig iron, from liquid steel, and from wrought iron, but we have not had a single instance of practical success to place before our readers. The general conclusions which seemed to force themselves upon the minds of metallurgists, by the results of all those unsuccessful experiments, were, as a rule, unfavourable to the treatment of iron in its more advanced stages of manufacture, and pointed to the blast furnace, if not to the calcining kiln, for the purification of the substances charged into them. Seeing, in fact, how difficult it was to remove sulphur and phosphorus from iron, if these substances are once combined with that metal, it became a question for investigation whether such a combination could not be prevented by removing from the raw materials all those substances which form the sources of these noxious contaminations when reduced in the smelting furnace.

The simplest means of improving the charges, and the one which suggested itself without much thought or science, was the mixing of phosphoric ores with others free from phosphorus, and thereby diluting the noxious impurity. This process is more effective than would appear at first sight. Given two kinds of ore, the one contaminated with sulphur to an extent which will make the iron produced from it unfit for the intended use, and another ore containing phosphorus to a similar extent, it is obvious that a mixture of the two ores will produce an iron which will be superior to that produced from either of the two kinds of ore when smelted by itself. The practice of mixing different ores for the blast furnace charges is, therefore, not a mere production of an average quality from superior and inferior kinds of raw materials, but it is, when properly carried out, attended by an actual improvement of the make of iron over the products derivable from any one of the ores mixed together when smelted singly and without other admixtures.

The next step to be recorded in that direction is the practice of washing iron ores after calcination. This, too, is at present an old-established process, but one which has been rarely used on account of the expense and inconvenience which was thought necessarily connected with this mode of purification. The washing process is applied exclusively for the removal of sulphur, and it is altogether without any effect upon the phosphorus that may be contained in the ore. The rationale of the washing process is the following:—An iron ore contaminated with pyrites, such as, for instance, the spathic ore or brown hematite of Styria, Rhinish Prussia, of the Weardale district, and of other localities, when submitted to calcination, under the free access and influence of the air, takes up a certain quantity of oxygen, and by that process the pyrites and other similar combinations of sulphur and iron become converted into sulphates of iron, which are soluble in water. If after calcination the ore is washed with a large quantity of water and for a considerable length of time, all those soluble salts, and with them the component sulphur will be removed from the ore, which remains in a more or less purified state according to the more or less efficient manner in which the calcination and washing have been effected. We have had occasion to describe two ironworks on the Continent where purification from sulphur is most effectively attained by washing the calcined ore previous to its being smelted, viz., the Kladno Ironworks, in Bohemia, where forge iron for puddling is the staple article, and the Ironworks, Maria Zell, in Styria, producing foundry iron and Bessemer pig-iron.

We now pass from the record of processes in practical existence to a new method of purifying iron ores now under experiment in this country, and patented by Mr. Thomas Rowan, of Glasgow. This is a process of purification from sulphur and from phosphorus by calcination and subsequent washing, only the calcination in this instance is not a mere oxidizing process as now practised, but the ore is mixed with chlorides, such as common salt or chloride of manganese, and calcined in contact with these substances. Such a calcination is well known to metallurgists, particularly to those accustomed to the extraction of copper and silver from their ore. It is called a chloridising calcination, as distinguished from the common or oxidising calcination, and its effect is to convert many of the substances contained in the ore into chlorides. The effect of calcining an iron ore containing sulphur and phosphorus in contact with common salt (chloride of sodium) would be the decomposition of the salt by the action of the sulphur, and the formation of sulphate of soda and the liberation of the chlorine, which combine with all the basic matter contained in the ore, such as lime, magnesia, &c., and also with the phosphorus. The idea of removing phosphorus from iron by the action of chlorine was originated by Dr. Crace Calvert, of Manchester, more than twenty years ago, but it appears that Dr. Calvert expected a gaseous combination of phosphorus and chlorine to be formed and passed off as a vapour either from the blast furnace or calcining kiln. Mr. Rowan's researches seem to show that none of the volatile combinations of chlorine and phosphorus are formed during such a calcination, but that a combination is formed which is soluble in water, and can be extracted from the ore by washing after the calcination is completed. The effect of washing the ore after this chloridising calcination is the removal of the sulphate of soda and of the chlorides of phosphorus formed in that process. The sulphur and phosphorus pass into the water, and can be recovered from it if desirable, but the insoluble residue is an iron ore purified to a considerable extent, and fit for use in the blast furnace after the moisture is evaporated. It has been proposed, at one of the great ironworks in the Cleveland district, to effect this calcination by charging the ironstone mixed with salt into the calcining kilns now in use, but this is not a suitable mode of working on a large scale. The time for calcination, and particularly for washing, should be ample, and much greater than can be allowed in the calcining kiln. The calcination should be carried on close to the mines in very large heaps, covered at the top, and connected at the bottom with flues which lead into a chimney. The salt mixed with the ore, or, still better, dissolved in water and sent into the calcining heap in the form of small jets or streams of brine, would act upon the mass for any desirable length of time. The whole calcining heap should, after being burnt out, be immersed with water, or be percolated by a large stream or body of water for several weeks. After this the ore may be sent to the smelting works, and the calcining kilns there will play the part of evaporators only. They will dry the ore and heat it to some extent previous to its being charged into the blast furnace.

The question of trouble and inconvenience will thereby be transferred from the ironmaster to the mine owner, and it will resolve itself simply into a question of price per ton of purified ore. Considering that the removal of sulphur and phosphorus from Cleveland pigs would raise their market value at least £1 per ton, and taking 3 tons of calcined ore for the ton of iron made, it is clear that the process of washing can be paid for at the rate of, say, 5s. per ton of ore, and have an advantage to those who use the washed ore instead of the raw ironstone. The quantity of salt required depends upon the quantity of phosphorus contained in the ironstone, but it will scarcely exceed 5 per cent. of the weight of iron ore in any case. The value of the salt added may be estimated therefore at 6d. per ton of ore, leaving a margin of 4s. 6d. for the expenditure of calcination and washing. This is a figure which ought to afford a very handsome profit to those who undertake the purifying process on a large scale. The Upleatham mines and others in the Cleveland district are almost within sight of the sea, which would afford both the salt for calcination and the water for extracting the heap when calcined. The process, although hardly tried on a scale which could be called practical as yet, deserves the utmost attention of every intelligent ironmaster and owner of ironstone mines. Its theory is supported by a great deal of experimental evidence, and the importance of the problem that Mr. Rowan has so far tried to solve, justifies the commencement of experiments on a full working scale without hesitation and delay. We look upon experiments of that kind as a question of national importance. A purification of the phosphoric iron ores of this country means no other thing but the universal and unreserved substitution of steel manufacture instead of the manufacture of iron, and the application of steel in all modern constructions; it is equivalent to a saving of an enormous value now annually destroyed by the wear and tear of the inferior materials produced from impure iron ores, and to a direct increase in the national wealth, amounting to many millions per annum."

58. *On the Shrinkage of Cast-Iron.*—"The following is the substance of a paper read by Mr. David Walker before the members of the London Association of Foremen Engineers, on Saturday, the 4th inst., Mr. Newton in the chair:—Shrinkage is the complement of the property which metals possess in common with nearly all other bodies—that of expanding by heat. It comes into operation more or less at all ranges of temperature, but varies very much in degree. In iron castings it proceeds very rapidly at temperatures high above the smelting point, which was proved by the sinking of the metal in a mould after it had been filled, and the large quantity of metal which was required to keep up the head—technically called 'feeding.' This would go on in castings of great thickness for a couple of hours or more. When this subsidence was not guarded against by the feeding operation, the castings inevitably became unsound. Exteriorly it would take the form of the mould, but in the centre it would be hollow; the experienced moulder so arranged his feeding head as to supply those parts of the casting which were thicker than the others. (The reader here introduced a piece of cast-iron caught, as it were, in the act of crystallization, and which presented an appearance analogous to that of water when freezing.) Mr. Walker then proceeded to say that whereas water expanded during crystallization, iron shrank. A block of metal measuring 1¾ cubic ft. took about 7 lb., or 26 cubic in., of metal to

feed it; this was equal to 1-10 in. to the foot, the usual allowance made for shrinkage in cooling from the smelting point. This appeared to confute the idea of iron expanding in the act of crystallization. It had been said to expand externally; he had never been able to observe any symptoms of this nature. If there were any of that irresistible power which ice exhibits, we should expect it to show itself in the case of a chilled roller, for example. This was not so to any perceptible extent, the chill or iron mould lasting till fairly worn out by heating and cooling. The only argument for the theory of iron expanding in crystallization, held by some scientific men, was that the solid was supported by the fluid, thus showing greater specific gravity.

That the metal shrank while cooling in the fluid state was beyond a doubt, and that the fluid supported its own solid was also quite clear, although how to reconcile the two facts he was at a loss. The contraction, however, was checked during the loss of a great portion of the heat, which was not easy to be accounted for, unless we looked upon the expansion by crystallization, on the one hand, and the contraction by loss of heat on the other, as two great opposing powers, which, like the centrifugal and centripetal forces in the heavenly bodies, balanced each other for a time, and thus checked the action in either direction. Mr. Walker observed that he had no desire to indulge in theoretical speculations, but would prefer to give the results of his own observations, extending over a considerable time, and sometimes producing rather conflicting ideas. It was admitted, as demonstrated by researches in chemistry, that fluids began to crystallize at certain fixed temperatures, varying according to the properties they possessed. Cast-iron, for example, was given at 2,754° Fahr. by some authorities, at 3,600° by others, whilst some authorities went even as high as 17,975° by the same thermometer. Copper was less, and the scale descended in silver, gold, zinc, lead, &c., down to mercury, which was 39° below zero. Now, leaving out of the question for the present the numerous qualities of cast-iron, it would seem safe to assume that two castings from the same charge would crystallize at the same temperature, and if the shrinkage could be calculated with any degree of certainty, our task would be comparatively an easy one. This was, however, by no means the case, for it was influenced by very many conditions—as thickness, position, the nature of the mould (whether of loam or sand) in its various forms, and others which baffled calculation. He (Mr. Walker) did not expect to succeed in arriving at any definite points as to the results of these conditions, but that even an approximation was important would be admitted by experienced pattern makers, who often found great difficulty in causing the various castings of large pieces of work to come to the required sizes, they having to be produced under the varying conditions alluded to.

The simplest form of casting, and that most easy of observation—the open sand plate—on being poured solidified very quickly, and parted with its heat rapidly. It would naturally be expected that in this case shrinkage would proceed in proportion, but this was by no means so. About ten minutes after it had become set it would be below the smelting point of copper, showing that it had, by the lowest estimate, lost 700° of heat, but there was no observable contraction. It would remain at its original size, varying according to thickness, perhaps half an hour, and then it would begin to shrink very slowly indeed till it had cooled to about 1,100°, or 1,200°. Here the contraction would cease for a time, and at this peculiar temperature a decided expansion would take place, and this existed until it cooled to about 800°, when the real work of shrinking began. That slowness of contraction at high temperature he had noticed, in a general way, frequently, but the observations in regard to temperature and the discovery of expansion, at a particular degree of heat, was made upon a plate of cast iron 14 ft. long and 1½ in. thick, and this was cast at ten minutes to three o'clock in the afternoon, and it set almost immediately. About ten minutes after, it had cooled below the smelting point of copper, and must have lost, according to the lowest estimate of temperature, upwards of 700° of heat. This it did without showing the slightest symptom of shrinkage; nor did it do so for quite half an hour, then shrinkage began to show itself very slowly, and continued until it reached the amount of 3-16 in. in 14 ft. length. Judging from the colour, it had now come to the temperature of about 1,100° or 1,200°. Strangely enough, at this point it began to expand again, and recovered ⅛th of its lost dimension, and thus it remained till it had fallen to about 900°, when the contraction proper began, namely, about two hours after casting. In one hour it amounted to $\frac{5}{8}$ in., heat about 700°. Next hour $\frac{7}{8}$ in., heat 600°. Next hour 1 1-16 in., heat about 550°. Judging from its effects upon metals of known degrees of heat at the fusing point, next morning, at six o'clock, the heat was 130° by the thermometer, the shrinkage 1 11-16 in. Finally, the contraction had reached $1\frac{3}{4}$ in., or exactly $\frac{1}{8}$ in. to the foot. There were some very curious phenomena to be observed upon in this example. It lost nearly 2,000° of heat without sustaining any longitudinal or appreciable shrinkage. This might or might not be accounted for by the idea suggested—that of the opposing forces, due to expansive crystallization on the one hand, and shrinkage, by the loss of heat, on the other. It was clear that nearly the whole of the shrinkage took place within the range of 600°. The reader of the paper said he had made numerous observations with similar results.

The most important condition, as effecting shrinkage, was, he thought, the relative thickness of castings. Two castings, poured at the same time, would yield very different results in shrinkage when they varied in thickness. It would be easy to adduce examples of this, and one should be mentioned. A bar of cast-iron, 1 in. thick and 3 ft. long, gave 1-10 in. per foot of contraction, while a block, cast from the same cupola, and within five minutes of the same time, gave in 2 ft. length no shrinkage at all! The latter, indeed, when cold, was exactly of the same dimensions as the mould. The measurements were made with great care in both cases. What seemed more remarkable, perhaps, was the fact that the same block took in feeding, as nearly as could be estimated, a quantity of metal equal to 1-10 in. per foot in its whole mass. These experiments agreed in their main features with the author's general experience, and showed that block castings do not, as a rule, shrink to any sensible extent. Generally, he had found that castings which were fed well had a very limited degree of shrinkage. It would be possible for him to make a sketch of a frame with which he was very familiar (a finely proportioned pattern $2\frac{1}{4}$ in. thick), in which the contraction of the resulting casting varied from 1-17 in. to 1-23 in. per foot longitudinally, and in depth, which was 24 in., gave no shrinkage at all. This was a casting with flanges all round it, so that there was no part of the results due to straining. They were attributable to careful feeding alone. In conclusion, Mr. Walker remarked that this subject naturally divided itself into two parts—First, the nature and condition of shrinkage proper; and, second, the effect of unequal contraction in ill-proportioned castings. The first of these he had hoped to deal with fully that evening, but found that want of time prevented it. At a future period it should be resumed, and then it was to be hoped the whole subject might be more satisfactorily developed."—*Mechanics' Magazine.*

59. *On the Recent Progress of Steel Manufacture.*—The following paper was read before the British Association by Ferdinand Kohn, C.E.—" At the last meeting of the British Association in Dundee I had the honour to draw the attention of this section upon a new mode of steel manufacture which at that time had commenced to gain ground on the Continent, but which had not been brought into commercial practice in any one of the numerous steelworks of this country. (See vol. of Engineering Facts and Figures for last year.)

I refer to the process of manufacturing steel upon the open hearth of a Siemens' furnace by the mutual reaction of pig iron and decarburized iron, or 'wrought-iron,' upon each other—a process which, in France, has received the name 'Martin process,' from its inventors, Messrs. Emile & Pierre Martin of Paris, but which, in justice to both the inventors to whom the practical and commercial success of this innovation is due, should bear the name of 'Siemens-Martin process.' Within this last year the Siemens-Martin process has been brought into operation in this country, and I have now the pleasure to lay before this meeting a few samples of steel which have been made by that new process in the Cleveland district, and, in a very considerable proportion, from Cleveland iron.

I hope, therefore, that it will not be out of place to give to this section a brief account of the technical detail of this new mode of steel manufacture, and to make a few remarks upon its commercial prospects, so far as the latter can be judged at present.

The Siemens-Martin process realizes the old and repeatedly proposed idea of melting wrought-iron in a bath of liquid pig iron, and thereby converting the whole mass into steel. The principal elements of its successful operation, and the points which distinguish it from all previous abortive attempts, are—first, the high temperature and the neutral or non-oxidizing flame produced by the regenerative gas furnace of Mr. Siemens; and secondly, the method of charging the decarburized iron into the bath of pig iron in measured quantities or doses.

These doses of wrought-iron or steel are added to the bath in regular intervals, so that each following charge in melting or in being dissolved in the bath increases the quantity of the liquid mass, and adds to the dissolving power of the bath until the stage of complete decarburization is arrived at. The charge is then completed by adding to the decarburized mass a certain percentage of pig iron, or of the well-known alloys of iron and manganese, such as spiegeleisen or ferro-manganese, and the degree of hardness or temper of the steel produced depends on the proportion of this final addition.

The process, as characterized above, has been experimented with at the Model Steelworks, in Birmingham, by Mr. Siemens, and on a larger scale at the Bolton Steelworks. From this latter establishment a railway tyre made from Bessemer steel scrap and pig iron upon the open hearth of a Siemens furnace has been sent for exhibition to this meeting. The first, and as yet, the only steelworks in this country which is working this process commercially, and which is laid out for the manufacture of steel by the Siemens-Martin process exclusively, are the Newport Steelworks, at Middlesborough-on-Tees, belonging to the well-known firm of Messrs. B. Samuelson & Co.

The Newport Steelworks commenced operations about two months ago, and have been working since that time with great regularity, and almost without interruption, day and night. There is one steel-melting furnace, constructed from the designs of Mr. C. W. Siemens, in operation at present, and a second similar furnace is to be erected very shortly.

The roof of the furnace is made of Dinas brick, and the bed upon which the charges are melted is made of ganister or pure silicious sand mixed with a red sand containing a small percentage of alumina, both kinds of sand being found in the Cleveland district. The preparation of the furnace bottom requires great care, and a certain amount of skill on the part of the workmen. All materials charged into the furnace are previously heated to redness in an auxiliary heating furnace. The pig iron employed for forming the bath is principally Swedish charcoal pig iron, and it enters into the charges in the proportion of about one-third of the total weight. The tables annexed to this paper, which are copies of the records of some interesting charges kindly placed at my disposal by Messrs. Samuelson & Co., give a clear idea of the precise mode of conducting the charge. Table No. 1 is the record of a charge made of Swedish pig iron (1,680

TABLE I.

No. *Furnace.* *Monday night, July* 20, 1868.

Times of Charging.	Charges.				Make.	
	Swed. Pig Iron.	K. & J. Pud. Bars.	Hæmatite Ironstone.	Spiegeleisen.	Ingot Steel.	Scrap Steel.
O'clock.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
8·0	1,680	—	—	—	—	—
9·40	—	22	—	—	—	—
10·0	—	224	—	—	—	—
10·30	—	224	—	—	—	—
11·0	—	224	—	—	—	—
11·45	—	224	15	—	—	—
12·30	—	224	15	—	—	—
1·0	—	224	15	—	—	—
1·40	—	224	15	—	—	—
2·40	—	224	—	—	—	—
3·20	—	224	—	—	—	—
4·0	—	224	15	—	—	—
4·40	—	224	—	—	—	—
5·30	—	224	15	—	—	—
6·10	—	224	—	—	—	—
7·15	—	—	—	224	—	—
8·5	—	—	—	112	—	—
8·45	—	—	—	224	—	—
9·0	—	—	Soft	steel,	4,962	116
5,466 lbs.	1,680	3,136	90	560	4,962	116
Cwts. Lbs. Oz. 48 3 6	Cwts. 15	Cwts. 28	Lbs. Oz. 3 6	Cwts. 5	Cwts. Lbs. Oz. 44 1 6	Cwts. Lbs. Oz. 1 0 4

Loss, ... 7·10 *per cent.*

lbs.), and of puddled bars from Cleveland iron (3,136 lbs.). A small quantity of hæmatite ironstone was added to the charge during the operation, with the intention to reduce the time required for the process, which occupied thirteen hours; but from the large proportion of spiegeleisen (1,560 lbs.) required at the end, it appears that the decarburization had been carried too far,

TABLE II.

No. *Furnace* *Thursday, July* 30, 1868.

Times of Charging.	Charges.					Make.
	Cleveland Grey Pig Iron.	K. & J. Pud. Bars.	K. & J. Patent Slag.	Ilmenite.	Spiegeleisen.	Scrap Steel.
O'clock.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
5·0	2,240	—	—	—	—	—
6·30	—	—	280	—	—	—
7·5	—	—	280	—	—	—
8·5	—	224	—	—	—	—
8·35	—	224	—	—	—	—
9·5	—	224	—	—	—	—
9·30	—	224	—	—	—	—
10·0	—	224	—	—	—	—
10·30	—	224	—	—	—	—
11·5	—	224	—	—	—	—
11·45	—	224	—	—	—	—
12·20	—	224	—	—	—	—
12·55	—	224	—	—	—	—
1·30	—	224	—	—	—	—
2·0	—	224	—	35	—	—
2·30	—	224	—	35	—	—
3·0	—	224	—	35	—	—
3·30	—	—	—	35	—	—
4·0	—	—	—	35	—	—
4·25	—	—	—	35	—	—
6·15	—	—	—	—	448	—
7·0	—	—	—	—	—	5,446
6,594 lbs.	2,240	3,136	560	210	448	5,446
Cwts. Lbs. Oz. 58 3 14	Cwts. 20	Cwts. 28	Cwts. 5	Cwts. Lbs. Oz. 1 3 14	Cwts. 4	Cwts. Lbs. Oz. 48 2 14

Remarks: Cold short, brittle (not to be smelted in steel furnace). Loss 17·41 *per cent.*

and the charge could have been completed several hours earlier. At the same time this example shows the great facility which the Siemens-Martin process affords with regard to the correction of errors committed in conducting a charge. The production of any desired temper of steel can be relied on with absolute certainty, since the ultimate success is a mere question of time, and it is of comparatively little consequence how far the desired charge of decarburization may have been overstepped or neglected during the operation, if the final addition brings the charge back to its proper temper and quality.

Table No. 2 is a record of an attempt to use Cleveland pig iron for the bath. The puddled bars added to the charge were

TABLE III.

No. *Furnace.* *Tuesday, August* 4, 1868.

Times of Charging.	Charges.					Make.	
	Millom. Hæmatite Grey Pig Iron.	K. and J. Billets Pud. Bars.	Hæmatite Ironstone.	Ilmenite.	Spiegeleisen.	Ingot Steel.	Scrap Steel.
O'clock.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
9·5	1,344	—	—	—	448	—	—
10·45	—	224	—	—	—	—	—
11·0	—	224	—	56	—	—	—
11·30	—	224	—	—	—	—	—
11·50	—	224	—	56	—	—	—
12·15	—	224	—	—	—	—	—
1·0	—	224	—	—	—	—	—
1·45	—	224	—	—	—	—	—
2·15	—	224	—	—	—	—	—
3·20	—	224	56	—	—	—	—
4·45	—	224	56	—	—	—	—
6·0	—	224	—	—	—	—	—
6·45	—	224	—	—	—	—	—
7·20	—	224	—	—	—	—	—
7·45	—	—	—	—	224	—	—
8·20	—	—	—	—	224	—	—
9·0	—	—	—	—	—	4,536	124
5,376 lbs.	1,344	2,912	112	112	896	4,536	124
48 cwts.	12 cwts.	26 cwts.	1 cwt.	1 cwt.	8 cwts.	40c. 21bs.	1c. 12 lbs.

of the same kind as those used with the Swedish pig iron, and the addition of Ilmenite, a mineral containing a high percentage of titanium, was made with a hope to remove phosphorus from the bath. With a similar idea a quantity of so-called patent slag—a mixture of ingredients to which a similar power is ascribed in the Cleveland district—has been added, but with-

Table IV.

Remarks: Rails. *Loss:* 17·02 *per cent.*

No. Furnace. *Wednesday, August* 5, 1868.

Times of Charging.	Charges.				Make.	
	Swed. Pig Iron.	K & J. Scrap Pud. Bars.	Hæmatite Ironstone.	Spiegeleisen.	Ingot Steel.	Scrap Steel.
O'clock.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
5.15	1680	—	—	1008	—	—
7.10	—	448	—	—	—	—
7.50	—	448	—	—	—	—
8.30	—	448	—	—	—	—
9.5	—	448	—	—	—	—
9.50	—	448	—	—	—	—
10.35	—	448	—	—	—	—
11.15	—	448	—	—	—	—
12.5	—	448	—	—	—	—
12.55	—	448	—	—	—	—
1.55	—	448	—	—	—	—
2.30	—	448	—	—	—	—
3.20	—	448	—	—	—	—
4.10	—	224	28	—	—	—
4.40	—	224	28	—	—	—
5.15	—	224	28	—	—	—
5.50	—	224	28	—	—	—
6.35	—	224	—	—	—	—
7.10	—	224	—	244	—	—
7.50	—	—	—	—	—	—
8.30	—	—	Soft steel, . .		8624	304
9764 lbs.	1680	6720	112	1252	8624	304
Cwts. Lbs. Ozs. 87 0 20	Cwts. 15	Cwts. 60	Cwts. 1	Cwts. Lbs. Ozs. 11 0 20	Cwts. 77	Cwts. Lbs. Ozs. 2 2 24

Remarks: Very Soft. *Loss:* 8·50 *per cent.*

out success. The product was found cold short and brittle, and the Cleveland pig iron has thereby been proved unsuitable for the Siemens-Martin process.

Table No. 3 records a charge made with grey hematite pig iron and Cleveland puddled iron. The product is a steel of less ductility and malleability than that derived from Swedish pig iron. There is also an excessive loss, amounting to 17·04 per cent. of the total weight charged into the furnace shown by this table. This seems to indicate a high percentage of silicon in the pig iron, to the partial and imperfect removal of which both the hardness of the steel and the great waste may be due. It is not possible, however, from this single experiment, to draw a reliable conclusion with regard to this class of pig iron.

Tables No. 4 and 5 show some of the most successful charges

TABLE V.

No. 1 *Furnace.* *Wednesday night, August* 5, 1868.

Times of Charging.	Charges.					Make.	
	Swed. Pig Iron.	K. & J. Pud. Bars.	Scrap Steel.	Hematite Ironstone.	Spiegeleisen.	Ingot Steel.	Scrap Steel.
O'clock.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
12.0	1680	—	—	—	560	—	—
1.35	—	—	224	—	—	—	—
2.0	—	—	224	—	—	—	—
2.30	—	448	—	—	—	—	—
3.5	—	448	—	—	—	—	—
3.40	—	448	—	—	—	—	—
4.15	—	448	—	—	—	—	—
4.50	—	448	—	—	—	—	—
5.25	—	448	—	—	—	—	—
6.5	—	448	—	—	—	—	—
6.45	—	448	—	—	—	—	—
7.30	—	448	—	—	—	—	—
8.30	—	448	—	28	—	—	—
9.25	—	448	—	28	—	—	—
10.45	—	224	—	—	—	—	—
11.15	—	—	—	—	224	—	—
12.0	—	—	—	Soft	steel,	6972	148

Remarks: Very soft. *Loss:* 12·32 *per cent.*

made at Messrs. Samuelson & Co.'s works. From these charges the samples which I have exhibited here are taken. The bath of pig iron in these charges is made of a mixture of white Swedish iron and of spiegeleisen; besides this, a quantity of spiegeleisen is added at the end of the operation. In these charges Cleveland bars enter in the proportion of about one-half. The steel produced in this manner is very soft and of a very fine quality; it is principally used for boiler plates and for similar articles. Some tests with regard to the strength and elasticity of this steel, are now in progress at Mr. Kirkaldy's testing works, but the results have not reached me as yet.

The quantity of fuel used in this process of steel melting, including the fuel for the auxiliary heating furnaces, is about one ton of coal per ton of steel produced.

From the above data the question of prime cost may be answered approximately.

Taking the price of Swedish pig iron and of spiegeleisen at £6 per ton, that of Cleveland bars at £5, and the average waste in the furnace at 10 per cent., we require for 1 ton of steel ingots:—

	£	s.
11 cwts. of pig iron at £6, ...	3	6
11 cwts. of puddled bars at £5, . . .	2	15
1 ton of coal, ...		5
Cost of Materials, ...	6	6

The expenses for wages, repairs of plant, and royalties to both the patentees, will bring the prime cost of the Siemens-Martin steel ingots to about £7 10s. per ton, which is precisely the same as the prime cost of Bessemer steel ingots made from hematite pig iron in this country.

The Siemens-Martin process seems to have a vast importance for the ironmasters of many localities. It is applicable to the conversion of old materials (wrought iron and steel), it can utilize the waste and offal of all other processes of steel manufacture, it is not limited to gray or highly carburized pig iron, and it can for all these reasons be introduced into localities which have hitherto been in an unfavourable position for the production of steel. The question naturally arises how this new process will affect the progress of the Bessemer process, of which it seems to be a rival. In my opinion the only influence which the Siemens-Martin process can have upon the Bessemer steel trade will be to stimulate and assist the latter, and to widen the sphere of its application. The two processes, working with two different classes of raw materials, can never come into direct rivalry. Wherever gray pig iron can be had of sufficient purity for direct conversion the Bessemer process will be the most advantageous, and, indeed, the only suitable mode of steel manufacture; but in all cases where the raw material is wrought iron, white pig iron, or pig iron which must be freed from its impurities by puddling before it can serve as a material for steel manufacture, the Siemens-Martin process will find its place. By working up the waste and offal of the Bessemer steelworks, the crop ends of steel rails, and similar material, the new process will assist in cheapening the prime cost of Bessemer steel, in which the waste plays an important part.

The Siemens-Martin process, although it is not capable of employing the inferior kinds of pig iron for the manufacture of steel direct, is a process of steel manufacture applicable to the inferior classes of iron. It seems destined, therefore, to render a most important service to all those great centres of an old established iron manufacture, the future existence of which has been endangered by the irresistible competition of the Bessemer process, which itself was inapplicable to the raw materials available in those localities.

The new process will, therefore, render another important service to the Bessemer process, and to steel manufacture in general, by introducing steel manufacture into localities which have been hitherto debarred from it by unfavourable natural conditions. This will, to a great extent, destroy the great and organized opposition which has been raised against the general introduction of steel instead of iron for engineering purposes, and will thereby remove one of the most powerful drawbacks now hampering the spread and progress of steel manufacture in this country.

60. *Another New Steel.*—"Of late," says a writer in the Oct. number of the 'Practical Mechanic's Journal,' "we have heard of several new processes for producing steel, but of the practical value of any of them extremely little information is known;

and without being able, as yet, to say exactly in what the process of manufacture consists, we are able to speak of the high character of a certain alloy which has been produced in Glasgow by Mr. J. P. Smith, C.E, the Secretary to the Institution of Engineers in Scotland. This alloy has now been used for a variety of purposes, producing bells of various sizes, of extremely clear and perfect tone; but it has, moreover, shown unheard-of durability as a metal for cutting tools, more especially when used for turning and planing metals. It has been tried in several works—Messrs. Napier of Govan, the Anderson Foundry Co., and elsewhere—in Glasgow, where cast-iron was cut with it at the rate of 60 feet per minute. This, however, was an early result; and during the last month it has been tested against the best tool steel. In the experiments the rate of cutting was commenced, we believe, at 50, whence it was increased to 75, and then to 100 feet per minute; and a few days since Mr. Smith informed us that he had just heard from the Darlington Engine Co. that 200 ft. per minute on Bessemer steel had been reached, with the edge of the tool remaining quite sharp and unworn. A Bessemer steel piston-rod has been turned from end to end at this rate, whereas when an ordinary tool was used a few turns of the lathe rubbed the cutting edge so blunt as to require re-grinding. Mr. Smith's patents are not yet complete; we of course cannot do otherwise than approve of his reticence, as it would be most unwise for him, until his specification is filed, to disclose his method of production.

We do know, however, that it consists in adding certain substances to molten cast-iron; these are added, we believe, but a few moments prior to the metal being cast, and their addition has the effect of eliminating the silicon in large yellow lumps, some of which we have seen—the silicon being probably eliminated in the state of silicic acid ($Si O^3$),—whilst the carbon is separated in the state of extremely thin, but often large, graphitic plates.

The metal is strictly a cast metal—that is to say, it cannot be forged; and indeed the first samples were, we believe, extremely brittle: this defect, however, Mr. Smith has now overcome, and he uses it in the form of short bars, which are held in special and ingeniously constructed tool-holders, which are again fixed in the slide-rest in the ordinary manner. The retaining power of the holder consists in the grip produced by two wedge surfaces abutting against each other, not in alternate directions, but the incline of both the tool and that of the wedge being both in the same direction, that is downwards; so that by this adaptation the tool can at once be set up to any height, without the least chance of the pressure of the cut forcing it downwards—the pressure of the cut, indeed, tightens the tool by forcing the two wedge surfaces firmer together in the socket of the holder. The material is capable of receiving the most delicate degrees of temper, and when it is required to be very hard is cast in chills of suitable shape. The specimens we have examined exhibit the most perfect homogeneity, and in some of the fractures the crystals are so small as to be scarcely visible under an ordinary pocket microscope.

Another peculiar and very valuable discovery which Mr. Smith's experiments have developed is the production of a bar of metal of various qualities; that is to say, Mr. Smith has shown how to produce a bar of metal which shall be common cast-iron for any part of its thickness, and coated all over, or at one or more sides, with any required thickness of steel. For instance, if we take the case of a locomotive engine motion bar, it can be made with as thick or as thin a coating of steel on the wearing side as desired, and yet perfectly united and thoroughly in one piece with the cast iron below.

Mr. Smith has also cast projectiles with a very hard steel punching front and a soft rear, his object being to produce shot that will not easily break when fired against armour plates or stone forts, but which, on account of the great hardness of their striking ends, will possess great punching endurance. It is extremely curious and interesting to examine the fractures of such compound castings; the junction of the two metals does not take place gradually, as we might expect, but a perfectly straight, even, and true line marks the boundary of the two conditions of the metal. The processes we have alluded to are only in the early stages of their development, but their value cannot be questioned, and certainly they mark another era in the vast strides of metallurgic science and practice which are now taking place. We are most truly living in a day when iron metallurgy is in a most metamorphic state.

Mr. Smith's tool steel is, we understand, in the market, but in limited quantities only as yet, and we hear that it is getting into demand.—V. D."

61. *Heaton's Patent Steel-Converting Process.*—We take the following paper from the 'Engineer' of Oct. 23d, 1868. "An age—never dreamt of by either mythology or geology, one neither of stone, nor of bronze, nor yet of iron, which has been its precursor, and which it is destined to succeed—one richer in material benefits and results than even the 'Golden Age,' is, without doubt, about to dawn upon us—the age of steel. It would be too much, perhaps, to say that within half-a-century wrought iron will be a thing of the past, the glories of Lowmoor, of Bowling, of Backbarrow, of Sweden, of old sable Russia, and of South Staffordshire dimmed or forgotten; but we may safely and with sobriety say, that within half that time articles of all sorts, sizes, and kinds—the most diverse and the most important—will no longer be fabricated as at present of wrought-iron, but of steel. The age of steel will have then set in, and the use of wrought iron will be exceptional, and by choice only, occasional. The immediate forerunner of this great manufacturing revolution and *æon* will be the reduction of the market price of steel for nearly all purposes, but those of cutting tools and the like, down to that now current for wrought iron of good quality. As the age shall advance we have no doubt even that that will be much lessened, and it is not a wild prediction to say that probably before the middle of the next century fine steel will be obtainable at a price per ton much inferior to that now paid for common merchant bar iron. Our grounds for this assertion are simple and plain. Steel-making then will cost less than wrought iron making does now, and wrought iron making cannot follow in the track *passibus equis*, for the vast improvements in the economization of fuel, and in the adaptation of small coal and other inferior fuels, yet to be fully realised and diffused over the world by the employment of the gas furnace and the regenerative system, equally apply both to wrought iron and to steel; while with the latter will remain the permanent advantages of less waste in manufacture, less labour in the processes of conversion, and a smaller outlay for plant.

Besides the older known steel-making processes—such as those by cementation, by puddling, that of Styria and parts of Westphalia by means of the refinery hearth, and those of Parry Uchatius and of Martin, nearly all of which are still in operation,—there are now employed in steel-making the Bessemer process, the Siemens, and the Martin-Siemens methods—the first upon a very great scale and in many countries, and the last upon a scale sufficient to warrant the great extensions which are said to be contemplated for it in the north of England.

But superadded to all these is that process which we are now about to describe and offer some remarks upon, namely, the Heaton patent conversion process, which, although at work for many months past in one locality—the Langley Mill Works, in the Erewash valley, near Nottingham—upon a manufacturing scale, and with complete success, both metallurgic and mercantile, is only just beginning to emerge from the obscurity in which it has been so far kept, through circumstances, we believe, principally, if not wholly, financial. Should the facts which have been laid before us as to this process—and which it is our privilege to be the first to lay publicly before the world of metallurgic manufacture—prove to be well grounded and exact (and from the names they come to us vouched by, we doubt not they are unimpeachable), we may, even at this early stage, avow our conviction that Heaton's is destined to become the great steel-making process of the future, and that even Bessemer's—which, while no one believed in it twelve years ago, few would now be disposed to say is *not* to be the process of the future—will not, in our judgment, after the expiration of his patent, receive at all those exclusive extensions that its chief advocates, paid or unpaid, imagine; possibly may even be destined ultimately, and after existing interests and plants shall have got worked out, to give place to this process of Heaton's.

Our anticipations are, in fact, that two great and quite distinct steel-making methods will constitute the processes of the future, reserving, of course, for various specially circumstanced localities various other methods, which may to the end of the chapter prove the best attainable by *them*. These leading processes, it appears to us, will be characterized by dealing with wholly different raw materials. The one will be the Siemens-Martin process, or some improvements upon it, which shall deal with the malleable or wrought iron already existing in the world, and as it gradually gets thrown out of use by wear, &c., and consigned to the 'scrap heap,' or becomes old iron, shall work it up again, and cause it to reappear in the form of steel. This will be the process, we believe, that in the end every great line of railway existing in the world will adopt as part of its repairing plant, and which shall enable it at cost price gradually to work up all its old rails and old iron of every other sort into steel rails, and so forth. The other process will deal, not with malleable, but with crude or pig-iron, as the Bessemer process does partially now, and this, we believe, will prove to be the Heaton process. Our reasons for this conclusion will be more fully found further on, but one paramount reason we may as well enunciate at once. Out of some hundreds of varied 'makes' of pig-iron now produced in England, Scotland, Wales, Belgium, and almost all of Germany, the Bessemer process is capable of producing marketable steel from probably not more than a dozen or two; and for this simple reason, that the Bessemer air-refining process is powerless to eliminate wholly, or even to a tolerably low point, the phosphorus and sulphur which any pig-iron submitted to it may contain—and hence practically has been and is limited to using, as its raw material, pig-iron such as the Barrow hematite iron, &c., which is practically phosphorus and sulphur *free*. On the other hand, it is no matter of speculation—or even of laboratory testing—but a fact *proved* upon the great manufacturing scale, and verified by the analyst, that Heaton's patent process is competent to make remarkably fine steel and 'steel iron' from the very worst and most sulphur and phosphorus-charged 'makes' of iron in Great Britain, and in a word, to make excellent marketable steel from any 'make' of pig iron that may be put into the Heaton converter.

We proceed to sketch the outlines of this patented process, and then to present to our readers the facts as to the results obtained from it, which have been put before us, and upon which we have grounded the opinions above given. Although all steel-making processes are chemical in their methods, they all depend upon very indirect chemical reactions, aided by constant mechanical manipulations, except Bessemer's. That, as is well known, consists in the direct oxidation of the silicon, carbon, and bases of the alkalies and earths, if present, by the stream of air through the molten cast iron. Heaton's process is also a *direct* chemical reaction, but consists in the application to the molten crude iron of a far more powerful and searching agent than heated air—namely, the *nascent oxygen* developed at the moment of contact between the molten cast iron and such classes of salts, nitrates, &c., as yield oxygen under those conditions. The mere idea of decarburising crude iron by the use of nitrates is, we believe, by no means novel. Notices will be found in many old docimastic and chemical works, of the reactions produced by nitre upon red-hot iron. Where the iron, especially cast iron, is finely divided, even though cold, it is well-known to every firework maker that vivid deflagration takes place. Should the cast iron in its fluid state be brought into direct contact with nitre, *i. e.*, nitrate of potass—although we are not aware that the experiment has ever been made upon a large scale—it might be inferred that the deflagration of the silicon and carbon would be so rapid as to produce explosion.

Nitrate of soda, however, a salt much more plentifully to be obtained than nitre, is the nitrate employed by Mr. Heaton. It is not decomposed in presence of fluid cast iron with the same intense energy that nitre is, but still would prove an agent for the burning out of the silicon, carbon, sulphur, phosphorus, &c., more or less unmanageable, were it not for the extremely simple but beautifully effective apparatus invented for its application, and which constitutes, in fact, the essence of Mr. Heaton's patents.

We shall not occupy space here by repeating the specifications of his patents—No. 798, of 1866, and No. 1295, of 1867, with their respective disclaimers of August, 1868. These our readers more immediately interested can consult for themselves. Instead, we give the following outline of the process itself, and its results:—

Pig or other cast iron, whatever be its quality, is melted in a common iron foundry cupola with coke fuel. The liquid iron in known mass—usually from a ton at a time to perhaps hereafter as much as five tons—is tapped out into an ordinary crane ladle, and the latter is swung round to the side of the converter. The converter consists of a tall cylinder of boiler plate, open at bottom, which is supported at a certain height above the floor beneath it. This cylinder is lined with firebrick, and above its upper part rises a cone and a funnel of plate iron, freely open at top. To the bottom of the cylinder any number in succession of short nearly cylindrical pots lined with brick and fire-clay, and in form very like crane ladles, are adjustable by simple means. Into the bottom of one of these pots a known weight of crude nitrate of soda of commerce is put; the surface of the gross powder is levelled and covered by a pretty thick circular plate of cast iron, perforated with many holes, which lies by its own weight upon the top of the nitrate. One of these pots thus prepared having been adjusted to the bottom of the cylinder, the converter is now ready for use. At one side of the cylinder described, is a sort of hopper funnel, covered by a loosely hinged flap of boiler plate. This plate is raised, and the ladle full of liquid cast iron is at once poured into the converter, and so descends right down upon the top of the cold cast iron perforated plate. The plate does not float up nor become displaced, nor does any action become apparent for some minutes, while the plate is rapidly acquiring heat from the fluid iron above it, and the nitrate getting heated by contact with it. What follows we may describe in Professor Miller's own words, from his personal observation and report:— 'In about two minutes a reaction commenced; at first a moderate quantity of brown nitrous fumes escaped; these were followed by copious blackish, then grey, then whitish fumes, produced by the escape of steam, carrying with it, in suspension, a portion of the flux. After the lapse of five or six minutes deflagration occurred, attended with a roaring noise and a burst of a brilliant yellow flame from the top of the chimney. This lasted for about a minute and a-half, and then subsided as rapidly as it commenced. When all had become tranquil the converter was detached from the chimney, and its contents were emptied upon the iron pavement of the foundry. These consisted of 'crude steel' and of slag. The 'crude steel' was in a pasty state, and the slag fluid; the cast iron perforated plate had become melted up and incorporated with the charge of molten metal.'

This first product of the Heaton process, which he denominates 'crude steel,' is in reality malleable iron of the very purest and finest quality. The broken up lumps of this material, direct from the converter, only require, after they have been 'patted' or squeezed under the 'shingling hammer' to condense their spongy texture, to be heated again in a common 'balling furnace,' and rolled at once into bars, or forged or rolled into any desirable form. In this state the material is very unhappily called by the inventor 'steel iron.' It has but little pretensions to be called so; it scarcely perceptibly hardens in water. What it really consists of is crystallo-fibrous wrought iron, almost absolutely sulphur and phosphorus free, of great strength and toughness, and for every structural purpose equal to the renowned wrought iron produced at Lowmoor and Bowling works. It welds perfectly; it is tough both hot and cold, neither red-short nor cold-short, and forges beautifully at both the test temperatures for iron—a low red, and a clear yellow heat.

So good is the material as it comes straight from the converter that 'piling and balling'—*i. e.*, rolling a second or third time, and each time heating over again, as commonly practised with the best wrought iron produced by the puddling process—is here found not only needless, but useless. The 'steel iron' is as tough, strong, fibrous, and good at the first passage through the rolls (with a given amount of reduction in size) as it can be made by any amount of re-heating and re-rolling down from the same sized balls, to bars of the same size. . . . .

The 'steel-iron,' to which product we had advanced, is itself of course a highly valuable material ready for market. From this material it is, that Mr. Heaton makes his cast-steel, *i. e.*, before it has been subjected to any rolling, while in the state merely of 'crude steel,' patted into cakes by the shingling hammer. These cakes are broken up, put into ordinary clay melting pots of the usual size, holding about 60 lb. each. To each 100 lb. of the material, about 2½ lb. or 3 lb. of spiegeleisen, or its equivalent of oxide of manganese and a little charcoal, are added, and the whole is fused and cast into the ordinary ingots of iron. It is now excellent cast-steel, and when the ingots have been tilted in the usual manner, cast-steel bars are produced fit for any uses to which steel is at present applied. Such is the Heaton process; its simplicity and directness need no comment to those acquainted with ordinary iron and steel making.

On the 10th of last July, Dr. Miller, V. P. Roy. Soc., Professor of Chemistry at King's College, and Assayer to the Mint, and Mr. Robert Mallet, C.E., attended at Langley Mills, by desire of the owners of the patent, and watched step by step the process of converting Cleveland and Northamptonshire pig irons into the above described materials.

The following extracts from the official preliminary report of Dr. Miller will convey to the skilled iron and steel maker or metallurgist conclusive and striking evidence of the effect and value of this process.

'On that occasion (says Dr. Miller) 6½ cwt. of Clay-lane forge pig, No. 4, was charged into a hot cupola which contained no other iron, and immediately afterward 6¼ cwt. of Stanton forge pig, No. 4, was added, and the whole, when melted, was drawn off into a ladle, from which it was transferred to the converter. I have made an examination of the following examples:—No. 4, crude cupola pig; No. 7, hammered crude steel; No. 8, rolled steely iron; No. 5, slag from the converter. I shall first give the results of my analysis of the three samples of metal:—

	Cupola. Pig (4).	Crude Steel (7).	Bar Steel (8).
Carbon, . . .	2·830	1·800	0·993
Silicon, with a little titanium,	2·950	0·266	0·149
Sulphur, . . .	0·113	0·018	traces
Phosphorus, . . .	1·455	0·298	0·292
Arsenic, . . .	0·041	0·039	0·024
Manganese, . . .	0·318	0·090	0·088
Calcium, . . .	—	0·319	0·310
Sodium, . . .	—	0·144	traces
Iron (by difference), . .	92·293	97·026	98·144
	100·000	100·000	100·000

It will be obvious from a comparison of these results that the reaction with the nitrate of soda has removed a large proportion of the carbon, silicon, and phosphorus, as well as most of the sulphur. The quantity of phosphorus (0·298 per cent.) retained by the sample of crude steel from the converter which I analysed is obviously not such as to injure the quality.

The bar iron (steel iron) was in our presence subjected to many severe tests. It was bent and hammered sharply round, without cracking. It was forged and subjected to a similar trial, both at a cherry-red heat and at a clear yellow heat, without cracking; it also welded satisfactorily.

The removal of the silicon is also a marked result of the action of the nitrate.

It is obvious that the practical point to be attended to is to procure results which *shall be uniform*, so as to give steel of uniform quality when pig of similar composition is subjected to the process. The experiments of Mr. Kirkaldy on the tensile strength of various specimens afford strong evidence that such uniformity is attainable.

The chemical principle appears to be good, and the mode of attaining the result is both simple and rapid. The nitric acid of the nitrate in this operation imparts oxygen to the impurities always present in cast-iron, converting them into compounds which combine with the sodium, and these are removed with the sodium in the slag. This action of the sodium is one of the peculiar features of Heaton's process, and gives it an advantage over the oxidizing methods in common use.

I have not thought it necessary to make a complete analysis of the slag, but have determined the quantity of sand, silica, phosphoric and sulphuric acid, as well as the amount of iron which it contains. It was less soluble in water than I had been led to expect, and it has not deliquesced though left in a paper parcel.

I found that of 100 parts of the finely powdered slag, 11·9 were soluble in water. The following was the result of my analysis:—Sand, 47·3; silica in combination, 6·1; phosphoric acid, 7·8; sulphuric acid, 1·1; iron (a good deal of it as metal), 12·6; soda and lime, 26·1; total 100·0.

This result shows that a large proportion of phosphorus is extracted by the oxidizing influence of the nitrate, and that a certain amount of the iron is mechanically diffused through the slag.

The proportion of slag to the yield of crude steel iron was not ascertained by direct experiment; but, calculating from the materials employed, its maximum amount could not have exceeded 23 per cent. of the weight of the charge of molten metal. Consequently, the 12·6 per cent. of iron in the slag would not be more than 3 per cent. of the iron operated on.

(Signed), WM. ALLEN MILLER.'

Within the brief space now remaining to us we do not know that we can offer any more pertinent or condensed commentary upon these important results, as thus proved before the balance of the analyst, than by printing entire the preliminary report of Mr. Robert Mallet, addressed as a private and confidential document to the owner of Heaton's patents, which, with all other information necessary, has been placed at our disposal.

Private and Confidential.

Offices—7, Westminster Chambers,
Victoria Street, London, S.W.,
12th September, 1867.

GENTLEMEN,—

You call upon me to express to you in this preliminary form my opinion upon the reality and commercial value of Heaton's patent process for the production of various qualities of wrought iron and of steel, or especially of those which Mr. Heaton denominates 'steel iron,' and of his 'tilted cast steel.'

I have at your desire twice visited the works at Langley Mills, where for some time this system has been in operation upon a manufacturing scale.

This process for converting crude pig iron into wrought iron and into steel, by the employment of nitrate of soda, in Heaton's patent converter, has been repeated at Langley Mills many times in my presence. I have examined minutely into its details as applicable in practice on a large scale, and its results, and I have also considered the chemical researches made as to the materials used and products obtained by Professor Miller, of King's College; and I have been present at experiments conducted by Mr. David Kirkaldy, at his testing works, Southwark, as to the physical qualities of the products which were obtained by this process in my own presence at Langley Mills. In view of all the facts that have come before me, I can affirm the following as truths established beyond question:—

1st. That Heaton's patent process of conversion by means of nitrate of soda is at all points in perfect accord with metallurgic theory. That it can be conducted upon the great scale with perfect safety, uniformity, and facility, and that it yields products of very high commercial value.

2d. That in point of manufacturing economy or cost, it can compete with advantage against every other known process for the production of wrought iron and steel from pig iron.

3d. Amongst its strong points, however, apart from and over and above any mere economy in the cost of production are these. It enables first-class wrought iron and excellent steel to be produced from coarse, low-priced brands of crude pig irons, rich in phosphorus and sulphur, from which no other known process, not even Bessemer's, enables steel of commercial value to be produced at all, nor wrought iron, except such as is more or less either 'cold-short' or 'red-short.' Thus wrought iron and cast steel of very high qualities have been produced in my presence from Cleveland and Northamptonshire pig irons, rich in phosphorus and sulphur, and every ironmaster, I presume, knows that first-class wrought iron has not previously been produced from pig iron of either of those districts, nor marketable steel from them at all.

Heaton's process presents, therefore, an almost measureless future field in extending the manufacture of high class wrought iron and of excellent steel into the Cleveland and other great iron districts, as yet precluded from the production of such materials by the inferior nature of their raw products. It admits of the steel manufacture also being extended into districts and countries where fuel is so scarce and dear that it is otherwise impossible.

I cannot, in this brief communication, point out the prospect which the employment of this system presents of greatly diminishing the existing waste of material, fuel, time, and wages, in the puddling process, and of lessening difficulties in relation to labour questions which beset that process, injuriously to the British iron trade. Nor can I adequately point out the large reduction in the original outlay for plant, which this system admits of, as compared with any other, for equal annual output of iron and steel.

Dr. Miller has proved incontrovertibly that the Heaton process does eliminate from the crude pig iron almost the whole of the phosphorus and sulphur, the trace remaining being unobjectionable in the wrought iron and steel produced, even when these have been made from the pig irons known to be the richest in these injurious constituents of any make in Great Britain.

The wrought iron made in my presence from Cleveland and Northampton pigs, and tested for tensile resistance also before me, bore a rupturing strain of twenty-three tons per square inch, and an elongation of nearly one-fourth of the original unit in length. It is therefore iron of great strength and toughness, and yet probably by no means the very best that this process is capable of producing hereafter. It possesses those qualities which best fit iron for artillery, armour plates, and iron ships or boilers.

The tilted cast steel, also made in my presence, from the very same pig irons as the above, bore a tensile strain at rupture of about forty-two tons per square inch, with an elongation exceeding one-twelfth of the unit of length. It is therefore a remarkably tough and fine quality of steel, well suited for rails, shipbuilding, and all other structural uses. In a word, steel suited for any purpose known to the arts, can be produced by this system from very inferior brands of pig iron, from such as by no other known process could serviceable steel be made at all.

I must not, however, further extend my letter; I conclude therefore by expressing my decided opinion that Heaton's patents only need the energy and capital requisite to develop all that they are capable of upon an adequate scale, to prove one of those metallurgic advances which leave their mark indelibly upon great national industries, like that of iron in Great Britain, and to richly reward those who are its pioneers and who shall join its progress.

I am, Gentlemen,
Faithfully your obedient servant,
ROBERT MALLET, F.R.S., M.A., M.I.C.E.

To the Proprietors of
Heaton's patents.

Mr. Kirkaldy has been engaged in making a large series of experiments upon iron and steel produced by this process from almost every characteristic 'make' of pig iron in Great Britain. We have not space here for the tables in which these important results are embodied. Meanwhile we leave with our readers this one parting remark:—Here is a process by which two results may be, and no doubt will be, realized, each in itself of an import and magnitude worthy of even national attention:—1st, by this process the vast deposits of, so far, nearly useless iron ores of Northamptonshire—useless because no one could point out any feasible or paying process to make them into good cast or wrought iron—can be brought into play remuneratively, and add to our national resources by making Northamptonshire a second Cleveland; 2d, The Cleveland pig iron, with its vast, exhaustless, and cheap supply of raw material, can now join the ranks of steel-producing districts—from which it has been hitherto excluded—as well as all others in Great Britain but a few, because neither the Bessemer nor any other known steel-making process could deal with iron so loaded with sulphur, phosphorus, and other impurities as the Cleveland iron is well known to be."

62. *Wolfram Steel.*—"If there is a question," says a writer in the 'Scientific Review' of August 1st, 1868, "which deserves as much as any other to be solved without delay in connection with the iron manufacture of this country, it is certainly that of the influence of Wolfram or Tungsten upon the making of steel. We say expressly 'Wolfram or Tungsten'—Tungsten is the metal itself, Wolfram is a compound of Tungstic acid with oxide of iron and manganese. Now, the first point we would desire to see solved is this:—Does the metal tungsten unite with the iron when crude wolfram is used in certain proportions, or does all the tungstic acid of this mineral find its way into the slag, whilst a little of the manganese is absorbed by the steel produced, giving to it the desirable qualities?

Considerable quantities of wolfram ore have been got in Cornwall, and large deposits of this mineral are met with in Germany. Since the year 1863, attention has been called to it as an invaluable agent in steel making, and we find that at the Belgian works of Messrs. Cockerill & Co. some two and a-half tons of wolfram ore are used per month.

That which is already known of the chemical properties of the metal tungsten would lead us to believe that, alloyed in small quantities with iron or steel, it would undoubtedly exert quite as much influence as manganese, the remarkable properties of which, in iron making, are, at present, universally recognised. Although the price of wolfram is somewhat high, on account of its comparative scarcity in nature, there is, nevertheless, abundance to be had, and Messrs. Keiffenheim, of Newcastle-on-Tyne, would doubtless be able to supply much more than our ironmasters are likely to consume for several years to come.

Let us see, however, what wolfram is said to have done for steel on the continent by those who have submitted the subject to special investigation. Every one knows that puddled steel, as generally manufactured, is not equal in quality to cast-steel; nevertheless it is extensively used in consequence of its comparative cheapness—for instance, in the manufacture of locomotive and waggon tires—it is said, however, to be four or five times less durable than cast-steel. Ordinary puddled steel is also less well adapted to the manufacture of files, saws, swords, edge tools, &c., since it does not possess the homogeneous texture, the tenacity, nor the hardness of cast-steel.

Now it is asserted that, by the use of wolfram, these superior properties can be imparted to puddled steel, so that its grain becomes as clear and fine as that of cast-steel; and this by the mere addition of one to seven per cent., according to circumstances, of *an alloy of iron manganese and tungsten,* directly smelted from the wolfram ore for this purpose, or even by adding the crude ore in certain proportions to the iron in the puddling furnace.

For wheel tires, two to three per cent. of tungsten alloy has been found to answer best in France; for files, saws, &c., two and a-half to four per cent. is used; and for dies, punches, borers, &c., four to seven and a-half per cent. The theory of the action of tungsten upon steel is, of course, much more obscure than that of manganese, which can scarcely yet be said to be entirely explained.

If used for iron instead of steel, the proportion of tungsten alloy must never exceed two and a-half per cent. of the entire metal, otherwise its hardness will be increased to a prejudicial extent; for cast-iron rollers, however, it is recommended to use at least five per cent.

In making experiments in England upon the use of tungsten in these circumstances, we recommend that the alloy produced directly from the wolfram ore should be tried. We have little faith in the addition of the crude ore to the contents of the puddling furnace. Attention should also be paid by submitting the various products to analysis, to the relative influence of the manganese and the tungsten on the metal produced."

63. *Alloys and Quasi Alloys.*—"We have noticed from time to time," says a writer in the 'Mechanic's Magazine,' "various mixtures or alloys of metals which have been brought forward as likely to be useful in manufacture. Some of them no doubt true alloys, but most of them simple mechanical mixtures. There seems to be a good deal of confusion in the notions of most people as to what is an alloy and what is not. To many a simple mixture of metals is an alloy, whether there be any chemical combination or not, or rather whether there be a perfect chemical combination or not. Any two metals that will enter into combination when melted together will certainly unite to a certain extent whether they be melted together in proper proportions or not. But then, if one of the constituents predominate over the other, the excess will remain in a free state. We noticed two of these so-called alloys of lead and tin lately, where the mixture had to be continually stirred till it was cool, to prevent the precipitation of the free lead on account of its greater specific gravity. No doubt these were alloys to a certain extent, and in both of the mixtures the alloys may or may not be the same, according to circumstances, tin being capable of uniting with some other metals in four different proportions, but only in two with lead.

It is surprising how few really valuable alloys we possess; one may count nearly all of them on the fingers, so few alloys are malleable. For castings many others can be used, but they must be true alloys, otherwise the free metal will tend to separate itself from the other portion of the mixture, and so spoil the casting; we have seen this result frequently, and especially with lead and zinc. Tin is a metal which will alloy with almost every other metal, and would indeed be a valuable constituent of various alloys if it were not for the property it has of making nearly all the compounds it enters into crystalline—consequently brittle. The only exception that we at the present can call to mind, are the alloys of tin and lead. We do not consider gun metal a true alloy of copper and tin, but simply an alloy of tin and copper in an excess of copper; but this is the most valuable quasi alloy we possess. The normal alloy of copper and tin is very brittle, the proportions of each are nearly equal, the copper being a little in excess of the tin, tin being tetratomic and copper biatomic. When electro-plating was discovered, brass and copper were the principal metals used as the bases of the articles which were manufactured to be plated, these being in use for the old close plating process.

But a new basis was desired more nearly the colour of silver with which the articles were to be covered. Naturally, attention was directed to the alloy called German silver, which already existed, but was not much known or used. This is a triple alloy of zinc, copper, and nickel, and the proportions for the best qualities are 50 copper, 30 zinc, and 20 nickel. For a true alloy, if nickel be biatomic, the proportions 50 copper, 26 zinc, and 24 nickel, would be nearer the true equivalent ratios. But if nickel be tetratomic, as it is now believed by some, the proportions will be 34 copper, 35 zinc, and 31 nickel. Very little German silver in commerce is really a true alloy, and most of it contains but a small proportion of nickel; in fact, much of the metal going by that name is little better than highly speltered brass. The reason of this is that nickel is comparatively a dear metal, the pure being 6s. or 7s. a-pound, and the crude 3s. or 4s.; so that an alloy using even the crude metal cannot be produced under 2s. 6d. a-pound, if nickel be biatomic: but what is called good German silver can be bought for 1s. 5d. a-pound. For electro-deposit the true alloy is much superior to the metal found in commerce, a sound deposit is much more easily obtained upon it, and it is much more easily cleaned; but labour is cheaper than nickel.

Many fancy names have been given to this alloy, such as nickel silver, electra, &c. There can be no doubt that true alloys are real chemical combinations, for the alloy of two metals seldom exhibit the properties of the two metals composing it, but have distinctly new properties. Alloys may be harder than either of the metals composing it, and may be denser than the mean of the densities of the two metals; moreover, its melting point may be higher or lower than either of them. Much has been done in finding out good alloys for various manufacturing purposes, but it has been done by mere blind groping; but let an alloy be considered to be a chemical compound, then it will be possible to see theoretically what combinations may or may not be attempted with any likelihood of producing a true alloy. Not that its properties can be predetermined, but, whatever these properties may be, it will be known that they will be constant, which is not the case with our present alloys; scarcely two meltings have precisely the same colour or hardness, or, in fact, any of their properties."

64. *Alloys—Review of a Lecture by Dr. A. Matthiesen, F.R.S.*—"Up to a very recent period," says the 'Scientific American,' "the knowledge of alloys was confined to the physical characters of a very few of the possible combinations of different metals, and the chief contributions to the general stock of information in relation to the subject were the result of unsystematic and desultory experiment. Nothing like generalization was reached, and it was impossible, from the knowledge of the properties of an alloy containing definite proportions of two or more elements, to predict, even approximately, the properties of a combination of the same elements in varied proportions. The great importance of the subject has, however, stimulated investigation, until at last something definite has been reached; and although as yet the smallest possible portion of the field has been worked over, an approach has been made to the proper method of working, and, as a consequence, we shall no doubt witness results equal in importance to other modern chemical discoveries which have created new branches of art and manufacture, and revolutionized many of the old.

The researches of Dr. Matthiesen, the results of which he submitted to the Royal Society, in a lecture delivered at the Royal Institution, on the evening of March 20, are of great interest. The lecture was illustrated by many beautiful and ingenious experiments, and undoubtedly ranks among the most valuable recent contributions to science.

Dr. Matthiesen's definition of the term alloy is, *a solidified solution of one metal in another.* By solidified solution is meant a solution of substances which have become solid, *e. g.*, glass obtained by fusing together different silicates, and allowing the homogeneous liquid to solidify. The most important characteristic of a solidified solution is its homogeneousness. The most powerful microscope should not reveal its components.

As an illustration of the difference between chemical combination and the solution of metal in metal, the lecturer plunged a rod of gold and another of copper into separate portions of molten tin. The gold dissolved rapidly in the tin, but the copper rod, though previously tinned to insure perfect contact between the two metals, remained undissolved. To properly appreciate this experiment it should be borne in mind that the fusing points of gold and copper are nearly the same (gold, 2,016° F., copper, 1,990° F.), and much higher than the fusing point of tin, which is 442° F.

This experiment was followed by others equally instructive and interesting, calculated to show the solvent power of fused substances.

Dr. Matthiessen proceeded to classify the phenomena attending the solution of metals in metals, as follows:—

I. The solid metal dissolves quickly in the melted one with evolution of heat. Examples: gold in tin just melted; sodium in mercury.

II. The solid metal dissolves quickly without evolution of heat. Example: lead in tin just melted.

III. The solid metal dissolves slowly. Example: copper in tin just melted.

IV. Only a partial alloy is formed, or in other words, each metal dissolves to only a limited extent in the other. Examples: lead and zinc, lead dissolving only 1·6 per cent. zinc, and zinc only 1·2 per cent. lead; bismuth and zinc, bismuth dissolving only 8·14 per cent. zinc, and zinc only 2·4 per cent. bismuth.

He also divided metals considered as components of alloys into two classes:—

Class A.—Those metals which impart to their alloys certain physical properties (such as conducting power for electricity) in the proportion in which they themselves exist in the alloys. The metals belonging to this class are lead, tin, zinc, and cadmium.

Class B.—Those metals which do not impart to their alloys such physical properties in the proportion in which they themselves exist in the alloys. All the metals, except the four named as belonging to Class A, probably come under this head.

He further separated alloys into three groups:—

a. Those made of the metals belonging to Class A with one another.

b. Those made of the metals belonging to Class A with those of Class B.

c. Those made of the metals belonging to Class B with one another.

The Doctor showed by a series of conclusive and remarkably ingenious experiments that in alloys specific gravity, specific heat, and expansion due to heat, are in all cases approximately equivalent to those possessed by the component metals; and that fusibility and some other properties are never equivalent.

Another class of physical properties are those which in some cases are, and in others are not, imparted to alloys in the ratio in which they are possessed by the component metals. This class of properties includes conducting power for heat and electricity, sonorousness, elasticity, and tenacity. The separation of metals into two classes (A and B) is founded on a consideration of the latter class of properties.

Alloys made of the metals belonging to Class A only (lead, tin, zinc, and cadmium) conduct electricity in the ratio of the relative volumes of the component metals. The conducting powers of a series of such alloys, say those of tin with zinc, may therefore be represented graphically by straight lines.

In alloys made of the metals belonging to Class A with those of Class B, the conducting power of the B metal undergoes a marked change, while that of the A metal remains unaltered. The conducting powers of a series of such alloys, say those of copper with tin, is represented graphically by a bent line approximating to the form of the Letter L. There is a rapid decrement on the side beginning with the metal belonging to Class B (copper in the case referred to) until a certain point is reached, when the line turns and goes straight to the metal belonging to Class A (tin in the case cited).

In alloys made of the metals belonging to Class B only, the conducting power of each component undergoes a marked change, hence such alloys do not conduct electricity or heat in the ratio of the relative volumes of their component metals. The curve which represents graphically the conducting powers of a series of such alloys, say those of silver with gold, has approximately the form of the letter U. There is a rapid decrement on each side of the curve, and the turning points are connected by a line nearly straight.

The turning points of the curves representing the conducting powers of series of alloys of the second and third groups, necessarily correspond to certain alloys in which the alteration of the physical properties of the components is most strikingly exemplified. It is a fact of no small importance, therefore, that these turning points represent approximately the composition of some of the most valuable alloys which are employed for technical purposes. Thus, gun metal, containing 10 per cent. tin, is marked on the copper-tin curve, the turning point of which corresponds to 12·5 per cent. tin. Brass, containing 28 per cent. zinc, is marked on the copper-zinc curve, the turning point of which corresponds to 25 per cent. zinc. Twenty-two carat gold, alloyed with silver, is marked on the silver-gold curve, close to one of its turning points, and the same alloyed with copper, on a corresponding portion of the copper-gold curve. Again, a silver-platinum alloy, containing 33 per cent. of platinum, employed by the electrical standard committee for their unit-coil, and largely used by dentists for making springs for artificial teeth, is the alloy which forms the turning point of the silver-platinum curve.

Further experiments demonstrated the fact that alloys of Class B with those of Class A give a great increase of sonorousness.

The following experiments were made to test the tenacity of metals and alloys, with the annexed results. The tension was made by the use of a winch, and measured by a spring balance. The wires used were double, gauge No. 23:—

	Breaking strain for double wire.
Tin, ...	. under 7 lbs.
Lead, ...	. ,, 7 ,,
Gold, ...	. about 25 ,,
Copper, ...	. ,, 30 ,,
Silver, ...	. ,, 50 ,,
Platinum, . . .	. ,, 50 ,,
Iron, ...	. ,, 90 ,,
Tin-lead alloy, . . .	. under 7 ,,
Tin-copper alloy (12 per cent. copper),	. about 7 ,,

Copper-tin alloy (12 per cent. tin),	about 90 lbs.
Gold-copper alloy,	,, 75 ,,
Silver-platinum alloy,	,, 80 ,,
Steel,	above 200 ,,

These results show that the tenacity of metals belonging to Class B is greatly increased by alloying them with metals of the same class. By experiments with spirals of hard drawn wire of the same gauge, it was shown that elasticity follows the same law as tenacity.

The practical conclusion drawn from the facts illustrated by these experiments was, that when a new alloy is desired which shall possess some special physical property, an examination should first be made of the alloy indicated by the turning point of the curve which represents the conducting power of the two metals.

We consider these conclusions to be of the greatest importance, and venture to predict that through their application during the next decade many valuable discoveries will be made, and a new impulse given to the art of metallurgy."

65. *New Alloys of Lead and Tin.*—" According to some experiments made by Mr. Pilho, two kinds of pewter can be obtained, each of which contains less tin than the ordinary pewter of commerce; he states that these two new alloys are not acted upon by boiling vinegar or by salt water. The first contains 1 part of tin and 2·4 parts of lead. Its specific gravity is 9·4, and it melts at 320° Fahr. It is obtained by first melting the lead, and after skimming it, gradually adding the tin, and stirring the mixture constantly with a wooden rod after each addition, otherwise the lead would settle at the bottom of the crucible. The other consists of 1 part of tin, and 1·25 of lead. It is less malleable and more brittle than the former."—*Scientific Review.*

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DIVISION ELEVENTH.

RAILWAYS.

66. *Railways and their Management.*—The paper from which the following is extracted was read before the Society of Arts by

Mr. Robert Fairlie, C.E. "We now come to that which is no less important than all that has gone before—I mean the working of railways. We cannot recall the outlay of the past, but I firmly believe that even the most unfortunate railways can be redeemed by a wise and well-arranged system of working. I shall endeavour to show that revenues can be increased concurrent with a large reduction of expenses, and I would not be here this evening soliciting your attention unless I felt myself in a position to satisfy you how this can be done.

As to the revenue, I do not believe that railway managers, as a rule, trouble themselves to know the return derived from each train run as compared with the expense of the same. I would have a debtor and creditor account with every train despatched; showing on one side the whole of the expenses incidental to it, and on the other the total amount earned. The experience of the last 35 years provides us with very reliable figures of the cost of the train mileage, in regard of every description of expenditure; and every train that would show a deficit in balancing the account should be unhesitatingly abandoned, except in such special cases as do not affect the general question.

I illustrate this in detail by a reference to the published accounts of the London and North Western Railway Company, for the half-year ending June, 1866, which I have selected because it is comparatively low in the per-centage of working expenses, and almost the best paying of all our railways. The gross earnings are at a rate of about 5s. per train per mile for passengers; and for merchandise 6s. 3¾d. To give shareholders the return to which they are justly entitled from this class of investment, I consider that the gross earnings necessary for this purpose ought not to be less than 7s. 6d. per mile for passenger trains at 20 miles speed, and increasing in amount to 10s. for 30 miles; 14s. for 40 miles; 20s. for 50 miles; and 30s. for 60 miles. It is absurd for companies to make so little difference in their charge between high and low speeds as they do, knowing that whether in respect to the road, plant, or fuel, the cost increases in proportion to the velocity, and the charges should, therefore, be proportionate. I was much struck when looking over the London and Brighton Railway accounts, to find that the gross earnings were under 4s. 10d. per train per mile, although, of my own knowledge, I am aware that many of their express trains, to and from Brighton, consist of some 20 carriages, each containing about 20 passengers, whose fares (allowing 25 per cent. for season-ticket holders) must realize not less than about £3 per mile. It is clear, therefore, that the Brighton Company are running a large number of trains at a positive loss, else the average would not be so seriously reduced. If 4s. 10d. be a fair and remunerative rate (which it is not) no train should be run under that standard; and the maximum of £3 per train per mile is as much beyond what is necessary as the minimum is below it; the medium between the two to be arrived at, by an abandonment of all unpaying trains, would produce to the company a handsome accession to its revenue on the one hand, a permit of a large reduction in the charges to the public on the other. I may be told that the cutting off of the unremunerative trains would be an invasion of the public convenience; but the best test of this is the patronage bestowed on particular trains, and the neglect of others which consequently do not pay. I am not forgetful that many of those unremunerative trains have been run, some from a spirit of rivalry, and some from a fear of competition: but rivalry must disappear in an effort to restore prosperity, and competition has found its level. Besides, the public are not so unreasonable as to expect that companies are to carry them without a proper return; the interests of both are identical, and neither is advantaged by a condition of things which has resulted in so much loss and misfortune. The expenditure part of the question is equally of vital importance, and I beg now to call attention to the amazing folly of railway engineers in overweighting the trains with that unnecessary and cumbersome appendage, the tender. The average gross weight of passenger trains may be stated at 70 tons; the average weight of a tender is over 25 per cent. of that, and invariably is over 200 per cent. in excess of the whole paying portion of the load carried. Now, when we know that not only is the tender costly, unnecessary, and cumbersome, but that the load of fuel and water which it conveys for supplying the engine can be made available for increasing the power and efficiency of the engine itself, I ask, what is to be thought of the persistency in continuing such an improvident system? There are at this moment working with great success, on a Welsh railway, engines with no tender, and where the fuel and water are in the highest degree conducive to the increase of power, economy, and safety. In their case the weight is distributed equally upon a large number of wheels, thus increasing the adhesion upon the rails whilst the weight per wheel is proportionately reduced. These advantages must at once be apparent, and, I believe, will lead to an entire revolution in our locomotive arrangements; besides, the enormous economy which is effected in the maintenance of both engine and road is of the highest importance in the embarrassed condition of our railways. As respects the cost of tenders, and how they affect the dividends of railways, the following is given by way of illustration:—The London and North-Western Railway, which has the most uniform, and therefore the best paying, merchandise traffic of any line in the kingdom, shows by its balance-sheet, already quoted, 7,333,371 tons of goods and minerals carried during that half-year, being about 46,800 tons net for each working day; the tare of this tonnage would not be less than a like amount, giving the gross tonnage per day at about 93,600. The average gross weight of each train, exclusive of the locomotive and tender, may fairly be set down at 300 tons; therefore the number of trains per day would amount to 312, but from the fact, as stated in the balance-sheet, that the gross earnings of those trains per mile are under 6s. 4d., and taking the rate of freight at one penny per ton per mile, which it is believed is a correct average, we are able to estimate the paying load to each of those trains of 300 tons gross to be about seventy-six tons, or only 25 per cent., and thus we find that the number of trains per day must really be about 609, instead of 312. It is true that merchandise is composed of classes according to bulk and frailty, in many cases less than half-a-ton filling a wagon, and thus reducing the proportion of dead weight to paying load, but it is also true that in all such cases charges are made not only to pay for the full carrying weight of the wagon, but leaving ample margin to cover the risk of breakage in handling. The same balance-sheet shows that each net ton carried produces to the Company a sum of 4s. 7½d., which, at a penny per ton per mile, gives the average distance of each ton carried to be 55½ miles; we have, therefore, 609 engines and tenders running 55½ miles every working day. Following this reasoning, let us see how doing away with the tender affects the question. Taking the tender to equal the weight of two loaded wagons, giving a net result of ten tons, and there being 609 in motion every day, it follows that their equivalent in net paying load would be about 6,000 tons carried per day 55½ miles, which, at the same average rate of one penny per ton per mile, gives the amount earnable from this source at £1,387 10s. per day, and for 313 working days—representing one year—£434,287 10s. We have been speaking of merchandise and mineral traffic only, but applying the same scrutiny to the figures of the passenger traffic (provided, of course, there were passengers to be carried), and substituting carriages for tenders of an equivalent weight, we should arrive at an income of a somewhat similar amount, both amounting to £868,575 per annum net earnings, equal to a dividend of over 3 per cent. on the ordinary share capital. It is well known that the cost of maintenance of tenders is fully as much, if not more, than that of the carriages or wagons which are suggested for substitution.

The method of conducting passenger traffic yielding so little per train per mile is of such importance, and the discrepancy between remunerative and unremunerative weights hauled is so irrational and glaring, that it deserves to be considered a little more in detail. Still quoting from the London and North-Western Railway balance-sheet, it appears that the gross produce of 9,613,195 passengers is £1,280,507, or under 2s. 8d. per passenger. Taking the average rate for each at 1½d. per mile, this gives 21 miles as the distance travelled by each, whilst the gross earnings per mile of passenger trains are about 5s., which, at a like rate of 1½d. per mile, shows that the average number of passengers per train per mile is 40; allowing for a considerable amount of luggage to each passenger, this number could not be estimated at more than 4 tons. Now 4 tons is neither more nor less than about one-twelfth of the weight of the locomotive engine and tender (the tender alone being about five times this weight), and taking the passenger trains at say 50 tons, the paying load will bear not more than 1-24th part of the gross weight of each train. It is evident, therefore, that the paying is altogether out of proportion to the unpaying load, although it is admitted that on railways such as the London and North-Western, from the circumstances of the great length and numerous unprofitable branches, there must always exist a much larger proportion of dead to paying weight than is the case with lines with no such encumbrances. Now, there is no reason whatever why the present disproportion should exist, or anything like it.

This is no new subject with men who have given their serious and unprejudiced attention to it. I find that in 1849 Professor Gordon, an engineer of considerable eminence, expressed, in a very able pamphlet called 'Railway Economy,' similar views to those which I have advanced. In page 4 he says—'The existing railway machinery will be found to be monstrously disproportionate to the useful effect produced in four-fifths of the number of times that the machine is put in action. And to this waste of power may be most justly attributed much of the present embarrassment of railway companies.'

The judicious despatch of trains, and the proportion of paying to unpaying loads, are two of the most important subjects connected with railway management. These, however, could be grappled with at any time by a really competent man, so as to enormously increase the net result even with existing stock; but there are the difficulties which always surround independent departmental control, exhibiting on all occasions a strange unwillingness to adopt any change which shall interfere with their preconceived opinions, or occasion trouble or thought in departing from a system which one is tempted to think has its own personal peculiar advantages. It seems never to have occurred to these gentlemen that in the discharge of their important duties, involving every consideration they can bring to them, in the interest of their employers, what a close relation there is between the question of the dead weight necessary to the efficiency of the traffic and the dividends to those who have entrusted them with their important functions.

The Metropolitan Railway is, without exception, one of the greatest engineering triumphs of the age, being one of the cases where cost, it would seem, has been of secondary consideration; but, certainly, its management cannot be commended, and time will not permit of dealing with the general question. The magnitude of the traffic is evinced by the fact that during the half year ending December, 1867, nearly twelve millions of passengers were carried over the line by 348 trains on week-days and 212 on Sundays, averaging over 328 trains per day throughout the year. The distance run by each of these trains is understood to be $4\frac{1}{4}$ miles, consequently the train miles per day are over 1,396. By dividing the actual number of passengers, 11,916,924, carried for the half-year, by the number of days in the same period, we obtain 65,298 passengers carried per day, which, in 328 trains, is 198 passengers per train. This number of passengers per train for the entire distance run—say $4\frac{1}{4}$ miles—would give an average of less than 47 passengers per mile. This, however, is not the case, because the gross earnings per train per mile being under 9s. 4d., the amount chargeable per passenger per mile would require to be about $2\frac{4}{10}$d. This would be above the average rate charged. It is, however, impossible to find out from the companies' balance-sheet what the real average is. To arrive at something like an average, I take 100 passengers, 50 single and 50 return journeys, from Moorgate Street to all stations, and divide these into 20 first class, 30 second-class, and 50 third class, which will give the average rate per passenger at 2·02d., and this divided into 9s. 4d., gives a little over 55 passengers per train per mile. The trains on this line are mostly composed of five carriages, weighing about 16 tons each, and one locomotive, weighing 42 tons, together 122 tons. Thus we have 122 tons of train weight to carry an average of 55 passengers, which, at 14 to the ton, is under 4 tons, being only 1 ton of paying load to 30 tons of dead weight. Some objection may be taken to this mode of dealing with figures. It will be said the average number of passengers given to each mile cannot be considered as the exact number travelling that distance. This is no doubt so, but it cannot materially affect the question, for if the whole average of 198 passengers travelled $1\frac{1}{4}$ mile, there would be none the remaining 3 miles; the only difference in the proportion of paying to unpaying load which could rise from this would be a slight increase of the former to the latter for $1\frac{1}{4}$ mile only, while for the three miles it would be wholly dead load. To prove the correctness of this calculation, we have only to assume what many might be disposed to imagine, that 198 passengers instead of 55 are carried per train per mile, the result would give 101,293,854 instead of nearly 24,000,000 now carried.

Nothing could be more appropriately said at this moment than the following quotation from Professor Gordon's pamphlet, written twenty years ago. At page 24 he says:—'These figures indicate the small portion of the mechanism of the railway system of transport that is actually brought into requisition even on the most frequented lines. Thousands, nay, millions of miles, are run by locomotives and carriages on the present system, whilst they are performing an amount of transport of passengers preposterously disproportioned to the power and capacity of the trains employed for effecting it.'

Contrast this condition of things on the Metropolitan Railway with our ordinary omnibus traffic. We find that the omnibus which has to travel over an infinitely worse road than any line, weighs somewhere about one ton, whilst it carries 28 passengers, or two tons, thus giving a proportion of two tons of paying to one ton of unpaying load; but as we have included the weight of the horse, *i. e.*, the locomotive engine in the calculation on the metropolitan working, it is but fair to include the horses which haul the omnibus. Two horses with every equipment cannot weigh a ton, consequently at the very outside, the proportion is one to one, or one ton of paying load to one ton of material employed to convey it. These are very suggestive facts; they have surprised me; and that this line has earned any dividend at all under these circumstances proves its enormous productive capability. Beyond the question of proportion of effective to non-effective duty, let us consider how it all bears on the maintenance of the railway stock and road, and how they are affected thereby. I have already given the weights of the locomotives and carriages, the former at 42 and the latter at 16 tons each.

The carriages have very long wheel bases, consequently they offer great resistance to the tractive force of the engine, besides being very injurious to the rails rounding the curves.

The engines have 32 tons on 4 wheels, or 16 tons per pair. We have only to imagine this enormous weight ploughing along at 30 miles an hour to form some idea of the destructive effect, not only to the rails, but to the substructure and the machines, the effect being destructive alike to all. No wonder that the line has, as it is stated, been relaid in many places three times with steel rails since it opened five years ago. Not content with this rate of destruction to road and stock, the Metropolitan Company are now receiving, or about to receive, locomotive engines of a still more destructive character to work the St. John's-wood branch, weighing 45 tons on 6 wheels, with a wheel base of 14 feet. The only approach to a saving feature in the 42 ton engines—viz., carrying the leading end of the engine on a bissel truck with four wheels—is in these new engines omitted. The bissel arrangement does to some extent reduce the enormous friction of the engines on rounding the curves, notwithstanding which the grating and grinding noise of the wheels can be heard at a considerable distance. The spirit of rivalry between armour plates and guns is reproduced in steel rails and locomotive engines, with this difference, that the armour plates can be made to withstand the power of the heaviest guns, whilst steel rails cannot withstand the battering of these 45-ton steam hammer locomotive engines.

The destructive element of the ordinary type of locomotive is so vital, and affects the question of shareholders' dividends so much, that I would fain trespass on the time of the meeting to show how this results. The superstructure or principal weight of a locomotive engine borne on six wheels is supported on six points close to and inside each wheel. Between these supports and the wheel the carrying springs are placed. Now, a very heavy engine with a great amount of overhang must, from the imperfections of the road, rock about a great deal, and the centre of gravity of the engine, instead of moving forward in a straight line, as it should do if the line and everything connected with it were perfect, forms a continuous line of curves and reverse curves on each side of the line of direction.

This is caused at first by some defect or slight obstruction in the road, and afterwards kept up by the springs receiving and deflecting with the force of the up-and-down movement of the great body of weight resting on them.

This action of the springs is caused by the oscillation of the centre of gravity to either side of the centre line of motion, and then easing themselves by flinging the weight from one to the other, either diagonal to, or at right angles with, the line of motion, and so repeated until the oscillations are gradually diminished; but it is found in practice that the oscillations never cease, for before one set is completely reduced another commences, keeping up a constant surging or soughing from side to side during the entire journey. The exact force of impact on the rail caused in this manner is represented by the amount of deflection of each spring beyond its normal condition. We shall be well within the mark by saying the destructive effect to the rail is over 60 per cent. more than the normal load on the wheels. Thus, in the case of the 45-ton Metropolitan engines it is not simply this weight divided over six wheels, but a concussion of 60 per cent. in addition, or between 11 and 12 tons blow on the rails. Herein we find the explanation of the frequent necessity for the renewal of the rails. It is often argued that, because the additional load is received, taken up, and afterwards thrown off by each spring, the damaging effect on the rails is very little beyond that of the normal load, but I submit that this is not so. On the contrary, whatever extra force is thrown on a spring by momentum to flatten it beyond its normal condition, that extra force passes to the rail—not, however, as the blow of a hammer, but as a load graduated from its normal condition according to the velocity of the wheels and the time taken up by the springs in their action of deflection and return.

The best practical illustration I can offer to the meeting upon all these points of mechanical engineering is to invite attention to the models and drawings before it of an engine which has been specially designed to meet the objections we have just been discussing. The engine does not exist as a mere abstract idea, but is daily in operation on the Neath and Brecon Railway; and within the last few days one of them, which has been working over two years, has undergone a severe test in the presence of several eminent engineers, who, in consequence, have accorded it their warmest approval, several of whom I have the pleasure to see here this evening, and who may probably be disposed to describe their own experience.

The engines are remarkable for the almost total absence of oscillation, and the graceful ease with which they run round the very sharpest curves is matter of surprise to all who have ridden on them, the sense of safety experienced when on the engine is irresistible, and the motion is so pleasantly unlike that of the ordinary engines, that it has been described by Captain Tyler, of the Board of Trade, as giving the sensation of flying, and by others as that of sailing in smooth water. In corroboration of this it may not be considered out of place here to quote a passage from the report of Captain Tyler and Mr. Eboral, who have lately returned from an inspection of the Grand Trunk Railway of Canada. In page 44, after giving a full description of the locomotive engines in use on that line, the report says, 'The class of engine best suited to the climate, and for the various circumstances of the case, would, I have no doubt, be an engine running on two bogie trucks, each provided with a pair of cylinders, and four-wheeled or six-wheeled, according to the work required—and without a tender. Such an engine would be peculiarly safe to travel over a winter road; would combine a minimum wear and tear to itself and the rails, with a maximum of adhesion, and would be the most effective and most economical that the company could employ. I had the opportunity some time ago of testing engines of this description on the Neath and Brecon Railway, designed by Mr. Fairley, and have found the principle to be good, though certain points of detail require improvement. Such engines are also in use for the sharp curves and steep gradients of the Queensland Railway.'

These engines have developed a relative power equal to two of the engines employed for hauling the goods trains on the London and North-Western Railway, whilst the destructive effect on the rails, road, and engine, is greatly reduced. The employment of such engines would enable companies to double the carrying capacity of their lines without necessitating any additional outlay, and therefore they are especially valuable in the case of single lines. There are those who might consider it inexpedient to increase the present dimensions of goods trains, and in that case the engines would be too powerful, but the point is met by their permitting a very large reduction to be made in the weight per wheel, amounting to so much as one-half that on the ordinary engine wheels, while its power remains equal to the best of them. It will therefore be readily understood that the life of the wheel tyres and rails would be greatly prolonged. Companies like the

London and North-Western, having reached, it is supposed, the maximum of load per train, have been driven to the costly expedient of triplicating their lines of rails for great distances. I venture to think that this immense outlay could have been avoided by the use of engines better adapted to the exigencies of an overcrowded traffic, whilst at the same time assuring a saving in haulage labour of nearly one-half, together with a most appreciable saving in fuel.

I have spoken of the Metropolitan Railway and its enormous traffic. That is but a portion of the prodigious traffic of the metropolis and its suburbs. This description of traffic should be treated in altogether a different manner to the main provincial lines. The Metropolitan should be conducted by stock giving the minimum of dead weight with the maximum of efficiency; this, I think, could be best done by what may be termed steam omnibuses, made to carry say 60 passengers, but with power sufficient to haul additional carriages during the busiest hours of the day—in the middle or slack time the omnibuses alone could carry the mean average of passengers. The weight of the entire machine, together with its load of passengers, would be less than that of the present locomotive engine alone. I have brought here to-night the drawing of a steam carriage, designed expressly for conducting the traffic of the proposed cheap lines in Ireland, which will be useful to show you the character of steam omnibuses (to be modified to suit circumstances) I should recommend for working metropolitan lines. This carriage would work with efficiency and economy the line over Mont Cenis.

Before closing this paper—already, I fear, too long—I desire to do justice to a gentleman, Mr. James Samuel, who, when engineer to the Eastern Counties Railway, successfully put in practice on that line very much the system of locomotive which I advocate now for metropolitan and branch lines. Mr. Samuel worked his invention for some time between London and Norwich, not only efficiently, but with very great economy. The economy was so striking as to be hard of belief. Why his system was discontinued I am not able to say; but of this we may be sure, that if the directors of that company had persevered with it, their shareholders would not to-day be mourning over an unproductive property. We should appreciate the man who in those

(no, [illegible] laying [illegible] third line. They have [illegible] wards down a fourth line (i.e. doubled their line) to Crewe 158 miles. If they had persisted it they would have twelve parallel lines of way, which is [illegible]) early days was the first to remedy the monstrous disproportion between the paying and unpaying load of the trains, and it is satisfactory to be able to show you the drawings of Mr. Samuel's invention of that day.

I have thus endeavoured to bring before the Society a practical means of insuring the cheap construction and working of railways. To the noble Marquis in the chair, who is so constantly engaged in practical measures for the development of Irish prosperity, I flatter myself this must be a subject of peculiar interest. It will, I venture to think, create an impression in his mind that the Irish railway system may be completed with comparative ease, and that it cannot fail to prove remunerative. Ireland has no truer friend than the noble Marquis; and it would not be difficult to prove that as a statesman and a resident landlord he has devised practical measures for the substantial advancement of the country which have had the merit (something of a novelty) of commanding almost perfect unanimity. My plans may not command uniform assent, but at all events they are practicable. They may be opposed in some respects to established notions; but they effect the great object of giving all countries what they need in the way of intercourse at the cheapest possible expense. I submit them as in some degree a remedy for the errors of the past and of the present in financial mismanagement, and as a security against the evils of competition. With regard to Ireland, the noble Marquis will be the first to admit the advantages of substituting locomotive power for horse labour in bringing producers and consumers together. This is one of the main elements in agricultural progress. There is no reason in the world why the locomotive should not reach the remotest parts of Ireland. It depends upon surface lines worked by engines such as I have described. Sheep and cattle will increase in value; and the products of the field will never be deteriorated and wasted by distance from their markets. All Irish industries will be stimulated, and new careers opened for labour and capital, beneficial alike to those who engage in them and to the country."

67. *Rolling Stock.*—The following able paper we take from the 'Mechanics' Magazine,' under dates October 2d and 9th, 1868:—"With the exception of the locomotive, the greater part

of the rolling stock of railways has not undergone any very radical change since their first introduction. We have still close, stuffy first-class carriages, cushionless second classes, and thirds only fit for cattle and pigs. Some alterations have, however, from time to time, been made in not only the carriages intended for the conveyance of passengers, but also in those which are appropriated for goods traffic, and come under the various denominations of waggons, trucks, lorries, horse boxes, and other names confined to local districts. For some years, engineers have been turning their attention to replacing a large portion, if not all, the timber in carriages and waggons by iron, and although the substitution cannot by any means be regarded as complete, yet a good deal of success has attended their efforts. The fact that carriages built principally of iron would be almost incombustible, has no doubt contributed to the favour with which the new material has been received. At the same time, there are some objections to the universal employment of metallic carriages, especially for those of the first class. Any one who may have reasons, whether caused by ill-health, nervousness, or general dislike to travelling, for making a journey by rail in the most comfortable manner possible, can do so by 'going first,' and paying for the extra accommodation. Under these circumstances, the invalid or the person of nervous temperament has a right to expect the maximum amount of ease and comfort compatible with the exigencies and requirements of steam locomotion. It is questionable whether these conditions could be ensured in carriages built altogether of iron. Wood appears to be necessary to deaden the jarring sound and vibration, arising partly from the permanent way and partly from the motion of the various parts of the rolling stock itself. The combined system of part iron and part wood is adopted upon lines in France, Prussia, Belgium, and Switzerland, and consists in constructing the longitudinal frame pieces of iron, and the cross pieces and smaller scantlings of timber. The Lyons Company build their express carriages upon iron frames carried by ten wheels, which effects the double object of distributing the weight more evenly and preventing the overheating of the journals. Upon French lines, the distance between any pair of axles rarely exceeds 13 ft., but the Prussian engineers fix their maximum distance at nearly 16 ft., which is greater than that adopted upon any other railway. So far as the carriage is concerned, the distance between the axles, or between the points of support, is simply one of strength of framing, which can, by the employment of iron, be increased to almost any extent. But the matter is otherwise when the distribution of the weight is taken into consideration, and the chance of accidents, owing to the heating of the axle boxes. It is not an uncommon event upon our own lines, where the distance between the axles is far from reaching these dimensions, to witness the porters drenching with water the axle boxes of the carriage of a mail train during its temporary stoppage.

As with passenger carriages, so with those destined for the conveyance of goods. Iron frames are rapidly extending in number, and in many instances not merely the frames but the entire body of the waggons are of that material. In connection with the alteration and improvement of goods waggons, there are two principal points to be kept in view. The one is the reduction of the number of distinct types or separate examples of construction, and the other that of an uniformity in the weight carried by them. Both these arrangements are in some measure contingent upon the nature of the traffic to be conveyed, and depend upon the relative volume and weight of the contents of the waggon. Coals, for instance, could not be carried in a cattle truck, nor could the same weight of timber be conveyed in a waggon which could be closely packed full of bricks. With a few exceptions, the various specimens of goods carriages may be included under three chief heads, viz., the common truck, which has no sides, but simply a platform; the covered waggon; and the coal truck, which has sides about 2 ft. 6 in. in height. Whether the frames and the body of the truck should be all in one, or detachable at pleasure one from the other, is a matter of detail best left to those engaged in their actual construction. No sooner was the problem of setting trains in motion by the agency of steam once satisfactorily solved and placed beyond a doubt, than a more difficult one, that of arresting their motion, arose in its place. It is not too much to assert that, in spite of the innumerable patents taken out, inventions experimented upon, and trials undergone, the question of obtaining a perfectly satisfactory brake action is yet an undecided one. Probably, the real reason why the difficulty has not been overcome, and the obstacle surmounted, is that too much has been sought for, and too rigorous a solution of the problem attempted. The end aimed at by nearly all those striving to devise an efficient brake has been one which is in reality foreign to the whole character of that mechanical appliance. Inventors, as a rule, have striven, with inexhaustible patience and assiduity, to design a brake that will stop a train almost instantaneously, and those who have effected the change from rapid motion to a state of complete repose in the shortest time, have considered that they have approached nearest to the vanquishing of the obstacle. But in fact they were very far from attaining the desired result. The great object of a brake is not to suddenly and totally arrest the progress of the train, but to gradually reduce it to a state of rest. It is not expected to act only on rare and special emergencies, but to be of continual use during the whole journey. In a word, it is for general, and not special, employment In order to obtain a sudden arrest of motion, all the earlier, and most of the recent, descriptions of brake were made to lock the wheels immediately upon their application. Independently of the great impactive force suddenly brought into play, and the violent torsion thrown upon the axles by this arrangement, it is radically unsound in principle, and does not effect the result desired. If the skids press so tightly upon the wheels as to lock them, the train is not brought to rest so soon as if they only had bite sufficient to prevent them from revolving. The limit between the rotation and the sliding of the wheels is the one to be attained to, as it is well known that a body will slide faster than it will revolve. To determine theoretically the exact velocity at which a body will cease to roll and commence to slide, is a very nice mathematical problem, but practically the limits may be ascertained experimentally with sufficient accuracy for all working purposes. At the late Exposition, the improvements in the details of brake gear were mostly confined to effecting the instantaneous application of the skids to the wheels. These comprised the use of levers, screws, springs, balance weights, and other contrivances, including automatic and electrical agency, which have at different times been laid before our readers in these columns. Perhaps the best working system of brake power is to be met with on the North London

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Mr [illegible]
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1868

Railway, which surpasses that exercised on the Metropolitan line, although the latter is no mean rival.

One of the alterations immediately attendant upon the increase of weight and size of rolling stock was the employment of larger axles, having diameters of 6 in. and upwards. In several instances, iron gave place to steel. The former material is still preferred upon French lines, but upon those in Germany cast steel is largely made use of. Until some experiments are undertaken to test the relative behaviour of these two metals under a strain of torsion, it is difficult to pronounce upon their separate capabilities for the duty in question. An essential quality for an axle to be endowed with is toughness, which can be imparted to either steel or iron by a particular method of manufacture. Independently of this, certain irons would be better adapted for the purpose than others. The Swedish iron, and that used for bolts and rivets, would probably be a good description to employ, not merely for axles, but for the numerous other details which are constructed of that material. Notwithstanding that a carriage or truck may be built altogether of timber, yet there is a considerable quantity of iron absorbed in the actual putting of it together. In addition to a vast number of bolts and screws, there are many angle pieces, brackets, rods, and bars fixed here and there to brace the whole frame together. Goods waggons intended for the conveyance of a heavy description of traffic may be said to be almost plated with iron upon all those parts liable to be injured by the loading or unloading of the contents. Many of these pieces are of a very irregular form, and lately the hammer has been replaced by the rolls, in order to produce the shape required without having recourse to the operation of welding. Cast-iron joint pieces are also used, but their brittleness renders them open to objection.

An important detail in connection with all wheeled vehicles is the springs, and various have been the modifications introduced to adapt them to the somewhat anomalous conditions of locomotive steam traffic. One of the objections against the ordinary carriage spring, composed of a number of thin bars superposed one upon the other, is that it cannot be made available in a small space, but must have a certain amount of room allotted to it. With the view of obviating this difficulty, spiral springs have been proposed and tried, and another description, consisting of conically-shaped discs, touching one another at their greater circumference. This is another of the problems to be satisfactorily solved by the mechanical engineer, and in spite of its apparent simplicity, it is yet beset with many difficulties of both a theoretical and practical nature. The enormous velocity, comparatively speaking, that trains run at, renders this subject much more complicated than one at first would imagine. It has been proposed to employ two separate sets of springs, one to break the jerk or sudden shock of the start, and the other for permanent use during the journey. By this arrangement more ease would result to the travellers, and less vibration and wear and tear to the vehicles. Upon the Prussian railway especially, india-rubber springs are still made to do duty, but this application may be regarded as exceptional, since the general tendency is to employ steel for both passenger carriages and goods waggons. From the springs we naturally pass to the wheels, and we find that those having flexible spokes are giving way to the solid or disc form. Some of the wheels on the Prussian lines, made of cast steel, are so excessively hard that no tyres are required. Upon the French railways, the system of MM. Peton et Gaudet, by which the wheel is all in one piece, is especially deserving of notice. In England there are some excellent examples of the Arbel principle. Belgium has the light disc wheel of La Providena, and Sweden gives the preference to a wheel possessing a wooden disc of timber on end, compressed between the tyre and the nave. The diameters of the wheels of rolling stock range from 3 ft. to 3 ft. 6 in., the mean of 3 ft. 3 in. giving a very good average dimension. Nearly every description of steel that can be possibly manufactured has been tried in the tyres of wheels; Krupp's steel, cast, Bessemer, puddled, and other kinds, have all been employed on one line or another. For the wheels of waggons and trucks, iron tyres are still largely used, as their strength is sufficient, and they are less brittle than those of the other material, particularly during the time of frost, which is especially fatal to wheel tyres, and which has given rise to many accidents through their breaking.

Passing from the general types of carriages and trucks to those designed and adapted for particular duties, one of the first that arrests the attention of every passenger by a mail train is the large carriage carrying the royal arms with the well-known V.R. on its centre pannel. It is in this carriage that the mails are carried and the letters sorted, and the bags made up during the journey for the several provinces lying along the route of the train. The great feat, however, performed, is the delivery and taking up of the various bags while the train is in progress. This arrangement is peculiar to our service, and in spite of many attempts made in France, the result has been a failure, and our system makes the *désespoir* of the Continental railway officials. The Prussians have so far surpassed the French that they are able to take up the despatches, but have not arrived at the capability of delivering them *en passant.* At the late Exposition there was a remarkable model of a railway carriage exhibited, which happily we have never had any need of, and in all probability never will. It was a model of a railway ambulance, for the sick and wounded, and, similarly to everything else that possesses novelty of design and inventive construction, hails from the other side of the Atlantic. The necessity for a vehicle of this description arose from the unhappy internecine war which lately raged in the States. According to the model, the ambulance was capable of containing thirty beds, a small surgery and operating department, together with a separate division for the medical officers and nurses. Everything that could be required for the purpose for which the carriage was intended was provided and ready at a moment's notice, and the whole of the fittings were so arranged as to afford the maximum amount of comfort and security to the unfortunate occupiers. While the design of the vehicle and the style of its build is deserving of eulogy, we trust in the cause of humanity, that it will have but very few imitators.

One of the recently constructed railways which has a special class of carriages is the Mont Cenis. These communicate with one another by doors in the ends, and each carriage is furnished with a pair of different brakes. One is of the ordinary kind, acting upon the wheels, and the other is for emergencies, and is brought into play by being attached to a pair of cams, which can be caused to grip the central rail when the break is thrown into gear. There is also a special arrangement for preventing the train getting off the line when passing round sharp curves. It has frequently been suggested that for long night journeys by rail, embracing upon the average ten or twelve hours, sleeping carriages ought to be provided upon our railways. The truth is, that our longest journeys are not of a duration sufficient to create any real demand for such conveniences. At the same time, there would be no absolute need for building special vehicles for the purpose. By a little ingenuity and alteration, any of the ordinary day carriages could be made to do the duty of a comfortable sleeping compartment, and, at any rate, would allow the weary traveller to assume a recumbent position, instead of compelling him to sleep restlessly and uneasily in a sitting posture. The great length of journeys by rail undertaken in Canada and the States have long since necessitated the adoption of sleeping cars, which, in their build, interior arrangements, and general features, differ essentially from anything connected with our rolling stock."

68. *The Fatal Defects of Railways.*—We take the following article from 'Engineering,' under date May 1st, 1868:—"First of all, there are the mechanical imperfections of the way. In consequence of these the resistances to traction are much greater at high than at low speeds, whereas, except from the resistance of the atmosphere, there should be no difference at all. The friction upon a railway as true as one of Mr. Whitworth's lathe beds would be the same at sixty as at six miles an hour, and it should be the steady aim of the railway science of the future to approach this degree of relative perfection. With this, too, the line of traction, instead of being 3 ft. or more above the plane of resistance, should be coincident with it. Railways should be so made that the body of the carriages should run between instead of above the rails. The latter would then be carried on bed plates rising high on each side, and the draw irons would be in a plane but little, if at all, above the line of resistance, and the continual oscillation, due to the present system of pulling at a height far above that line, would be avoided, getting off the line would be impossible, and in the case of breaking a rail, wheel, or axle, the danger would be less than at present.

One of the worst evils of our present system of locomotive construction and working is that whereby the whole line must be made of a strength at least twice greater than is required for the load drawn. We have from 2 to 3½ tons on a carriage wheel or a waggon wheel, and from 5 to 7 tons on a locomotive driving wheel. Just as a bridge must be made to carry the maximum load, the whole line must be planned for the heaviest engine weight, although this weight is carried on but two, four or six wheels in a train numbering from fifty to one hundred and fifty wheels. When engine weights, on each wheel, are kept down, as they should be, to the standard weight of carriages per wheel, we may have much lighter rails, chairs, sleepers, and ballasting, and much less cost of maintenance. This can only be done upon the double bogie system, whereby eight, ten, and twelve wheel engines may be easily worked with no more than 3 or 4 tons on a wheel, and that without undue friction from coupling.

There is room for a thorough reform of railway construction and working. There should be found engineers and managers with sufficient perception, courage, and practical talent, to carry out such reforms, the principles of which are sufficiently clear to all. Our present timid, halting policy is losing millions yearly to the railway interest of the kingdom, and is perhaps the chief cause of the present unfortunate condition of railway investments."

◆

DIVISION TWELFTH.

SHIPS.

69. '*On Naval Construction, viewed from the year* 1800 *to the Present Time, and its Probable Future.*' By Vice-Admiral Sir Edward Belcher, K.C.B., Vice-President of the Institute of Naval Architects.

The title of this paper enables me specially to contrast the various styles of build which prevailed previous to our late adoption of armour—the full bluff bow and its attendant head gear, the cutwater, gripe, keel, and clean entrance—the facility which such forms afforded for easy handling, and more peculiarly their safety when beset by the dangers attendant on gales or the difficulties of a lee shore. On the other hand we have to view the results which deviation from the old forms seems to entail now that the mere chance of ramming appears to have superseded the first and most important qualities demanded of a ship of war. What, indeed, are those primary qualities?

My own ideas lead me to insist on their being made good and lively sea-boats, capable primarily, under spars and canvas alone, of holding a good wind and being as trustworthy, under any conditions, on a lee shore as if they had no machinery on board, or it had been disabled.

That under any circumstances, in light airs or gales, they should obey the helm readily; indeed, from their build as well as trim, be capable of being brought, by the judicious appliance of the seaman's art, to trust only to the assistance of the rudder in critical cases, but never to render its application, as I have of late years witnessed, a matter of severe labour to the helmsman, or even danger to the vessel if crippled. Under the old *régime* our ships, as regarded their tonnage, carried only a certain amount of furniture, in which I include masts, sails, store, rigging, and ballast—the latter, as well as munitions of war, being secondary items, changeable, as we all know, if found too heavy. But each of these items were so placed in accordance with certain secrets of pure seamanship, that any deviation caused the monstrous difference between the 'crack frigate,' or the old seaman's appellation, the 'clumbungay.' But it did not depend so much then on the construction. The problem, 'There, sir, is the greatest tub on the face of the waters, make her walk and speak,' was given for solution. But it was further accorded, 'You may trim, mast, and rig her as you may judge meet.'

On this previous condition the second hung, obedience to the helm. That obedience, as an old yachtsman and trimmer of obstinate ships, I found to depend on the trim, in connection with the position of the masts and canvas, not only carried but treated in a seamanlike manner. And in accordance with the trim, so also depended the careen, and, practically, the proper power of the rudder. Therefore it was imperative on the officer in command to exercise his reasoning powers as to the various forces which might be called into action, to make his vessel *per se* perform most of her duties, calculating on the distribution, as well as nice management, of her canvas, which hardly called for, in tacking especially, the aid of the tiller.

In illustration of this faculty of trimming it was my lot to serve in several vessels denominated tubs. First, the old Bellerophon, of 74 guns, bearing the flag of Admiral Sir Richard Keats, in 1814. The former character of that ship, participating for fifty years in every general action, was "a desperate roller," specially, too, rolling away her masts, which she did when at anchor in Oazely Bay. She was also sluggish under canvas; 'eight knots close hauled, and ten knots free (not bad, however, at that period), nor would she obey her helm;' so much for fifty years' doubtful character. Her new commander was the late Admiral E. Hawker, noted for the kelter as well as handling of that beautiful frigate the Melampus (still in the Dutch navy), which astonished, as well as excited, the admiration of our acute cousins of America. His management evolved her latent qualities. He trimmed and sailed the Bellerophon in chase of the noted American privateers Fox, Amelia, and Mammoth, both on and off the wind, from dawn until dark; with lee guns bowsed in and weather guns out, royal studding and sky-sails, going free, she realized 11·6 knots. That was due to sheer seamanship. Captain Hawker's creed was, 'Every tub has its capabilities,' and it is the duty of the officer commanding to evolve them, not by straining, overmasting, or over canvas, but by judicious trimming, and, above all, never allow the strain on a rudder to 'impede motion.' Her Majesty's ships Samarang, Ætna, and Sulphur, under my own hands, were similar cases. Therefore, I maintain that we must not be too hard upon the constructor, who simply adheres to those well-known laws which afford the mould out of which success may be attained.

From the year 1800 it may be assumed that the finest models of sailing ships, mostly of French lines, were in our possession; and, moreover, that for length and breadth, until we broke through all the old rules, we never constructed faster or easier vessels.

But in what did their sea qualities consist? They all centred in the profile of stem, gripe, keel, and sternpost. If the vessel griped, or would not keep out of the wind, she was added to abaft, or her gripe or rake of stern was altered. Alterations of rudder never were successful; then it was that the abilities of the seaman, so absurdly underrated by civilians, were called into play; and our naval constructors, *par excellence* in their time (Admiral Hayes and Sir W. Symonds), proved where the essence of control lay, simply by making trim—position of masts, cut of sails, and attention to the aids in steering, act in unison.

But referring to construction, what has been the process from the period of coppering our fast ships, boats, or yachts, up to the present armoured fleet? First, taking the Dutch, they found that where no keel was available a leeboard was demanded; next the Norway yawl; that truly had no stem or sternpost, but they had bilge keels from amidships aft, which enabled them to hold a wind, and yet more important, serve as sledges on the ice. Two of these, from a model supplied by Admiral Baillie Hamilton, then second secretary to the Admiralty, were supplied to the late Arctic expedition in 1852, and indeed may be deemed the type of the two sternposts for the twin-screws of the late talented inventor, Mr. Roberts.

Then turning to America we have the Virginia pilot boat, the beau ideal of their clippers, of which the Mugian is but a variation, showing a long overhanging bow, with her forefoot scarph about one-sixth from the stem abrocell, and the scarph of the sternpost about the same distance from the taffrail. Those forms were considered to be the best adapted to meet the heaviest weather off the capes of Virginia, which, for a continuance, is about the worst experienced in any part of the world.

Next, when we view the inexpert Chinese, or *au contraire*, those clever seamen, the Malays, we find the rudder in the first lowered far down below the bottom; or, in the latter, two rudders, one on either quarter, deemed indispensable.

On the drawings before you I have endeavoured to exhibit the various classes of vessels to which I have alluded, and I think that my naval friends will not fail to remember as regards the sailing vessels first improved by America, and followed by us at Greenock, Liverpool, and finally in the Thames, the great superiority as to seaworthiness in the overhanging flanching bow.

I offer these remarks for the serious consideration of those constructors who, not being seamen, have, I think, too suddenly jumped to the conclusion that vessels which are expected to perform well under canvas require no keels; and, further, that the steerage is as perfect without that long keel which led the fluid direct to the rudder.

It is also necessary to observe that a rudder which descends below the line of keel for the purpose of obtaining steerage—as with the Chinese—is manifestly endangered by any objects—as weeds—beneath the surface, as well as inevitably destroyed, should the vessel ground by the stern.

Before the 'iron age,' or sacrificing everything to steam and armour plating crept in, our ships could thread the most intricate or dangerous channels. Our merchant shipping, although constructed of lighter iron, still under canvas perform more than any seaman dreamed of; but they have bows as well as sterns fit to secure their seaworthiness.

To prove that we demand no new 'lines' for our ironclads, I beg to offer the following performance of the Cunard steamer Scotia on a December run from New York, furnished by Sir Edward Cunard, taking passage:—

December 16, quitted New York.		
„ 17, at noon, ...	314	knots made good.
„ 18, „	310	„ „
„ 19, „	333	„ „
„ 20, „	336	„ „
„ 21, „	335	„ „
„ 22, „	338	„ „
„ 23, „	351	„ 14·6 „
„ 24, „	341	„ „
	2,658	„ „
On to Liverpool, ...	358	„ „
	3,016	„ „

The average for five days exceeds fourteen knots.

Under certain alterations of hull, light protection to decks, and giving this vessel two of the heaviest guns, what vessel in the world could approach her? And if those heavy guns threw shells at extreme range, what armoured vessel could withstand her fire? The time may suddenly find us compelled to arm anything which can carry a respectable implement of war. Why should our navy be without such models, propelled at such speed and as active under canvas as the fleetest of our British China Clippers?

Now the point which I am prepared to maintain is that, looking to recent alterations in the bows of our ships of war in order to protrude beneath water an unscientific ram, you not only destroy every chance of good behaviour of the vessel, but you literally, by the immense weight at the fore end of this ploughshare and the screw abaft, so balance your ship that her proper motion of 'dancing' over the waves is now a myth. As to the idea that iron ships cannot be made to sail as well as those of wood did, it is beneath science to reply; for we have the performances in our ocean races between China and Great Britain to prove that iron ships can, ay, and will yet exceed, in doing before long.

On that paper you have the types of fast vessels, and, moreover, of handy easy craft. Now, why were the first, the Virginia, Mugian, and Norway yawl so constructed with such rake of stem? Simply to make one sail perform all that was demanded, and almost to do without a jib or the bowsprit. So with our ironclads we should consider, if we require seaworthiness, activity, and handiness, if we could not obtain it in a more sensible and scientific mode by transferring the ram point, as the Romans did, to the beak.

Every officer who has experienced the mode of wrecking at Bermuda must recollect that boats equivalent to our launches in tonnage run stem on to grounded vessels, and destroy all chance of their getting off. I witnessed that attempt, and interfered, thus saving thirteen vessels from destruction, getting them safely into port; for which, instead of thanks, I was threatened with lawsuit! And yet, what better type of ram could you select?

I feel perfectly satisfied that when the officers of the United States wake from their dreams of submarine fighting we shall see the old bow recover its use, as well as beauty (to the eye of the seaman), and that new beak prove the terror of sluggish adversaries?

Leaving our old ships, let us now look to those building, or built, of iron. The central object in the plan before you may be supposed to be the Warrior, and here at once I do not mean to yield the point, that like the Bellerophon fifty-four years ago, some intelligent captain may yet discover the secret of making her, properly rigged and trimmed, to perform, under canvas, what her type should justify us at least in hoping for.

Now why should we not make the Warrior a terrific ram above water? We who have worked under water know pretty well how wretched the force must be compared with the radial power in free air. To my mind I can but compare it to the artificer with penmaul or sledge, who delivers his blow at the full radius, compared with him who places one hand half-way up the helve, or who would hurl that same mass of iron from his hand.

Let us bear in mind the active weight of the whole line of gun decks with all the paraphernalia of warlike stores, and consider what the effect of that compact, well-connected mass delivered with at its own *vis inertia*, plus that of the velocity due to speed.

In that plan I have assumed that we adopt the best known form of tool for cutting iron or wood—the mortice or bevel chisel. Where the direct line of resistance is demanded, you have a deck of some 400 ft. As the bevel, supported, too, by your keelson, you have the best form of bow for leaping over a sea, as well as an adversary, and yet on the line of flotation, the same length.

Now let us produce the sections of an adversary, and it will be well to inquire, as a primary consideration, on what point is it assumed the submarine ram will prefer to infringe, vertically or oblique? By fitting the curves which may represent any imaginary build, it will be seen that without any chance of having an interposed wave or cushion of water, that the impact would be so given by the mode I propose that the whole impetus would be directed to turn over an adversary outwards on his beam ends—indeed, cut him down and pass over him.

By the ploughshare mode the blow would be delivered, if it did not glance off below; and, if effective, cause your adversary to roll in the opposite direction on, and towards, and over you, destroying both. This regards the foremost sections. Now, when we come to deal with those about the counter, it will appear, without selecting the greatest hollows, that before the hatchet nose would touch the bottom her upper works would impede further progress.

Leaving these new ships, then, to fight their separate actions, I now come to their classification, under the term of the present condition of our armoured or plated fleet.

First, we are at a loss to determine where the rates, as known among the timber ships of 1860, commence or terminate. As to ships of the line, that would seem to depend on the speed of those vessels which could get into position, and, being there, be arranged for action as the admiral commanding in chief might determine, for we may have a captain in a vessel of minor force superior in rank to one who commands what may be assumed to be or hold the place of the ship of the line.

Without referring to the names of ships or captains, the Navy List affords more than one case where the captain of a frigate of forty-three guns and over 3,000 tons would be senior to one in command of an ironclad of over 4,000 tons, nominally of thirty-five guns, and yet the superior would, not being an ironclad, belong to the line of battle; nevertheless, both are classed as frigates. Then we have a corvette of twenty-two guns, 1,467 tons, commanded by an officer senior to the captain in command of the Warrior, 6,109 tons. These matters, however, would speedily be arranged by the Admiralty in the event of active war operations.

The important questions to be asked are: Are our ironclad ships as fit to go into action, and as efficient for war purposes in every respect, as our old timber-built coppered vessels? Can they sail and steam as well? And, finally, is it probable, as some naval men hold forth, that we are likely to be eclipsed by the ships of France or America? We must hope not.

My own impression is that we are fast losing our *prestige* on the critical points of speed, seaworthiness, celerity of evolution—indeed, excepting for action *à l'outrance*, we are driven to depend more on the resources of mechanism than on the old seamanship and valour of the British navy.

The question is constantly asked, Why, with the lines of the finest and fleetest ships in the world, should our iron ships fail to prove as fit as any timber built vessel? The only reasonable reply I can find is, that we have sacrificed so much to the iron shell, and sought for so many advantages in one tool, that we have failed to secure any one important good quality. Not content with a monitor fit for harbour work, and demanding less men, stores, coal, &c., we must needs look to make her a clipper! Or, not satisfied with a certain speed and imposing size of guns, we must needs require a prodding nose, which shall prove the destruction of the vessel, or, wanting speed, prevent her coming up with and dealing with an adversary which it is her duty to engage.

I had almost omitted to refer to the modes of propulsion. It is a curious fact that in Great Britain we seem to scout native talent, and are prone to seek for notions from some other country which has actually improved on what we have cast away. At the beginning of this century masts and sails gave us nearly as much speed as steam now affords. Taking intervals of twenty years, we find that about the year 1820 paddle steamers were thought of, and in 1822-24, the Lightning and Meteor were at Algiers.

Twenty years afterwards, after a death struggle of opposition, the screw worked its way. In 1843, we may say, it was acknowledged as a success. Twenty years more, after very strong language, assertion, and denial in these rooms, the twin-screw conquered; and I envy not the feelings of those who so vigorously coined their untenable reasons to prove it never could succeed. True science, however, beat them. Facts against theories. Later, we find another power forcing its way, but, like the others, demanding twenty years of resistance. Ruthven's hydraulic system of propulsion has, I find, been before the Admiralty for upwards of twenty-four years. Detraction, false reasoning, and the system of writing down, have all been tried. As a last resource it was fitted on board H. M. S. Waterwitch, but so overladen with iron plating that, viewing her hull alone, she is unfit to withstand what we term simply, 'a double-reefed topsail breeze.' As to the machinery, that is as independent of the vessel's behaviour as any chronometer would be in the captain's cabin. It was assumed she might be impelled seven or eight knots, but lo! she attained *ten*, and as compared with the twin-screw, in a sister ship, was equal.

Is all this creditable to our country? Are inventors to wait twenty years? Are our best men to be sickened, insulted, and turned aside as all these men of great talent have been, because official minds cannot rise to the level of the thoroughly educated engineer? How was it that Ericsson was driven to America, all his schemes, termed notions, scouted? I happen to know. Might not select members of this Institution, properly supported by Government, furnish Courts of Inquiry which would lend force to any inventor presenting himself at Whitehall? We know too well, even here, how roughly some might be tested; but there would be this great advantage, both to the inventor and the public, that a strong opinion expressed in its favour here might save the twenty years which seems hitherto to have been the Admiralty period of incubation.

Turn we now to the construction of our present armoured ships of war.

Are the new bows and sterns introduced for the support of these ram protuberances below water as well adapted to sustain a ship and keep her dry and healthy as our ships of old?

In former times, since 1831, when the ice was broken, and Hayes and Symonds were permitted to have their fling, was it not an invariable rule, and the creed now with all crack seamen and yachtsmen, that the extremes were to be most religiously kept free from excessive weights, which, we well know, as instance withdrawing guns when in chase, or in bad weather, prevented a ship from easily, nay, or safely, performing her duty? How, then, are we to view this monstrous appendage below water, strengthened by such masses of iron in order that it may not, Amazon fashion, prove a cause of destruction? But more, producing such a gripe that one cannot feel surprised at these difficulties of steerage which seem lately to have increased instead of diminished with the increase of science.

In the Symonds and Hayes types we had lively vessels; more important yet, our seamen confidently trusted themselves on a lee shore, well knowing how surely they could 'claw off.' Again, we are getting too much of the upright structure, losing the balance on one side and increased bearing on the other. But referring to this ram before you, the lines of H. M. S. Waterwitch. The form under water presents that of the hind-pin, the axis being just central between the keel and water line; under a five-knot speed she will raise a wave over that bow of 12 in., increasing up to ten knots, so as to lift the water over her forecastle. In fact, the faster she goes the more the bow becomes immersed, and, consequently, the steering power destroyed.

Seamen all know how critical such a condition would be in any timber-built vessel scudding. I ask, if any of this class should be so circumstanced could she live? And we must not lose sight of the impossibility, under any circumstances, of lightening vessels of this character. No, everything is fixed, and so sudden would be disaster that small chance of saving life remains.

There are two parties concerned in this ram question. First, the gunnery party. They wish to show their dexterity with their guns. Good. If we are to credit the *on dits* of the day the adversary hit by one of these heavy shot or shell would have other duty to perform than playing antics to find his chance of dealing the ram impact; and, further, you must have two captains, one to ram, another to gun. Again, to ram involves competent speed on one side, and, I suspect, incompetent ability to avoid or foil it on the other. And yet, for this very doubtful chance of it ever being called into action, we are jeopardising the very essence of the gallant seaman's aim, *getting alongside of his adversary!* For rest assured, my landsmen friends, he who plays at the zigzag tactics of ramming loses distanee; nay more, there may be those on board who may attribute it to want of courage—seamen are queer fellows in such moments—and when it arrives at fight or ram who will take excuses?

There is yet a more serious aspect to my mind. We must look to our future; we should change martial law, or the martial feelings of our officers. We are intent—I cannot say I am—on impregnability. Granted that we acquire it. Granted, I suppose, it is to be conceded that our opponent is on an equality. You are alongside, engage, make no impression. Neither can move ahead or astern for fear of this cursed ram. You have no power of parting laterally, your decks and closed ports cut off the old glory of the tar—boarding. We cannot forget the gallant Irby in the Amelia. The man who parts from his adversary is lost, however gallantly he may have behaved!

It has occurred to me that when twenty years' further thought has ripened the faculties of our Whitehall magnates, that this turbine may, by multiplication of jets, be brought to aid any desired motion where even the twin screws would prove useless. Besides, the screws are easily fouled or destroyed by spars or nets, whereas nothing can injure the hydraulic.

Further, if this country should ever adopt the monitor of light draught the hydraulic is the only rational power by which it should be moved. There is no complication of machinery; the jets may be multiplied so as to produce any desired, even spinning, motion more rapidly and steadily than the turret, thus making the monitor the carriage of the largest possible gun.

Where fuel is in sufficient quantity, and the vessel once employed for coast defence, it is indeed contemplated multiplying the turbines. Indeed, three could be placed even now in a vessel of the Warrior class. And when we hear of signals from the watch tower, 'go ahead, astern, stop,' &c., how insignificant all such devices become when the commander, without an order, or the knowledge of officers or crew, with his own hand governs every motion without interfering, directly or indirectly, with the even and continuous action of the engines, which are never interfered with, consequently are never reversed.

I have hurriedly thrown together these remarks with the hope that some of the new school will be able to inform us how it is proposed to meet the difficulties which I know those of my day agree with me in thinking are not mere phantoms I have to thank you for.

70. *Captain Cowper Coles' Turret Ship.*—The following description of this ship designed by Captain Coles, we take from an illustrated paper in the 'Engineer,' under date March 27th, 1868:—"The tonnage is about the same as the Bellerophon (4,272 tons), but with low freeboard from 3 ft. to 4 ft. out of the water. Her length between perpendiculars would be 320 ft.; beam, 53 ft.; two turrets, with guns 12 ft. above the water and 11 ft. horizontally from the sea. Between the turrets a deckhouse is built, of the ordinary scantling of an iron ship, extending towards the vessel's sides at an angle that allows the turrets to cross their fire at 68° on the beam, and commanding an uninterrupted fire around bow and stern. This deckhouse may be one, two, or three storeys high, according to the accommodation required—in the present instance it is two storeys high, surmounted by a hurricane deck 22 ft. out of the water. In the upper or second storey good accommodation is provided for the captain, the dining cabin being 24 ft. by 13 ft., with a suite of cabins in proportion, a commander's cabin, a wardroom, and four other cabins for officers, office, galley for the officers, a sick bay, baths, and w.c.'s for both officers and men. The cabins and apartments on this deck would receive light and air from ports 2 ft. square and 18 ft. out of the water, besides ventilation

from the hatchways communicating with the hurricane deck. The lower or first storey would have mess-tables for 300 men (her fighting complement), a galley, midshipmen's, engineers', and warrant-officers' berths, besides four cabins for officers. This deck would receive air and light by means of ports 18 in. square, 11 ft. 6 in. out of the water, beside hatchways. All the hatchways on this deck leading below would have the means of being closed and kept water-tight the same as in Monitors. The remaining nine cabins for officers would be on the lower deck, which corresponds with the Captain's and Royal Sovereign's, receiving light from deck-lights, and ventilation by tubes communicating direct with the outer air through the deck-house; there would also be provision made on this deck for messing 300 extra men should it be required.

From the central position of the deck-house, as well as the horizontal and vertical distance from the water to the ports and openings in it, free ventilation will be insured in all weathers, whilst the comfort and accommodation will be second to no vessel in her Majesty's navy.

From the form of this vessel above water, and the little resistance shown to wind or sea, lighter anchors and cables might be used than usual; but in this case we will suppose them to be the same weight as the 'Captain's.' The cables would be led through fairleads at the edge of the bow along the upper deck, and through hawse pipes (8 ft. above the water) into the lower storey of deck-house, where they would be worked by two steam capstans, on each side, as in the Royal Sovereign. The bower anchors (Martin's) at sea would be stowed upon the deck without interfering with the firing or depression of the turret guns, and the spare anchors against the deck-house. The anchors can be worked on the bow or stern with equal facility. She would have the usual complement of boats, viz., two 42 ft. launches, two 32 ft. steam cutters, two 28 ft. life-boats, a captain's galley, and an officer's gig, which would be hoisted up by davits to the deck-house, and so arranged that at any moment they can be turned inboard when firing at sea.

Opinions will differ upon the question of masts, but after considering the report of our ironclad squadron, as well as other practical evidence, from which it appears that our ships as now masted are incapable as a fleet of manœuvring under sail without the aid of steam, the balance of advantage is (in Captain Coles' opinion) against such useless masts and sails, and in favour of fuel being substituted for the weight thus gained. Masts may be desirable to assist in decreasing the rolling propensities of high freeboard ships, but for vessels of low freeboard, with their decreased rolling, the gallant captain maintains that we can afford at once to sweep away the masts, gear, and rigging, as antagonists to the steaming and fighting powers of war ships, and can at any time resort to temporary or small ones for fore and aft sails, such as the Royal Sovereign and Prince Albert have, should it be considered desirable. In the stowage of fuel weight and space have to be considered. In this vessel every hundred tons would make a difference of about 3 in. draught of water. In an armoured vessel the saving in weight and the absence of masts get rid of the greatest part of the difficulty under the head of weight; and the author of the design finds that after giving ample accommodation, as before explained, for a crew of 300 men, and extra accommodation for 300 more men, making in all 600 men besides the officers, she would stow upwards of 1,000 tons of coals, and even more at the sacrifice of 3 in. immersion for every 100 tons.

The armament would consist of two turrets, with 13 in. armour, carrying four of the heaviest guns that can be procured, say 600-pounders, 12 ft. above the water. and two pivot guns, if thought expedient, on the hurricane deck, 22 ft. out of the water; the latter may be found advantageous for firing down upon a ship's decks, and it is believed a vigorous fire kept up by rockets and breech-loading rifles from the position and height of this hurricane deck would have a great effect upon an enemy's upper deck and open ports. Leaving the pivot guns out of the question, the fighting powers of this ship's turrets would remain as follows:—88° of the circle are commanded by two 600-pounders, throwing a broadside of 1,200 lb., and the remaining 272° by four 600-pounders throwing 2,400 lb.; and it will be observed that this ship can engage end on with two 600-pounders, and at 22° from the line of keel, or only two points on the bow with *four* 600-pounders, which would be her strongest point of attack; the importance of this is much increased when it is considered that all well-designed ironclads will endeavour to present their bows to the enemy, when this ship would show the deflecting surface of a sharp protected bow, not more than from 3 ft. to 4 ft. out of the water, and a circular turret 9 ft. high above it: whilst in broadside ships of approved model, a bulkhead some 20 ft. above the water is placed across the ship to protect their guns, which, when fighting end on, presents a large and weak target at right angles to the enemy's raking fire, which might place their battery *hors de combat* before a chance of using their broadside guns occurred.

In comparing the defensive powers of Captain Coles' ship with the high and weaker sides of broadside ships, and of the Monarch, when we say that her sides and turrets would be protected with 13 in. of iron, we give but a small idea of her great superiority, in some respects, over any high freeboard vessel yet built, for her lowness of freeboard will give her antagonists but a sorry chance of hitting her, whilst her steadier platform will reduce the chances of her being hit below the water-line to the minimum. Lowness of freeboard may be said to facilitate being boarded, but supposing an enemy to get upon the turret-deck, he would have to take possession of the deck-house, which, from its position and height, as well as being enfiladed by the turrets, would be a matter of great difficulty.

Twin screws and no masts, in combination with the peculiar form of the vessel above water, showing so little resistance at her ends to the wind and sea, it is believed will assist in insuring both speed and handiness to the fullest extent, as well as her absence of motion as compared with our present ironclads, whose great loss of speed at sea may be attributed in a great measure to their floundering propensities. Her engines would be of 900-horse power, and capable of propelling her at the rate of 14 knots. The principle of a deck-house can be modified to suit vessels of all sizes, carrying from one turret upwards.

A one-turret ship would have the deck-house extending within about 10 ft. of the stern, balancing the turret by the other weights in the ship. A three-turret ship would have the third turret mounted on the hurricane-deck before the funnel, bringing four guns right a-head. A four-turret ship would have the second and third turrets mounted at each end of the hurricane-deck, bringing four guns right a-head and astern. It might be thought advisable in some instances to make the upper turrets of lighter iron than the lower ones, merely covering the guns mounted in pairs on turntables by a light iron turret, protecting their crews from rifles, grape, and canister."

71. *A Monitor for Coast and Harbour Defence, and on Submarine Artillery.*—The following is a paper read before the 'Institute of Naval Architects,' by James A. Longridge, Esq., Associate:—"The question of harbour defence is one which, like many other practical questions, does not admit of a general solution. The circumstances are so varying that a mode of defence suited to one locality would be totally unsuitable for another, and it is therefore not surprising that from time to time controversies should have arisen between the advocates of the various systems, such as fixed forts, floating batteries, torpedoes, and other proposed methods. Into this controversy I have no intention to enter, for I am convinced that each system has its own merits and its own defects, and that the selection of one or more systems, their application and combination, can only be properly decided on after a careful consideration of the special circumstances under which the application has to be made. There can, however, be no doubt that wrought-iron will henceforth play a very important part in defensive structures, whether on land or afloat, and the extensive experiments which, within the last few years, have been made, have afforded data from which the engineer can pretty accurately determine the nature of the structure requisite to resist any assumed power of attack. Thus, it is known that a projectile of proper material will pierce an iron plate when its accumulated work, or one-half its *vis viva*, is equal to about 1·4 ft. tons multiplied by the square of the thickness of the plate in inches for each inch of the circumference of the projectile. The effects of various kinds of backing has also been ascertained, and, making use of such data, the engineer can design with some confidence the protection requisite to resist any given attack.

The increasing power of modern artillery has called for increased thickness in armour plating, and whilst a few years ago a 4½ in. plate was justly considered a marvel of skill, we have now arrived at the manufacture of plates of excellent quality of no less than 15 in. in thickness. But the power of artillery is still, I believe, in its infancy, and I am satisfied that we are very far from having attained its limit, and that guns will be produced which will pierce the 15 in. plate as easily as the guns of the present day the plates of three or four years ago.

Land defences seem to have this advantage, that there is no limit to the thickness of the iron plating, while with ships the enormous size which would be required to carry plates of such thickness must soon bring their construction, according to the present type, to a practical limit. But the question is worthy of consideration, whether by a modified system of construction we may not give a greatly increased power both of attack and resistance to ships of war. This has been carried out in one direction by the American monitor system, and in another by Captain Coles' turret system of construction. Both of these have been so fully discussed that I will not waste the time of this meeting by offering any remarks on either, but will at once proceed to offer for consideration a design which appears to me to possess considerable advantage.

This design is based upon two principles, the first being that of oblique surfaces opposed to the shot for defence, the second that of submarine artillery for attack. Before proceeding farther allow me distinctly to disclaim any credit for the invention of these principles. I desire only to lay before the Institution what I think to be practical methods of their application; and, having done so, leave those methods to the consideration of those whose professional experience renders them always the fit judges of such questions.

As it has already been remarked, in direct impact a plate will be pierced when half the *vis viva* of the projectile is equal to 1·4 foot-tons multiplied by the circumference of the shot and by the square of the thickness of the plate, both in inches. But in oblique firing, so far as experience yet goes, it confirms the law which would be given by showing that, instead of the thickness, we must use the thickness divided by the sine of the angle of impact, the formula thus becoming

$$\frac{v^2 W}{29} = 1{\cdot}4 \frac{\pi . d t^2}{\sin.^2 \theta}$$

It is obvious, therefore, that by so arranging the armour-plating that the angle, θ, at which the shot strikes shall be small, a very great resisting power may be given to a plate of moderate thickness. This is what is attempted in the designs represented in the diagrams on the wall. The first is the design of a monitor for harbour defence, of the following dimensions:—Length between perpendiculars, 180 ft.; breadth, extreme, 32 ft.; depth, moulded, 16 ft.; depth between girders, 11 ft.; draught of water, 14 ft.; tonnage, builders' measurement, 875 ft.; horse-power, nominal, 320 ft.

If the maximum angle of depression of the antagonist were 15°, the projectile striking at the water line would strike at an angle of 60°, and the plating at that part being 10 in. thick, the equivalent thickness would be—

$$\frac{10}{\text{sin. } \cdot 60} = \text{about } 11\tfrac{1}{2} \text{ in.}$$

But, in point of fact, such a vessel should never be exposed to such a fire. Being provided with twin-screws or with hydraulic propellers for steering, the vessel would always be kept head on to her opponent, so that the fire would be received nearly in the line of keel. This being so, it will be seen that with an angle of 15°, the angle of impact would not exceed 36° at the water line, so that the equivalent thickness of the plate would be—

$$\frac{10}{\text{sin. } 36^\circ} = 17 \text{ in.}$$

This is a thickness which no gun that is likely to be carried afloat, and which could be depressed to 15°, could pierce, and therefore the object of the monitor would be to go straight into close quarters—in fact, not to fire a gun till her bow was in contact with the hull of the enemy. At the moment of contact she would fire her bow gun, which would place a 9-in. shell into her opponent at a depth of 10 ft. below the water line, and, consequently, beneath her armour-plating. Having done this she would, by means of her twin-screws or hydraulic propellers, pivot round and fire her broadside guns also at the same depth below the water line. She might then drop astern, and, ranging up on the other side of her opponent, deliver the other broadside, which would probably be quite sufficient to decide the contest.

There can, I think, be no doubt as to the result of such a conflict if the monitor can get alongside. The question, then, is, can she do so with impunity to herself? What is to prevent her? In the first place she is impenetrable to the fire of her adversary. Then she has far superior steering powers, and could at all times keep one end in position. Then, again, she would have great speed, because, not being a sea-going vessel, she could carry fuel enough to supply enormously powerful engines for the short time she would require to be under steam.

It may be said that the attacking vessel would ram the monitor. No doubt she would if she could catch her, but it seems to me quite impossible that a large vessel with far inferior manœuvring powers could do so. Besides, the enemy would not have one but three or four of such small opponents to deal with, and it seems to me impossible that she could escape. Her only safety would be in running away, if she had superior speed, and this is exactly what is required in harbour defence.

In the drawings accompanying this paper (not here given) a light upper deck and deck houses are shown, as also an inclined shield. When the object was simply harbour defence, as, for instance, at Spithead or for the Thames, I would abandon these, and the funnel might also be abolished in favour of horizontal apertures voiding the products of combustion at the stern under the quarters, the draught and ventilation being provided for by fans.

Diagram No. 2 represents the same system as applied to a sea-going vessel, carrying besides five submarine guns, two turrets, and deck accommodation for the crew. This vessel would have the following dimensions:—Length between the perpendiculars, 240 ft.; extreme breadth, 40 ft.; depth, 30 ft.; ditto between girders, 22 ft. 6 in.; draught of water, 23 ft.; tonnage, builders' measurement, 1,838 tons; horse-power, nominal, 700. The construction of the guns and the system of working may be thus described:—Diagram No. 6 represents a sectional elevation of the gun and its application to the stern of a vessel. The gun has no trunnions, properly so called, but is mounted on four wheels, which run on a railway laid in the line of keel for the bow gun, and at right angles for the broadside guns. There are proper compressors for regulating the recoil. The muzzle of the gun passes through a valve-chest fixed to the stern or side of the vessel. This chest contains a slide-valve, the rod of which passes through a stuffing-box. The outside or valve-chest carries a circular face, which is faced truly to fit the surfaces of the disc, a cup, which is fixed to the gun. Thus, when the gun is run out, there is a circular air-chamber between the air-chest and the disc. A pipe, fitted with a stop-cock or valve, communicates between the space and another chamber in which a vacuum is kept up by the engines of the vessel or a small donkey engine.

As soon as the gun is run out, and the surfaces of the disc and the valve-chest are in contact, the valve is open, and a partial vacuum formed, and also in the chase of the gun which communicates with the space by holes. The gun is thus held firmly to its place without any lashings. Instead, however, of this apparatus a breech-strap with breaking bolts might be applied. As soon as the gun is loaded, a disc of thin wrought-iron, with an india-rubber ring, is placed in a recess in the muzzle. The gun is then run out, the valve having been raised and the cock or valve opened, and a vacuum established in the inside of the gun and the space, whereby the gun is held fast with a force proportional to the extent of the vacuum and the area of the disc.

Immediately before firing the valve is shut, but as soon as the gun is fired, the gases which pass by the windage enter the space and destroy the vacuum, and the gun is free to recoil, which it does. As soon as the muzzle passes, the valve drops and prevents any water entering the vessel. The gun is then reloaded and run out ready for firing as before."

72. *On the Turret and Tripod System.*—The following paper was read before the same Institute by Admiral Halsted:—"Admiral Halsted began this paper, for which we can only find room for a somewhat lengthy abstract, by saying that a brief summary of his system of combined turret and broadside armament would be brought most readily before the Institute by passages read from the explanatory test-book, which guided the cause for his own seven weeks' examination by the late French Imperial Commission at Paris.

From the preface he read one or two passages, and went on to say that so soon as his undertaking grew into definite form it became imperative to select some defined system of rifled artillery on which to found its further progress. The turrets must have some defined conditions in size, thickness, weight, by which to fix the conditions for the several ships to carry them. These conditions for the turrets must be ruled by the guns to fight in them. The guns to fight in them must necessarily be those best able, with effect and security, to fire the most destructive armour-plate projectiles producible or produced. The confidence thus felt was founded on several reasons shortly stated, but it has now been fully realised by the recent proof of the two first 9 in. Whitworth guns of compressed steel, on which this combined system is based. After firing their 'proof' charge of 45 lb. behind two shots of 320 lb. each, the bores when measured by the micrometer in eighteen places were found to have taken an increase or 'set' amounting in the sum to $\frac{15}{10000}$ in.

These necessities gradually revolved themselves into these four propositions, which, it is submitted, must equally apply to any other attempt practically to solve, on a reasonable system, the still pending controversy between armour ships and guns:—

1. As in all past battles between ships of wood, so in future fights between ironclads, the respective hostile projectiles must decide, *cæteris paribus*, the issue of victory or defeat.

2. The armour-plate projectiles of the future will decide this issue, according to their relative excellence in material, proportions, form, range, accuracy, penetration, and explosive force.

3. These requisite conditions of excellence for the projectiles must rule the conditions for the gun which fires them.

4. These requisite conditions for the guns must rule the mode of turret and turret ship best able to carry and to fight them.

To work out these propositions required the choice not only of some defined and progressive system of rifled artillery, but pointed to some actual projectile within that system on which, as on a 'unit of force,' the whole undertaking might with steady confidence be carried on. And in England that confidence could alone find reasonable foundation in Mr. Whitworth's polygonal system. In his 15-ton 9 in. rifle, then perfecting, and in the most destructive projectile to fire from it which has as yet been devised, viz., a 350 lb. 9 in. shell of compressed steel, with a bursting charge of 20 lb., which thus became the adopted 'unit of force" for fixing all further working conditions up to the ships themselves.

1. Because no ironclad or other ship firing only solid shot can resist an equal fire of destructive shells.

2. Calibre for calibre, Whitworth 'unfused' steel shells are the most destructive yet produced.

3. When these shells of only 7 in. calibre were fired from 800 yards at the Warrior target in November, 1862, the standard of 'work done for power employed' exceeded that of all performances before or since.

4. All Whitworth projectiles have a range, accuracy, penetration, and flat trajectory at present unequalled. They alone include rifled spheres, or can give penetration under water. They are simple in form, material, and manufacture.

5. All essential principles for projectiles and guns have been established by tests of all gradations, throughout all calibres, from the ·451 in. bullet of the Hythe target of April, 1857, to 350 lb. 9 in. shell of 'compressed steel," with its bursting charge of 20 lb. of powder, which is the adapted 'unit of force' for this system.

6. Because no other artillery could or can be found to give equal proof of having attained conditions of 'permanence' to justify adoption for a comprehensive turret system.

The mode of armament proposed by Admiral Halsted, is seven turrets, or cupolas, with two guns each, so arranged that, 1, the fire of four guns can be delivered in the line of keel 'ahead' and 'astern;' 2, the central turrets, and very largely the deck itself, are protected from all raking fire; 3, the deck can be swept fore-and-aft to prevent possibility of boarding, as shown in summary of the command of turrets:—

No. of turret.	Degs.	Points.	No. of turret.	Degs.	Points.
1	315	28	1	8	⅔
2	284	25¼	2	24	2⅓
3	277	24½	3	21	2
4	284	25¼	4	24	2⅛
5	277	24½	5	21	2
6	284	25¼	6	24	2⅛
7	315	28	7	8	⅔
With both guns mean command,	290° 51′	25¾	With single guns there is an additional mean command of	18° 35′	1½

1. The whole fourteen guns can concentrate on points in direct line on either beam, 100 ft. distant from the guns of the central turret No. 4; and can train from thence against ships or batteries. throughout an arc of 50° afore and abaft.

2. The four guns of 1, 2, and of 7, 6, can simultaneously concentrate on points, in direct line of keel, forward and aft, 100 ft. distant from stem and stern. If engaged only forward, or only aft, this fourfold line-of-keel fire can be supplemented; if forward, by the alternate single guns of 6, 7; and, if aft, by those of 1, 2; all four of which command a line of fire of 87°, or only 3° from line of keel, forward and aft, on either side respectively. Whether chasing or chased, a fire of six guns out of fourteen, practically in line of keel, can thus be maintained.

3. To illustrate the bow and quarter fire:—If a radius of 300 ft. be struck from the centre of the centre cupola, it will describe two arcs practically equidistant from both bows and both quarters. And if an angle of 17°, or 1½ point, be measured from the same centre and extended on each side of the keel forward and aft, it will fix two points in each arc, 100 ft. distant, practically, from the nearest part of each bow and each quarter of the ship. While the four guns of 1, 2 are still engaged in line of keel forward, six other guns can concentrate on the above point on the port bow, viz., the two guns each from 3, 6, and the single port guns from 4, 5, respectively. So, at the same time, the four remaining guns can concentrate on the other like point on the starboard bow, viz., the two guns of 7, and the single starboard guns of 4, 5; which two turrets can thus ply their single guns alternately on each of the above bow points. But it is further obvious, on reference to the plate, that turret 1 can concentrate, or alternate, the fire of both its guns, as required, against either the starboard or port bow point, while turret 2 equally commands the starboard point; and the defence of the ship, in single or in general action, can thus be maintained with her whole fourteen guns—*as with an end-on broadside*—throughout an arc of three points, or only 17° divergent on each side of her line of keel forward. And similarly complete and symmetrical is her means of defence aft. Both guns of turret 1, with the starboard single ones of 3, 4, can concentrate a fourfold fire on the point on the port quarter; while a sixfold fire pours on the point on the starboard

quarter from the two guns each of 2, 5, backed by the single port guns of 3, 4, the whole four guns of 7, 6, being still engaged, if needs be, in line of keel aft, or both of those of 7 firing either upon the port or starboard quarter point, and both those of 6 pouring their fire upon the port point.

4. The power of concentration is as simple as it is perfect. It exists from the moment the turrets are 'clear for action,' without any complicated preparation or combination between them, and is carried out by simple direction for all or any turrets to direct their fire on any specified point of an enemy's hull within their command of training.

This illustration of the destructive and defensive power for future ships of the line—and proportionately for all other classes, of which Captain Coles' turret system admits:—1, Abeam, and for 50° on each side of it; 2, in line of keel direct; 3, in bow and quarter action—is obviously unapproachable by any projected mode of broadside armament, even if broadsides could carry 15-ton guns, or larger, or fight them if carried. In the single exampler deck-plan here presented, it far exceeds any power ever yet contemplated since guns were first carried at sea. But it would be indeed difficult, if not impossible, to find any past standard by which to measure the naval force of any nation first possessed of a fleet of such ships; and such difficulty is much enhanced by these further specialities: 1. Whether in single or general action all guns are effective, practically, on all points, without any shifting. 2. Their force, separate or concentrate, requires no evolution to elicit. 3. It exists at anchor, or even if ashore, or in dock, as completely as when at sea; and when at sea either with or without any change of the ship's course.

Admiral Halsted then read letters speaking in terms of praise of the design from Captain Coles, and Messrs. Napier, Watts, and Oliver Lang.

The ratio of length to breadth (6½ times) is adopted from that of the Warrior and sisters. It is less than that of the Minotaur and sisters, which is 6¾ times; but in the Ocean Despatch, and first-class corvettes, designed for 'protection of commerce,' it is 6¾ and 7 times. These dimensions are adopted from the invariable experience of more than twenty years, as being essential for

The following Table of General Dimensions and Particulars Shows the General Dimensions of the Proposed Fleet.

	SHIPS OF THE LINE.			FRIGATES.		CORVETTES.		OCEAN DESPATCH.
	First.	Second.	Third.	Fourth.	Fifth.	Sixth.	Seventh.	Eighth.
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
*Height of 'centre of fire' of turrets above load-water line, ...	19 0	19 0	19 0	17 6	17 6	14 6	14 6	14 6
Height of midship port-sill above load-water line, .	8 9	8 9	8 9	7 9	7 9	6 9	6 9	6 9
Height of spar deck above load-water line, . .	28 0	28 0	28 0	26 0	26 0	22 0	22 0	20 0
Height of upper deck above load-water line, . .	16 0	16 0	16 0	15 0	15 0	12 6	12 6	12 6
Height of armour up to main deck load-water line,† .	5 0	5 0	5 0	4 0	4 0	3 0	3 0	3 0
Total number and calibre of guns in turrets, . .	14 of 9 in.	12 of 9 in.	10 of 9 in.	8 of 9 in.	6 of 9 in.	4 of 9 in.	4 of 9 in.	2 of 9 in.
Total number and calibre of guns in broadside, .	4 of 7 in. 10 of 4 in.	4 of 7 in. 8 of 4 in.	4 of 7 in. 6 of 4 in.	4 of 7 in. 6 of 4 in.	4 of 7 in. 6 of 4 in.	10 of 7 in.	10 of 5½ in.	10 of 5½ in.
Total weight in pounds of combined broadside,‡ .	5,360	4,628	3,896	3,196	2,496	2,150	1,636	1,050

* The height of all can be increased 6 in.

† The armour-plating in all cases extends below the load-water line to an angle of heeling of 11°.

‡ All guns are Whitworth's polygonal rifles with weights of projectiles as follows:—9 in. = 350 lb.; 7 in. = 150 lb.; 5½ in. = 70 lb.; 4 in. = 32 lb.

a maximum of speed with a minimum of power. These co-requisites for economy are not the less important in ships of war than of commerce. But they are additionally important in the former, as the sole basis for all steady co-operative action, an essential of naval force so entirely provided *against* in our present so-called fleet. The same object of effective co-operation has ruled the provision of fuel, which, by its present stint, so paralyses the services of our few best ships. The words of a well-known brother officer, in a recent pamphlet to the late 'First Lord,' are so wise and true to this point, that they will, I am sure, be welcomed. Captain Hoseason says:—

'I wish to impress this simple physical law—that the speed of a steamer can be as effectually increased by the removal or omission of any obstruction opposed to her easy passage through the water, as by increasing the mean power of the engines, and that the increased velocity due to superior speed form is an unmixed and lasting good, whilst speed obtained by a greater development of power forced upon us by inferior speed lines of construction is a lasting evil, which does not end with the first cost of the engines, but is an incubus pressing on us throughout the life of the ship.'

The elements of stability have been determined throughout by those of the Achilles, confessedly our highest modern standard in this war-engine quality hitherto produced in England.

The equipments of all rates have been distributed, as far as practicable, on the well-proved principle that 'all weights should be waterborne severally as well as collectively.' Hence, it is believed, has arisen the superior ease at sea of the Achilles, as now armoured from end to end, when compared with her still central-weighted and less easy sisters Warrior and Black Prince. Hence also the superior ease at sea which the Minotaur, armoured from end to end, will doubtless exhibit.

Enough has now been said to show that the requirements and equipments fixed on have determined the size of the ships necessary to fulfil and carry them, with all sea-going conditions—*i.e.*, the ships have, as it were, fixed their own size, and the requirements thus fixed on have been of the fullest, purposely to illustrate the capacity of the turret system to meet every reasonable demand. But its elasticity is also thereby made evident; and without breach of systematic principle, any class or rate, as here ruled by its number of turrets, may include any number of individual ships, modified in their requirements, and, therefore, size, so as to suit all local or limited services. Thus the particular conditions actually embodied are not attempted to be dogmatically imposed. They fulfil the office of presenting a connected series of defined forms, with defined equipments alone worthy the name of a naval system. But it is believed that Captain Coles' combined turret and tripod can, as a system, yield every description of ship for every description of ironclad service.

Even with these full equipments throughout, this quality has been restricted to that of similar classes hitherto built.

Construction.

The following main details are thus stated:—

The construction of the hull is on the same principle of combined longitudinal and transverse frames as in the Achilles, Agincourt, &c., and other British ironclads of war; with an inner and outer skin plating, as introduced by Mr. Scott Russell in the Great Eastern steamship.

The extreme ends are made cellular and water-tight, with the same preparation for 'ramming' as in the above-named ships. The whole of the immediate space between the inner and outer skin platings is subdivided into sectional watertight compartments, arranged to be used as water ballast to compensate, when necessary, for consumption of fuel, &c., and for maintaining the ship at her proper trim.

Throughout all classes and rates, as the guns are the same, so the armour and backing are of one character and thickness. The outer armour is 6 in. thick; next, teak 11 in. thick; next, 9 in. depth of Mr. John Hughes' hollow metal backing of ¾ in. iron; the bars in contact, running longitudinally from end to end of the ship, and securely riveted to the ¾ in. skin, as well as to the frames, thus combining with, and giving great strength and rigidity to, the whole structure. As in other ironclads, the armour and teak backing taper towards the ends, but not the Hughes' backing. The weight per square foot of the combined resisting media is, maximum 533 lb., minimum 444 lb., mean 488½ lb. The resistance of the metal backing is estimated as equal to 3 in.

plating, making the hull armour equivalent to that of 9 in. plates.

As regards the spar deck it is acknowledged, in sincere obligation, that this most important feature in aid of the whole undertaking is adopted from the rudimental spar decks, connecting turret with turret, in American monitors. In the present application of the spar deck as a war arrangement, the leading idea has been this, the upper deck proper being regarded as if it were the main deck of an ordinary frigate. In such case the beams of the over-head deck would receive end support from the walls or sides of the ship, as pierced with ports with broadside fire. But these beams would receive central supports also, from two rows of stanchions, not fixed, but hinged, and removable as required. Now the support of these spar decks represents, as it were, those two rows of central moveable stanchions converted into a system of fixed central support; the main deck sides or walls of the ship being then altogether removed, so as to give free scope to a central, rotary, all-round turret fire, substituted for that of the broadside. But the strength of that system of trussed diagonal support for the spar deck enables it to fulfil also every office of a complete working upper deck, for boats, capstans, rigging, working ship, &c., &c., whether the turret guns beneath it be silent or in action. And in all bad weather, and specially when steaming head to wind and sea, it thus constitutes a practical freeboard of ample height to secure all comfort and safety. The spar deck is constructed as a girder. Its lower convex skin is of $\frac{5}{16}$ in. steel plates laid perfectly smooth; its upper convex is of $\frac{3}{4}$ in. iron, covered with 3 in. teak. Its edge is stiffened and strengthened by a contiguous box girder of $\frac{1}{2}$ in. plates, 4 ft. deep and 2 ft. wide, constituting the hammock netting. Its diagonal truss support is a patent by R. Napier, Esq.

The sail equipment has been studied with the special view to restore England's navy to its former distinctive character as a sailor service.

To that distinctive character England owes, *par excellence*, her naval eminence; and the education and habits to form that character are acquired—not in the stoke-hole, but on the topsail-yard.

Hence the sail system is here considered as primary to the steam system.

The Proportion of Sail Power.—The English Lisbon squadron of competitive 50-gun sailing frigates, 1850-52, has furnished the standard of 'proportion' under an impression that, as a whole, that squadron presented the most complete sail application of pure sailing days. The proportion is based on the areas of load midship-sections, not displacements, and the mean result from the several ships gives 37 square ft. of plain sail to every square foot of mid-section. When adopting three equal masts with equal sets of yards for the equipment of each ship of this system, it became requisite, towards completing the intended full sail power up to 40 ft. per foot of section, that the fore and main courses should be repeated as a mizen course, and the spanker be repeated as a gaff foresail and gaff mainsail. These sails, however, as being exceptional in the above squadron, are placed separately in the sail table as 'supplemental.' But where masts are so widely separated, these important sails are considered essential to full equipment, and the one screw ship of the above squadron, which was furnished with similar gaff sails, found them most serviceable, not only as 'steam sails,' but on almost every point of sailing.

The forty square feet of combined sail is considered not to be excessive for ships so far more powerful under canvas than any former frigates.

Admiral Halsted then explained at great length the system of sail adopted and the mode of working the ship going head to wind.

As regarded steam equipment, the author stated that this has been left all but entirely to the decision of the selected builders and engineers, but with these primary conditions:—The indicated horse-power for the maximum load speed of fourteen knots before the 'measured mile' to be at least six times the nominal. Every recent improvement for the economy of fuel to be applied. The fuel supply to be one ton per nominal horse-power throughout, but greater in the ocean despatch. After much consideration the superior advantages of two separate sets of boilers and stoke-holes decided that arrangement. The drawings of engines, boilers, &c., have been put in by the engineers, subject, of course, to further reconsideration. Lifting screws, with a simple permanent lifting apparatus, to be always ready, were made essential, it being considered a folly to provide for full sail power with the steam power ready to nullify it. Our first full-powered screw frigate lost two knots out of speeds above six knots when keeping her screw down and fixed for experiment; and a six-knot speed will not always turn a revolving screw.

The mode of turret was ruled by the decision to deliver its fire from over the upper deck at such height above water as to secure its efficiency, practically, in all weathers, and to command the low decks of 'monitors' with a plunging fire. This removal of the chief battery of the ship from the main deck to the upper deck surrendered the main deck to accommodation, except the amount required for the broadside rifles. This supplementary broadside armament is deemed essential to the efficiency of ocean turret ships, the turrets and turret guns of which must be regarded as fixtures. For general purposes of war these smaller rifles must thus be requisite:—1st, for combined operations on land; 2d, for the important use in action of directing a powerful fire of case-shot and shrapnel from true guns of precision into the ports of an enemy, turret, or broadside. The guns to be abandoned whenever greatly overmatched, and remanned when the fire on them slackens; 3d, for defence against attack by boats; 4th, for daily discipline and exercise at 'quarters,' with or without shot practice; 5th, for all signals and salutes.

The mode of turret was further studied to give full development to this main deck accommodation by free access and ventilation throughout all decks. The lower portion, or 'turret bed,' was constituted as a fixed circular main-deck hatchway, having coamings 4 ft. 6 in. high as securely armoured as the turret itself. On the top surface of the walls of this fixed 'turret bed' the turret itself rotates on coned rollers embedded in a circular box girder embodied into the floor of the turret, the armoured sides of which drop below the top of the wall of 'turret bed,' and thus protect the roller and roller path.

The diameter of the turret also extends beyond that of the turret bed on which it works, so as to leave between the two an annular open space 2 ft. 6 in. in width. The floor of the turret being laid in grating work, removable whenever required, this annular space, 2 ft. 6 in. wide, and of 17 ft. minimum diameter, provides at all times an ample central ventilation to the main deck accommodation additional to its ports, besides a free access by ladder-ways, whether for manning the turret itself or to communicate with the upper and spar and lower decks, even if all other hatchways leading to those decks were closed.

In like manner, the same central ventilation, additional to scuttles and free access with all other decks, is provided for the lower deck by means of the fixed turret bed of 13 ft. interior diameter, the armoured sides of which give protection to the transit from below of all munitions required in the turret, as well as to the vertical steel shaft turning the turret itself, and which is worked by mechanical or manual power applied on the free space of the lower deck under protection of the ship's armour.

Even when in action, a small central hanging ladder revolving with the turret communicates direct through each turret from the spar deck above to all parts below, providing armoured access by messenger for all orders to turrets, main-deck battery, lower deck, engine-room, stoke-holes, and magazines.

The armour of turrets consists of an inner skin of 1 in. iron; then Hughes' metal backing of ¾-in. iron, riveted around the skin in rings in contact with each other and 7 in. deep; then vertical or diagonal teak, 8 in.; then 8 in. armour plates, forged in complete rings 2 ft. 6 in. wide, shrunk over all; no vertical joints. The walls are thus 2 ft. thick; inner diameter, 21 ft.; outer, 25 ft. The combined resistance of turrets and turret beds is calculated as equal to 11 in. plates, exclusive of the 1 in. skin and 8 in. of teak. The armour of turret bed is an inner skin 2 in.; then Hughes' backing, vertical, in contact, 10 in. deep; then 8 in. armour plates forged in complete rings as before.

The turret is a patent by R. Napier, Esq., and as no series of drawings could have made it clearly comprehensible in all points, it was therefore decided to model it with every care for full explanation, which the author will be happy to afford to all its visitors at the Kensington museum.

The muzzle pivoting gun carriages of Captain Heathorn, R.A., are adopted for turret and broadside armaments throughout. They have, according to Admiral Halsted, great constructive merit — 1st, in the simplicity and small number of parts; 2d, in their capability for any required strength; 3d, in their adaptability to all guns for all services except boats, in which they would be needless; 4th, in providing a minimum of port with a maximum of training command, vertical and horizontal. The parts, though simple and few, as well as their action, are the product of practical mathematical application. The muzzle pivoting appliance can be worked by any mechanical power.

The paper concluded with some remarks on boat systems and coast warfare, and the steerage of screw ships."

For the discussion which followed on the reading of the last two papers see the 'Engineer' of May 8th, 1868.

73. *Floating Dry Dock for the Scinde Railway Company.*— "In our large cut," says the 'Engineer' of date February 7th, 1868, "we illustrate a floating dry dock, built from the designs of Mr. G. P. Bidder, by the Victoria Graving Docks Company, for the Scinde Railway Company, which is to form part of their Flotilla in the river Indus, where it will be moored on arrival in India.

The dock consists of a wrought iron open top pontoon, having double sides carried up 8 ft. 6 in. above the top of the interior framing or floor on which the vessel to be repaired will rest. This, therefore, forms a hollow wall or bulwark round the ship, which floats within it when the floor is submerged, as is requisite for the reception of the craft. One end is made of a like form to the bows of a ship so as to meet the stream, and the other end is square the full breadth of the pontoon. It is secured above the level of the framing by a hinged caisson or gate. The hollow bulwarks forming the sides of the dock are divided into twelve water-tight compartments, by close diaphragms at certain intervals. The floor, which is divided into ten compartments, consists of thirty-four wrought iron transverse girders, placed on the bottom skin of the dock, the top flange being used as a bed for the wood blocking on which the vessel is to rest. These girders are stiffened by three longitudinal girders of the same depth, carried the entire length of the dock. Valves, ten in number, each having a circular aperture 1 ft. 9 in. in diameter, are attached inside the wrought iron bottoms, for the purpose of admitting water when the dock is to be lowered for the reception of a vessel. An enlarged view of one valve is shown in our engraving. Two well executed 12-horse power engines, manufactured by the Messrs. Jones, at the Victoria Graving Dock Works, are to be erected as shown in our large illustration for working the pumps, Gwynn's patent, by which the water is ejected from the dock when the vessel is in position, and is thus rendered dry for the shipwrights to work, the caisson, gates, and the valves having been previously closed. The dimensions of the dock are as follows:—Extreme length of dock from bow to stern, 294 ft. 6 in.; extreme length over all, 303 ft.; extreme length available for vessels, 208 ft.; extreme breadth over all, 70 ft. 2 in.; extreme breadth available for vessels, 62 ft.; distance between centres of sides, 3 ft. 6 in.; extreme height of sides of dock, 12 ft. 6 in.; height of floor girders, 4 ft.; draught of dock for docking a vessel 3 ft., 9 ft. 6 in.; height of top of sides above water line at 3 ft. draught, 3 ft.; height of top of sides of platform, 3 ft. 10 in.; breadth of platform around sides, 4 ft.; breadth of platform for engine houses, &c., 12 ft.; length of platform for engine houses, &c. (each side) 48 ft.; height of caisson gate, 8 ft. 8 in.; breadth at top, 2 ft.; breadth at bottom, 6½ in. The engines are of the ordinary description. The pumps are driven direct from the fly wheels, and each pump is capable of lifting six thousand gallons per minute. One engine is provided with an extra pulley for driving the workshop machinery as well as the pump. The sheds on the other side are for offices, stores, &c. The following are the principal dimensions:—Diameter of cylinder, 12 in.; stroke, 20 in.; pressure, 45 lb.; revolutions, 60 per minute; grate surface of boiler, 15 square feet; heating ditto, 202 square feet; tubes (63) 5 ft. long, 2 in. diameter; bore of pump, 1½ in.; 20 in. stroke; connecting rod, 5 ft.; slide lap, $\frac{11}{16}$ in.; lead, $\frac{5}{32}$ in.; travel, 3⅛ in.; cut off at ·78 of stroke.

The gates are each hung by five hinges fixed to the end transverse girder, one being at each end in the rebate on the main girder, and the others opposite each longitudinal girder. At each hinge the web plates are cut away for 2⅞ in. height, so as to allow of play, and the bottom plates and angle irons discontinued. On either side of each hinge a solid plate diaphragm is fitted in the trough, and secured in the box by an angle iron 2½ in. × 2½ in. × 5/16 in., carried round it, and jointed and covered in the centre of its height. The long spaces between the diaphragms are caulked and made air-tight in order to float the gate in rising. Each compartment of the caisson is furnished with two brass screw valves, the lower 8 in. in diameter, placed on the outside of the gate, and the upper 4 in. in diameter, on the inside. These valves constitute outlets or inlets for air or water as may be requisite. When the water has been excluded from the two end compartments of the dock, the excess of flotation thus provided will be more than counterbalanced, and the gate made to sink in the water by iron kentledge added to the outer edge of the top plate. The hinges are made of malleable cast iron and the pin of wrought iron, 4 in. in diameter. Each hinge is attached to the gate by twelve screw-bolts, each ¾ in. in diameter, and the socket attached to the end transverse girder by six similar bolts. The joint of the gate is made water-tight by the pressure of the inner web plate against a packing of india-rubber continued in one sheet round the end of the dock. This rubber is attached to a timber packing, which is secured by two lines of screw bolts, ⅜ in. in diameter and 12 in. pitch, to the flush surfaces of the back of the rebate at the end of the dock. The top of the outer edge of the gate carries a piece of timber 5 in. × 3 in., as a cushion or padding. The gate, when horizontal, will rest on five wrought-iron brackets each 8 ft. 6 in. long, attached to the end transverse girders in a line with the hinges and longitudinal girders. The gate is pulled up by a chain attached to a gusset piece at each end, which is formed of two rows of 2½ in. × 2½ in. × 5/16 in. angle iron, surrounding a plate 2 ft. 6 in. high, 2 ft. wide at bottom, and 6½ in. at top. The two shackle bolts for attachment are each 1 in. in diameter, fixed to the flange of the angle iron at the top. The gate will be closed by chains made of ⅝ in. round iron, attached at each end as before described, and worked at the other end by double-purchase crabs, each crab being capable of lifting ten tons. The dock will be secured in the Indus by two mooring chains, one on either side the bow; each chain being 60 fathoms in length, made of 1¾ in. iron, attached at the up-stream end to the wrought iron shaft of a cast iron screw mooring of 4 ft. diameter in the screw. The end of each chain terminates in a bridle or double chain, the ends of which will be attached to opposite sides of the bow.

The hollow bulwarks or sides of this dock have sufficient displacement to support the whole of its own weight, with its steam-engines, workshops, &c., at an immersion of from 3 ft. to 4 ft. less than the total depth of the sides, and notwithstanding that water is admitted to the central part or compartments in the bottom, when the caisson gate at the end is closed with a vessel inside, and the water pumped out; the floating power thus obtained raises the dock up against the keel of the vessel to be repaired.

Valves are provided in each compartment, so that when the vessel is to be undocked the water is admitted by them, and the dock sinks to the depth due to its weight as compared with the displacement due to the immersion of the sides, as can be regulated at pleasure by admitting water into special compartments of the sides, and the gate then allowed to open by turning round on its hinges until it becomes on a line with the floor of the pontoon, in which position it is retained by the excess of its own weight over its flotation.

The dock, as we before stated, is provided with Gwynne's patent centrifugal pumps, two in number, each of which will be capable of discharging 6,000 gallons of water per minute. The arrangement of pipes and pumps is extremely simple.

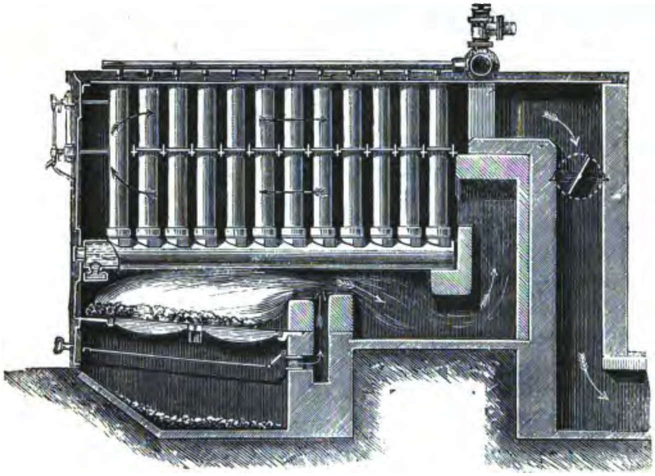
There is one pump, with its system of pipes, on either side of the dock. These pumps are constructed with a double suction, by which means a perfectly straight suction has been obtained. From the main pipe three inlets branch off on one side and two on the other side of the pump. The inlets have conical mouthpieces, and can be closed by sluice valves. The branches curve gradually into the main pipe in order to reduce resistance as much as possible. The diameter of the inlet branches is 12 in., as is also the outer part of the main pipe, but gradually increases to 14 in. at the second branch. From the third branch to the pump the diameter of the main pipe is 15 in., and the diameter of the discharge bend 18 in. The most striking feature of this pumping machinery is its simplicity, and the circumstance that all self-acting valves, which invariably increase the resistance considerably, have been avoided.

Should it be necessary to stop the pumps when the discharge opening is already above water it can be done readily, either by closing the discharge opening or all the sluice valves. A saving of two feet of lift and a proportionate amount of power could have been effected, we imagine, if the pumps had been placed on the bottom of the dock, which in this case, however, Mr. Bidder could not manage.

We have examined this dock during the progress of its construction, and we are able to state that the workmanship is excellent, and reflects much credit on Messrs. Jones and the contractors."

INDEX.

HOWARD'S SAFETY BOILER AND SUPERHEATER.



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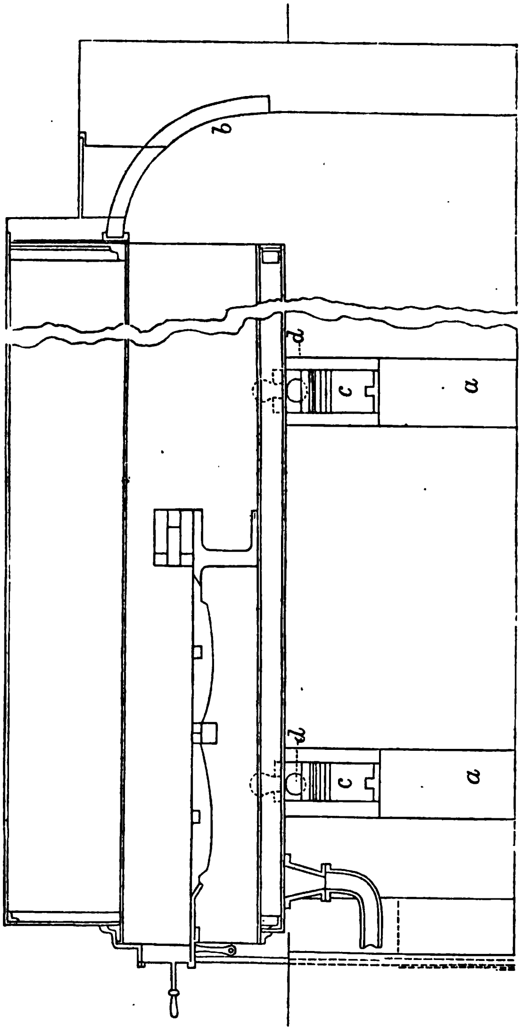

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By this mode of setting Boilers the freest inspection of all the parts is permitted, so that all leakages, cracks in angle iron, plates, and seams, and corrosion of parts, can be certainly and quickly detected. The boiler virtually is set in a hot-air chamber, and all the parts are acted equally upon by the fire and heated gases. The equality of expansion, thus to a large extent secured, is also further attained by setting the Boiler on "rollers" and "cradles," which keep it in a perfectly horizontal position, without the possibility of being strained by the giving way of the brickwork, which is a frequent cause of started rivets.

For a full Description, with Illustrations, see Volume of Engineering Facts and Figures for 1868,

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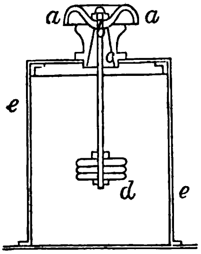
PARSONS' PATENT SAFETY VALVE.



The Illustration will explain the construction of this valve. It covers the orifice by a spherical face *b*, and is confined in a scroll-like form in section *c c*, extending over the flanges projecting from the body of the valve, leaving a vaulted-like recess from 2 to 3 inches encircling the whole of the valve and outwards to the angle of 60°, which, meeting, would form a cone above the centre of the valve. It will be seen from the annexed sketch that this valve is kept in contact with a very small surface of the seating, by weights, *d*, hanging in the interior part of the dome *e*, on a spindle passing through the valve to a brass nut on the top *c*; any additional weighting is quite impossible by the person in charge of the boiler, and the valve cannot stick or be impeded from lifting by becoming jammed, as it simply sits on a knife-like edge. The next advantage arising from the vaulted formation of the valve is, that the steam, in issuing between the points of the seating, is directed downwards, and by the shape of the outer edge of the valve being at the angle of 60°, the steam issues forth in the shape of a large cone whose base is the dome, and the frustrum is the centre of the valve. Now the recoil caused by the volume of atmospheric air being displaced by the steam pressing downwards, will efficiently lift the safety-valve to the requirement of the production of steam in the boiler. And so well has this system proved its efficiency, that, in every instance where a safety-valve has been erected, it has been found invariably to relieve itself accurately to the gauge under trying circumstances where, in the old valve, explosions must have undoubtedly followed. The accurate action of this valve must be seen to be believed.

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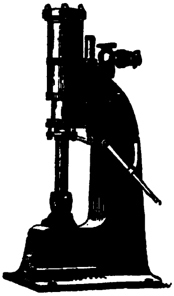

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