FRONTISPIECE to the SECOND VOLUME

THE

MECHANIC;

OR,

COMPENDIUM

OF

PRACTICAL INVENTIONS;

CONTAINING

TWO HUNDRED AND FIFTEEN ARTICLES,

SELECTED AND ORIGINAL,

Arranged under the following Heads:

I. MANUFACTURES AND TRADE,
II. PHILOSOPHICAL APPARATUS AND THE FINE ARTS,
III. RURAL AND DOMESTIC ECONOMY, AND MISCELLANIES

ILLUSTRATED BY

One Hundred and Eight Copperplate Engravings;

WITH A

COPIOUS ANALYTICAL INDEX.

BY JAMES SMITH,

AUTHOR OF "THE PANORAMA OF SCIENCE AND ART."

IN TWO VOLUMES.—VOL. II

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Contents of Vol. II.

Inventions relative to Rural and Domestic Economy, and Miscellanies.

APPENDIX.

THE MECHANIC:

OR,

COMPENDIUM OF PRACTICAL INVENTIONS.

CLASS II.—RELATIVE TO PHILOSOPHICAL APPARATUS AND THE FINE ARTS.

An Account of a Method of dividing astronomical and other Instruments by ocular inspection; in which the usual Tools for graduating are not employed; the whole operation being so contrived, that no error can occur but what is chargeable to Vision, when assisted by the best optical means of viewing and measuring minute quantities.

This paper was accompanied by the following Letter from the Inventor to the Astronomer Royal.

SIR, London, June 23, 1808.

THE science which you profess, and the art which it has fallen to my lot to cultivate, are so nearly allied, that had I been personally unknown to you, and a stranger to the patronage which you have always given to the useful arts, I should still have wished the papers annexed to have passed through your hands to the public. You will readily thence infer, how much I feel myself flattered by having obtained, from your condescension, the privilege of their being presented to the Royal Society through a channel which must secure for them the most favourable reception.

My reputation for dividing of astronomical and other instruments, is by no means unknown to the world; but the means by which I accomplish it, I have hitherto thought proper to conceal: and if that concealment had been essential to the advancing of that reputation, or to the immediate security of my own interests, it is probable that it might still longer have rested with myself. Relying, however, as I do, on the probability that I shall find sufficient employment while I am capable of active life, I know of no honourable motive that should prevent me from allowing it to be useful to others.

How a young artist, who may be just beginning to make his way to fame or wealth, may receive it, I know not; but I wish him to understand, that I consider myself now in the act of making him a very valuable present.

I have the honour to be, Sir,
Your obliged and obedient servant.
EDWARD TROUGHTON.

To the Rev. NEVIL MASKELYNE, D. D.
Astronomer Royal, F. R. S. &c.

ACCOUNT OF A METHOD OF DIVIDING ASTRONOMICAL AND OTHER INSTRUMENTS, BY OCULAR INSPECTION, &c.

It would ill become me, in addressing myself to the Members of this Society upon a subject which they are so well enabled to appreciate, to arrogate to myself more than may be assigned as my due, for whatever of success may have been the result of my long continued endeavours, exerted in prosecuting towards perfection *the dividing of instruments immediately subservient to the purposes of astronomy.* A man very naturally will set a value upon a thing on which so much of his life has been expended; and I shall readily, therefore, be pardoned for saying, that considering some attainments, which I have made on this subject, as too valuable to be lost, and being encouraged also by the degree of attention which the Royal Society has ever paid to practical subjects, I feel myself ambitious of presenting them to the public through what I deem the most respectable channel in the world.

It was as early as the year 1775, being then apprentice to my brother, the late Mr. John Troughton, that the art of dividing had become interesting to me; the study of astronomy was also new and fascinating; and I then formed the resolution to aim at the nicer parts of my profession.

At the time alluded to, my brother, in the art of dividing, was justly considered the rival of Ramsden; but he was then almost unknown beyond the narrow circle of the mathematical and optical instrument makers; for whom he was chiefly occupied in the division, by hand, of small astronomical quadrants, and Hadley's sextants of large radius. Notwithstanding my own employment at that time was of a much inferior nature, yet I closely inspected his work, and tried at leisure hours on waste materials to imitate it. With as steady a hand, and as good an eye, as young men generally have, I was much disappointed at finding, that after having made two points, neat and small to my liking, I could not bisect the distance between them, without enlarging, displacing, or deforming them with the points of the compasses. This circumstance gave me an early dislike to the tools then in use; and occasioned me the more uneasiness, as I foresaw that it was an evil which no practice, care, nor habit, could entirely cure. Beam compasses, spring dividers, and a scale of equal parts, in short, appeared to me little better than so many sources of mischief.

I had already acquired a good share of dexterity, as a general workman. Of the different branches of our art, that of *turning* alone seemed to me to border on perfection. This juvenile conceit, fallacious as I afterwards found it, furnished the first train of thoughts, which led to the method about to be described; for it occurred to me, that if I could by any means apply the principles of turning to the art of dividing instruments, the tools liable to objection might be dispensed with. The means of doing this was first suggested, by seeing the action of the perambulator, or measuring wheel; the surface of the earth presenting itself as the edge of the instrument to be divided, and the wheel of the perambulator as a narrow roller acting on that edge; and hence arose an idea that some easy contrivance might be devised, for marking off the revolutions and parts of the roller upon the instrument. Since the year above mentioned, several persons have proposed to me, as new, dividing by the roller, and I have been told, that it also occurred long ago to Hook, Sisson, and others; but, as Hatton on watch-making says, " I do not consider the man an inventor, who merely thinks of a thing; to be an inventor, in my opinion, he must act successfully upon the thought, so as to make it useful." I had no occasion, however, to have made an apology for acting upon a thought, which, unknown to me, had been previously conceived by others; for it will be seen in the sequel, how little the roller has to do in the result, and with what extreme caution it is found necessary to employ it.

When a roller is properly proportioned to the radius of the circle to be divided, and with its edge made a small matter conical, so that one side may be too great, and the other side too little, it may be adjusted so exactly, that it may be carried several times round the circle, without the error of a single second; and it acts with so much steadiness, that it may not unaptly be considered as a wheel and pinion of indefinitely high numbers. Yet, such is the imperfection of the edges of the circle and roller, that, when worked with the greatest care, the intermediate parts, on a radius of two feet, will sometimes be unequal to the value of half a minute or more. After having found the terminating point of a quadrant or circle so permanent, although I was not prepared to expect perfect equality throughout, yet I was much mortified to find the errors so great, at least ten times as much as I expected; which fact indicated; beyond a doubt, that if the roller is to be trusted at all, it must only be trusted through a very short arc. Had there been any thing slippery in the action, which would have been indicated by measuring the same part at different times differently, there would have been an end of it at once; but, that not being the case in any sensible degree, the roller becomes a useful auxiliary to fill up short intervals, whose limits have been corrected by more certain means.*

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* There are two things in the foregoing account of the action of the roller, which have a tendency to excite surprise. The first is, that the roller should, in different parts of its journey round the circle, measure the latter so differently. One would not wonder, however, if in taking the measure across a ploughed field, it should be found different to a parallel measure taken upon a gravel walk; and, in my opinion, the cases are not very dissimilar. Porosity of the metal, in one part of the circle more than in the other, must evidently have the same effect; brass unhammered is always porous; and the part, which has felt the effect of two blows, cannot be so dense as other parts which have felt the effect of three; and, should the edge of the circle be indented by *jarring-turning*, it would produce a visible similitude to ploughed ground. Every workman must be sufficiently upon his guard against such a palpable source of error; yet, perhaps, with our greatest care we may not be able to avoid it altogether. The second is, that notwithstanding the inequality above mentioned, the roller having reached the point upon the circle from whence it set out, should perform a second, third, &c. course of revolutions, without any sensible deviation from its former track; this is not perhaps so easily accounted for. It must be mentioned, that the exterior border of the circle should be *turned rounding*, presenting to the roller a convex edge, whose radius of curvature is not greater than one-tenth of an inch. Now, were the materials perfectly inelastic and impenetrable, the roller could only touch the circle in a *point*, and in passing round the circle, it could only occupy a *line* of contact. This in practice is not the case; the circle always marks the roller

Bird, who enjoyed the undisputed reputation of being the most accurate divider of the age in which he lived, was the first who contrived the means how to render the usual divisions of the quadrant bisectional; which property, except his being unusually careful in avoiding the effects of unequal expansion from change of temperature, chiefly distinguished his method from others who divided by hand. This desirable object he accomplished by the use which he made of a finely divided scale of equal parts. The thing aimed at was, to obtain a point upon the arc at the highest *bisectional number of divisions* from 0, which in his eight-feet quadrants was 1024,=85° 20′. The extent of the beam compasses, with which he traced the arc upon the limb of the instrument to be divided, being set off upon that arc, gave the points 0° and 60°: which, being bisected, gave 30° more to complete the total arc. A second order of bisections gave points at 15° distance from each other; but that which denoted 75° was most useful. Now, from the known length of the radius, as measured upon the scale, the length of the chord of 10° 20′ was computed, taken off from the scale, and protracted from 75° forwards; and the chord of 4° 40′, being ascertained in the same manner, was set off from 90° backwards, meeting the chord of 10° 20′ in the continually bisectional arc of 85° 20′. This point being found, the work was carried on by bisections, and the chords, as they became

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with a broad list, and thereby shows that there is a yielding between them to a considerable amount. The breadth of this list is not less than one-fiftieth of an inch; and it follows, that at least 12° of the circle's edge must be in contact at the same time; that the two surfaces yield to each other in depth, by a quantity equal to the *ver. sin.* of half that arc, or $\frac{1}{1800}$th of an inch; and that the circle has always hold of the roller by nearly 1° of the edge of the latter. Whoever has examined the surfaces of metals which have rolled against each other, must have observed that peculiar kind of indentation that always accompanies their action; and there can be no doubt that the particles of a roller, and those of the surface on which it acts, which mutually indent each other, will, upon a second course begun from the same point, indent each other deeper: this is not, however, exactly the case in question: for, whatever of fitting might have taken place between the surfaces of our roller and circle in the first revolution of the former, one should imagine would be obliterated by the fifteen turns which it must repeat over fresh ground. Experience shows, however, as every one will find who tries the experiment with good work, that on coming round to the point of commencement, the roller has the disposition to regain its former track; for, were this not the case, although the commensurate diameters were adjusted so exactly as to be without sensible error in one course, yet a less error than that which is so would become visible when repeated through many courses.

small enough, were set off beyond this point to supply the remainder of the quadrantal arc. My brother, whom I mentioned before, from mere want of a scale of equal parts upon which he could rely, contrived the means of dividing bisectionally without one. His method I will briefly state as follows, in the manner which it would apply to dividing a mural quadrant. The arcs of 60° and 30° give the total arc as before; and let the last arc of 30° be bisected, also the last arc of 15°, and again the last arc of 7° 30′. The two marks next 90° will now be 82° 30′ and 86° 15′, consequently the point sought lies between them. Bisections will serve us no longer; but if we divide this space equally into three parts, the most forward of the two intermediate marks will give us 85°, and if we divide the portion of the arc between this mark and 86° 15′ also into three, the most backward of the two marks will denote 85° 25′. Lastly, if we divide any one of these last spaces into five, and set off one of these fifth parts backwards from 85° 25′, we shall have the desired point at 1024 divisions upon the arc from 0°. All the rest of the divisions which have been made in this operation which I have called marks, because they should be made as faint as possible, must be erased; for my brother would not suffer a mark to remain upon the arc to interfere with his future bisections.

Mr. Smeaton, in a paper to be more particularly noticed presently, justly remarks the want of a unity of principle in Mr. Bird's method: for he proceeds partly on the ground of the protracted radius, and partly upon that of the computed chord; which, as Smeaton observes, may or may not agree. Bird, without doubt, used the radius and its parts in order to secure an exact quadrant; but Smeaton, treating exactness in the total arc as of little value to astronomy, would, in order to secure the more essential property of equality of division, reject the radius altogether, and proceed entirely upon the simple principle of the computed chord. The means pursued by my brother, to reach the point which terminates the great bisectional arc, is the only part in which it differs from Bird's method; and I think it is without prejudice that I give it the preference. It is obvious that it is as well calculated to procure equality of division, as the means suggested by Smeaton; at the same time that it is equal to Bird's in securing the precise measure of the total arc. It proceeds entirely upon the principle of the protracted chord of 60° and its subdivision; and the uncertainty, which is introduced into the work by the sparing use which is made of subdivision by 3 and 5, is, in my opinion, likely to be much exceeded by the errors of a divided scale,* and those of the hand and eye, in taking off the computed chords, and applying them to the arc of the instrument to be divided.

Ramsden's well known method of dividing by the engine, unites so much accuracy and facility, that a better can hardly be wished for; and I may venture to say that it will never be superseded, in the division of instruments, of *moderate radii.* It was well suited to the time in which it appeared; a time when the improvements made in nautical astronomy, and the growing commerce of our country, called for a number of reflecting instruments, which never could have been supplied, had it been necessary to have divided them by hand: however, as it only applies to small instruments, it hardly comes within the subject of this paper.

The method of Hindley, as described by Smeaton,† I will venture to predict will never be put in practice for dividing astronomical instruments, however applicable it might formerly have been for obtaining numbers for cutting clock-work, for which purpose it was originally intended. It consists of a train of violent operations with blunt tools, any one of which is sufficient to stretch the materials beyond, or press them within their natural state of rest; and although the whole is done by contact, the nature of this contact is such as, I think, ought rather to have been contrasted with, than represented as being similar to, the nature of the contact used in Smeaton's pyrometer, which latter is performed by the most delicate touch; and is represented, I believe justly, to be sensible to the $\frac{1}{60000}$th part of an inch. Smeaton has, however, acquitted himself well, in describing and improving the method of his friend; and the world is particularly obliged to him for the historical part of his paper, as it contains valuable information which perhaps no one else could have written.

The only method of dividing large instruments now practised in London, that I know of, besides my own, has not yet, I believe, been made public. It consists in dividing by hand with beam compasses and spring dividers, in the usual way; with the addition of examining the work by microscopes, and

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* That Bird's scale was not without considerable errors, will be shown towards the end of this paper.

† Philosophical Transactions for 1788.

correcting it, as it proceeds, by pressing forwards or backwards by hand, with a fine conical point, those dots which appear erroneous; and thus adjusting them to their proper places. The method admits of considerable accuracy, provided the operator has a steady hand and a good eye; but his work will ever be irregular and inelegant. He must have a circular line passing through the middle of his dots, to enable him to make and keep them at an equal distance from the centre. The bisectional arcs, also, which cut them across, deform them much; and, what is worse, the dots which require correction (about two-thirds perhaps of the whole) will become larger than the rest, and unequally so in proportion to the number of attempts which have been found necessary to adjust them. In the course of which operation, some of them grow insufferably too large, and it becomes necessary to reduce them to an equality with their neighbours. This is done with the burnisher, and causes a hollow in the surface, which has a very disagreeable appearance. Moreover, dots which have been burnished up are always ill-defined, and of a bad figure. Sir George Shuckburgh Evelyn, in his paper on the Equatorial,* denominates these "doubtful or bad points;" and (considering the few places which he examines) they bear no inconsiderable proportion to the whole. In my opinion, it would be a great improvement of this method, to divide the whole by hand at once, and afterwards to correct the whole; for a dot forced to its place, as above, will seldom allow the compass point to rest in the centre of its apparent area: therefore other dots made from those will scarcely ever be found in their true places. This improvement also prevents the corrected dots from being injured, or moved, by the future application of the compasses, no such application being necessary.

I will now dismiss this method of dividing, with observing that it is tedious in the extreme; and did I not know the contrary beyond a doubt, I should have supposed it to have surpassed the utmost limit of human patience.† When I made

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* Philosophical Transactions for 1793.

† At the time alluded to, the double microscopic micrometer was unknown to me, and I did not learn its use, for these purposes, till the year 1790, from general Roy's description of the large theodolite. Previous to that time, I had used a frame which carried a single wire very near the surface to be divided; this wire was moveable by a fine micrometer screw, and was viewed by a single lens inserted in the lower end of a tube, which, for the purpose of taking off

my first essay at subdividing with the roller, I used this method, according to the improvement suggested above, of correcting a few primitive points; but even this was too slow for one who had too much to do. Perhaps, however, had my instruments been divided for me by an assistant, I might not have grudged to have paid him for the labour of going through the whole work by the method of adjustment; nor have felt the necessity of contriving a better way.

I might now extend the account of my method of dividing to a great length; by relating the alterations which the apparatus has undergone during a long course of years,* and the various manner of its application, before I brought it to its present state of improvement; but I think I may save myself that trouble, for truly I do not see its use: I will, therefore, proceed immediately to a disclosure of the method, as practised on a late occasion, in the dividing of a four feet meridian circle, now the property of Stephen Groombridge, esq. of Blackheath.

The surface of the circle which is to receive the divisions, as well as its inner and outer edges, but especially the latter, should be turned in the most exact and careful manner; the reason for which will be better understood, when we come to describe the mode of applying the roller; and, as no projection can be admitted beyond the limb, if the telescope, as is generally the case, be no longer than the diameter, those parts which extend further must be so applied, that they may be removed during the operation of dividing. Figs. 1 and 2, plate LXXVII, represent the principal part of the apparatus; fig. 1. showing the plan, and fig. 2. the elevation; in both of which the same letters of reference are affixed to corresponding parts, and both are drawn to a scale of $\frac{4}{16}$ths of the full dimensions. A A is a part of the circle, the surface of which is seen in the plan, and the edge is seen in the elevation. BBB is the main plate of the

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the parallax, was four inches long. The greatest objection to this mode of constructing the apparatus is, that the wire being necessarily exposed, is apt to gather up the dust; yet it is preferable to the one now in use, in cases where any doubt is entertained of the accuracy of the plane which is to receive the divisions.

* The full conception of the method had occupied my mind in the year 1778; but as my brother could not be readily persuaded to relinquish a branch of the business to me in which he himself excelled, it was not until September, 1785, that I produced my first specimen, by dividing an astronomical quadrant of two feet radius.

apparatus, resting with its four feet *a a a a* upon the surface of the arc; these feet, being screws, may be adjusted so as to take equal shares of the weight, and then are fastened by nuts below the plate, as shown in fig. 2. CC and DD are two similar plates, each attached to the main plate, one above and the other below, by four pillars; and in them are centred the ends of the axis of the roller E. F and G are two friction wheels, the latter firmly fastened to B, but the former is fixed in an adjustable frame, by means of which adjustment these wheels and the roller E may be made to press, the former on the interior, and the latter on the exterior edge of the circle, with an equal and convenient force.* At the extremities of the axis of the roller, and attached to the middle of the plates C and D, are two bridges, having a screw in each; by means of which an adjustment is procured for raising or lowering the roller respecting the edge of the circle, whereby the former, having its diameter at the upper edge about ·001 of an inch greater than at the lower edge (being, as before described, a little conical,) it may easily be brought to the position where it will measure the proper portion of the circle.

Much experience and thought upon the subject have taught me, that the roller should be equal to one-sixteenth part of the circle to be divided, or that it should revolve once in 22° 30′; and that the roller itself should be divided into sixteen parts; no matter whether with absolute truth, for accuracy is not at all essential here. Each of such divisions of the roller will correspond with an angle upon the circle of 1° 24′ 22″·5, or $\frac{1}{256}$th part of the circle. This number of principal divisions was chosen, on account of its being capable of continual bisection; but they do not fall in with the ultimate divisions of the circle, which are intended to be equal to 5′ each.

The next thing to be considered is, how to make the roller measure the circle. As two microscopes are here necessary, and those which I use are very simple, I will in this place give a description of them. Fig. 6, is a section $\frac{4}{5}$ths of the full size, and sufficiently explains their construction, and the position of the glasses; but the micrometer part and manner of mounting it, are better shown at H, in figs. 1 and 2. The micrometer

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* Sufficient spring for keeping the roller in close and uniform contact with the edge of the circle, is found in the apparatus, without any particular contrivance for that purpose; the bending of the pillars of the secondary frames and of the axis of the roller, chiefly supplies this property.

part consists of an oblong square frame, which is soldered into a slit, cut at right angles in the main tube; another similar piece, nicely fitted into the former, and having a small motion at right angles to the axis of the microscope, has at one end a cylindrical guide pin, and at the other a micrometer screw; a spring of steel wire is also applied, as seen in the section, to prevent play, by keeping the head of the micrometer in close contact with the fixed frame. This head is divided into one hundred parts, which are numbered each way to 50; the use of which will be shown hereafter. A fine wire is stretched across the moveable frame, for the purpose of bisecting fine dots. Two of these microscopes are necessary; also a third, which need not have the divided head, and must have in the moveable frame two wires crossing each other at an angle of about 30°: this microscope is shown at I, fig. 1. In the two first micrometers, a division of the head is of the value of about $0''{\cdot}2$, and the power and distinctness such, that when great care is taken, a much greater error than to the amount of one of these divisions cannot well be committed in setting the wire across the image of a well-made dot. The double eye-glass has a motion by hand, for producing distinct vision of the wire; and distinct vision of the dots is procured by a similar adjustment of the whole microscope.

The first step towards sizing the roller, is to compute its diameter according to the measure of the circle, and to reduce it agreeably thereto, taking care to leave it a small matter too large. The second step is, after having brought the roller into its place in the plate BB, to make a mark upon the surface of the circle near the edge, and a similar one upon the roller, exactly opposite each other; then carry the apparatus forward with a steady hand, until the roller has made sixteen revolutions. If, now, the mark upon the roller, by having overreached the one upon the circle, shows it to be much too large, take it out of the frame and reduce it by turning accordingly: when, by repeating this, it is found to be very near, it may be turned about ·001 of an inch smaller on the lower edge, and so far its preparation is completed. The third and last step is, the use and adaptation of the two microscopes; one of these must take its position at H in fig. 1, viewing a small well-defined dot made for the purpose on the circle; the other, not represented in the figure, must also be fixed to the main plate of fig. 1, as near to the former as possible, but viewing one of the divisions on the roller. With a due attention to each microscope, it will now be seen to the greatest exactness when, by raising or depressing the roller, its commensurate diameter is found.

Fig. 3, is a representation of the apparatus for transferring the divisions of the roller to the circle. It consists of two slender bars, which, being seen edgewise in the figure, have only the appearance of narrow lines; but, when looked at from above, they resemble the form of the letter A. They are fastened to the main frame, as at W and Z, by short pillars, having also the off leg of the angle secured in the same manner; Y is a fine conical steel point for making the dots, and X is a feeler, whereby the point Y may be pressed down with a uniform force, which force may be adjusted, by bending the end of the bar just above the point, so as to make the dots of the proper size. The point Y yields most readily to a perpendicular action; but is amply secured against any eccentric or lateral deviation.

The apparatus so far described, is complete for laying our foundation, *i. e.* making 256 primary dots; no matter whether with perfect truth, or not, as was said respecting the divisions of the roller; precision in either is not to be expected, nor wished; but it is of some importance, that they should be all of the same size, concentric, small and round. They should occupy a position very near the extreme border of the circle, as well to give them the greatest radius possible, as that there should be room for the stationary microscope and other mechanism, which will be described hereafter.

It must be noticed, that there is a clamp and adjusting screw attached to the main plate of fig. 1; but, as it differs in no respect from the usual contrivances for quick and slow motion, it has been judged unnecessary to encumber the drawing with it.

Now, the roller having been adjusted, with one microscope H upon its proper dot on the circle, and the other microscope at the first division on the roller; place the apparatus of fig. 3, so that the dotting point Y may stand directly over the place which is designed for the beginning of the divisions. In this position of things, let the feeler X be pressed down, until its lower end comes in contact with the circle; this will carry down the point, and make the first impression, or primary dot, upon the circle; unclamp the apparatus, and carry it forwards by hand, until another division of the roller comes near the wire of the microscope; then clamp it, and with the screw motion make the coincidence complete; where again press upon the feeler, for the second dot: proceed in this manner until the whole round is completed.

From these 256 erroneous divisions, by a certain course of examination, and by computation, to ascertain their absolute and individual errors, and to form these errors into convenient tables, is the next part of the process, and makes a very important branch of any method of dividing.

The apparatus must now be taken off, and the circle mounted in the same manner that it will be in the observatory. The two microscopes, which have divided heads, must also be firmly fixed to the support of the instrument, on opposite sides, and their wires brought to bisect the first dot, and the one which should be 180° distant. Now, the microscopes remaining fixed, turn the circle half round, or until the first microscope coincides with the opposite dot, and if the other microscope be exactly at the other dot, it is obvious that these dots are 180° apart, or in the true diameter of the circle; and if they disagree, it is obvious that half the quantity by which they disagree, as measured by the divisions of the micrometer head, is the error of the opposite division; for the quantity measured is that by which the greater portion of the circle exceeds the less. It is convenient to note these errors + or —, as the dots are found too forward or too backward, according to the numbering of the degrees; and for the purpose of distinguishing the + and — errors, the heads, as mentioned before, are numbered backwards and forwards to fifty. One of the microscpes remaining as before, remove the other to a position at right angles; and, considering for the present both the former dots to be true, examine the others by them; *i. e.* as before, try by the micrometer how many divisions of the head the greater half of the semi-circle exceeds the less, and note half the quanity + or —, as before, and do the same for the other semi-circle. One of the micrometers must now be set at an angle of 45° with the other, and the half differences of the two parts of each of the four quadrants registered with their respective signs. When the circle is a vertical one, as in the present instance, it is much the best to proceed so far in the examination with it in that position, for fear of any general bending or spring of the figure; but for the examination of smaller arcs than 45°, it will be perfectly safe, and more convenient, to have it horizontal; because the dividing apparatus will then carry the micrometers, several perforations being made in the plate B for the limbs to be seen through at proper intervals. The micrometers must now be placed at a distance of 22° 30′, and the half differences of the parts of all the arcs of 45° measured and noted as before: thus descending by bisections to 11° 15′, 5° 37′ 30″, and 2° 48′ 45.″ Half this last quantity is too small to allow the micrometers to be brought near enough; but it will have the desired effect, if they are placed at that quantity and its half, *i. e.* 4° 13′ 7″·5; in which case the examination, instead of being made at the next, will take place at the next division but one, to that which is the subject of trial. During the whole of the time that the examination is made, all the dots, except the one under examination, are for the present supposed to be in their true places; and the only thing in this most important part of the business, from first to last, is to ascertain with the utmost care, in divisions of the micrometer head, how much one of the parts of the interval under examination exceeds the other, and carefully to tabulate the half of their difference.

I will suppose that every one, who attempts to divide a large astronomical instrument, will have it engraved first. Dividing is a most delicate operation, and every coarser one should precede it. Besides, its being numbered is particularly useful to distinguish one dot from another: thus, in the two annexed tables of errors, the side columns give significant names to every dot, in terms of its value to the nearest tenth of a degree, and the mistaking of one for another is rendered nearly impossible.

The foregoing examination furnishes materials for the construction of the table of half differences, or apparent errors*. The first line of this table consists of two varieties; *i. e.* the micrometers were at 180° distance for obtaining the numbers which fill the columns of the first and third quadrant; and at 90°, for those of the second and fourth quadrant. The third variety makes one line, and was obtained with the distance of 45°: the fourth consists of two lines, with a distance of 22° 30′: the fifth of four lines, with a distance of 11° 15: the sixth of eight lines, with a distance of 5° 37′ 30″: the seventh of sixteen lines, with a distance of 2° 48′ 45″: and the eighth and last variety, being the remainder of the table, consists of thirty-two lines, and was obtained with a distance of 4° 13′ 7″·5.

The table of apparent errors, or half differences, just explained, furnishes data for computing the table of real errors. The rule is this: Let *a* be the real error of the preceding dot.

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* If the table of real errors be computed as the work of examination proceeds, there will be no occasion for this table at all, but I think it best not to let one part interfere with another, and therefore I examine the whole before I begin to compute.

and *b* that of the following one, and *c* the apparent error, taken from the table of half differences, of the dot under investigation; then is $\frac{a+b}{2} + c =$ its real error. But, as this simple expression may not be so generally understood by workmen as I wish, it may be necessary to say the same thing less concisely. If the real errors of the preceding and following dots are both +, or both —, take half their sum and prefix thereto the common sign; but if one of them is +, and the other —, take half their difference, prefixing the sign of the greater quantity: again, if the apparent error of the dot under investigation has the same sign of the quantity found above give to their sum the common sign, for the real error; but if their signs are contrary, give to their difference the sign of the greater for the real error; I add a few examples.

EXAMPLE I.

For the first point of the second quadrant.

Real error of the first point of the first quadrant . .	0·0
Real error of the first point of the third quadrant . .	—6·9
Half sum or half difference	—3·4
Apparent error of the dot under trial	+12·2
Real error	+8·8

EXAMPLE II.

For the point 45° of the second quadrant.

Real error of the first point of the quadrant	+8·8
Real error of the last point of the quadrant	—6·9
Half difference	+0·9
Apparent error of the dot under trial	—8·9
Real error	—8·0

EXAMPLE III.

Point 88°·6, or last point, of the third quadrant.

Real error of the point 84°·4 of the third quadrant. .	—21·0
Real error of the point 2°·8 of the fourth quadrant. .	—2·9
Half sum	—11·9
Apparent error of the dot under trial	—4·0
Real error	—15·9

EXAMPLE IV.

Point 88°·6, or last, of the fourth quadrant.

Real error of the point 84°·4 of the fourth quadrant.	—21·6
Real error of the point 2°·8 of the first quadrant. . .	—10·2
Half sum	—15·9
Apparent error of the dot under trial	+9.5
Real error	—6·4

It is convenient, in the formation of the table of real errors, that they should be inserted in the order of the numbering of the degrees on their respective quadrants; although their computation necessarily took place in the order in which the examination was carried on, or according to the arrangement in the table of apparent errors. The first dot of the first quadrant having been assumed to be in its true place, the first of the third quadrant will err by just half the difference found by the examination; therefore these errors are alike in both tables. The real error of the first dot of the second quadrant comes out in the first example; that of the fourth was found in like manner, and completes the first line. It is convenient to put the error of the division 90° of each quadrant at the bottom of each column, although it is the same as the point 0° on the following quadrant. The line of 45° is next filled up; the second example shows this: but there is no occasion to dwell longer upon this explanation; for every one, who is at all fit for such pursuits, will think what has already been said fully sufficient for his purpose. However, I will just mention that there can be no danger, in the formation of this table, of taking from a wrong line the real errors which are to be the criterion for finding that of the one under trial; because they are in the line next to it; the others which intervene in the full table, not being yet inserted. The last course of all is, however, an exception; for, as the examining microscopes could not be brought near enough to bisect the angle 2° 48′ 45″, recourse was had to that quantity and its half; on which account the examination is prosecuted by using errors at two lines' distance, as is shown in the two last examples.

When the table of real errors is constructed, the other table, although it is of no further use, should not be thrown away; for if any material mistake has been committed, it will be discovered as the operation of dividing is carried on; and, in that case, the table of apparent errors must be had recourse to; indeed, not a figure should be destroyed until the work is done.

Respecting the angular value of the numbers in these tables, it may be worth mentioning, that it is not of the least importance; 100 of them being comprised in one revolution of the micrometer screw; and, in the instance before me, 5·6 of them made no more than a second. It is not pretended that one of these parts were seen beyond a doubt, being scarcely $\frac{1}{50000}$th of an inch, much less the tenths, as exhibited in the tables; but, as they were visible upon the micrometer heads, it was judged best to take them into the account.

Having now completed the two first sections of my method of dividing; namely, the first, which consists of making 256 small round dots; and the second, in finding the errors of those dots, and forming them into a table;—I come now to the third and last part, which consists in using the erroneous dots in comparison with the tabulated errors, so as ultimately to to make for them the true divisions.

It will here be necessary to complete the description of the remaining part of the apparatus. And first, a little instrument which I denominate a subdividing sector presents itself to notice. From all that has hitherto been said, it must have been supposed that the roller itself will point out, upon the limb of the instrument to be divided, spaces corresponding to others previously divided upon itself, as was done in setting off the 256 points: but to obviate the difficulty of dividing the roller with sufficient exactness, recourse was had to this sector; which also serves the equally important purpose of reducing the bisectional points to the usual division of the circle. This sector is represented in half dimensions by fig. 5: it is formed of thin brass, and centered upon the axis at A, in contact with the upper surface of the roller: it is capable of being moved round by hand; but, by its friction upon the axis and its pressure upon the roller, it is sufficiently prevented from being disturbed by accident. An internal frame BB, to which the arc CC is attached, moves freely in the outer one, and by a spring D is pushed outwards, while the screw E, whose point touches the frame B, confines the arc to its proper radius. The arc of this sector is of about four times greater radius than the roller, and upon it are divided the spaces which must be transferred to the instrument, as represented on a magnified scale by fig. 4. Now, the angle of one of the spaces of the circle will be measured by sixteen times its angular value upon the sectorial arc, or $22^\circ 30'$; but this does not represent any number of equal parts upon the instrument, whose subdivisions are to be $5'$ each; for $\frac{1^\circ 24' 22'' 5}{5}$ is exactly $16\frac{7}{8}$ths, therefore so many divisions are exactly equal to a mean space between the dots whose errors have been tabulated. Let therefore, the arc of the sector be divided into sixteen spaces of $1^\circ 20'$ each, and let a similar space at each end be subdivided into eight parts of $1'0$ each, as in fig. 4; we shall then have a scale which furnishes the means for making the true divisions, and an immediate examination at every bisectional point.

I have always divided the sector from the engine, because that is the readiest method, and inferior to none in point of accuracy, where the radius is very short; but, as it is more liable than any other to centrical error, the adjustment of the arc by the screw E becomes necessary: by that adjustment, also, any undue run in the action of the roller may be reduced to an insensible quantity.*

When the utmost degree of accuracy is required, I give the preference to dividing by lines, because they are made with a less forcible effort than dots are; and also because, if any small defect in the contexture of the metal causes the cutter to deviate, it will, after passing the defective part, proceed again in its proper course, and a partial crookedness in the line will be the only consequence; whereas a dot, under similar circumstances, would be altogether displaced. But, on the other hand, where accuracy has been out of the question, and only neatness required, I have used dots; and I have done so, because I know that when a dot and the wire which is to bisect it are in due proportion to each other, (the wire covering about two-thirds of the dot) the nicest comparison possible may be obtained. It may be further observed, that division by lines is complete in itself; whereas that by dots requires lines to distinguish their value.

On the upper side of fig. 1, is represented the apparatus for cutting the divisions. It consists of three pieces JKL, jointed together so as to give to the cutter an easy motion for drawing lines directly radiating from the centre, but inflexible with respect to lateral pressure; *d d* are its handles. The cutting point is hidden below the microscope H; it is of a conical form, and were it used as a dotting point, it would make a puncture of an elliptical shape, whose longer diameter would point towards the centre. This beautiful contrivance, now well known, we owe to the ingenuity of the late Mr. Hindley of York; it was borrowed by Mr. Ramsden,† and applied with the best effect to his dividing engine.

It might have been mentioned sooner, that in the instance which I have selected as an example of my dividing, the operation took place when the season of the year, and the smoke of London, had reduced the day to scarcely six hours of effective light; and rather than confine my labours within

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* See note, page 19.

† This I learned from that most accurate artist, Mr. John Stancliffe, who was himself apprentice to Hindley.

such narrow limits, I determined to shut out the day-light altogether. Fig. 7, shows the construction of the lanterns which I used. A very small wick gave sufficient light, when kept from diverging by a convex lens; while the inclined nozle was directed down exactly upon the part looked at, and the light, having also passed through a thin slice of ivory, was divested of all glare. I enter into this description, because, I think, I never saw my work better, nor entirely to so much advantage, as in this instance; owing, perhaps, to the surrounding darkness allowing the pupil of the eye to keep itself more expanded, than when indirect rays are suffered to enter it. The heat from a pair of these lanterns was very inconsiderable, and chiefly conducted along with the smoke up the reclining chimney.

Previous to cutting the divisions, the parts now described must be adjusted. The cutting apparatus must be placed with the dividing point exactly at the place where the first line is intended to be drawn, and clamped, so that the adjusting screw may be able to run it through a whole interval. The microscope H must be firmly fixed by its two pillars *b b* to the main frame, with its micrometer head at *zero*; and with its only wire in the line of the radius, bisecting the first of the 256 dots. And it should be observed, that the cutting frame and this must not vary respecting each other, during the time that the divisions are cut; for any motion that took place in either would go undiminished to the account of error. The microscope I is also fastened to the main frame: but it is only required to keep its position unvaried, while the divisions of the sector pass once under its notice; for it must have its wires adjusted afresh to these divisions at every distinct course. The microscope I use has two wires, crossing each other at an angle of about 40°; and these are to be placed so as to make equal angles with the divisions of the sector, which are not dots, but lines. The sectorial arc must also be adjusted to its proper radius by the screw E, fig. 5; *i. e.* while the mean frame has been carried along the circle through a mean interval shown by H, the sector must have moved through exactly $16\frac{7}{8}$ths of its divisions, as indicated by I.*

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* For the sake of simplicity, the account of the process is carried on as if the roller measured the mean interval without error. But it was said (page 84) that the roller, in a continued motion quite round the circle, would in some part of its course err by 30″ or more; therefore, when that is the case, an extreme run of the roller cannot agree with a mean interval of the circle nearer

Things being in this position; after having given the parts time to settle, and having also sufficiently proved the permanence of the micrometer H and the cutting frame with respect to each other, the first division may be made; then, by means of the screw for slow motion, carry the apparatus forward, until the next line upon the sector comes to the cross wires of I; you then cut another division, and thus proceed until the 16th division is cut, =1° 20′: Now the apparatus wants to be carried further, to the amount of $\frac{7}{8}$ths of a division, before an interval is complete; but at this last point no division is to be made: we are here only to compare the division on the sector with the corresponding dot upon the instrument. This interval, however, upon the circle will not be exactly measured by the corresponding line of the sector, which has been adjusted to the mean interval, for the situation of the dot 1°·4 is too far back, as appears by the table of real errors, by —4·8 divisions of the micrometer head. The range of the screw for slow motion must now be restored, the cross wires of H set back to —4·8 divisions, and the sector moved back by hand, but not to the division 0 where it began before; for, as it left off in the first interval at $\frac{7}{8}$ths of a division, it has to go forwards $\frac{1}{8}$th more before it will arrive at the spot where the 17th division of the instrument 1° 25′ is to be made, so that in this second course it must begin at $\frac{1}{8}$th short of 0. Go through this interval as before, making a division upon the circle at every one of the 16 great divisions of the sector; and H should now reach the third dot, allowing for a tabular error of—10·2 when the division $\frac{6}{8}$ths of the sector reaches the cross wires of I. It would be tedious to lead the reader through all the variety of the sector, which consists of eight courses; and it may be sufficient to observe, that at the commencement of every course, it must be put back to the same fraction of a division which terminated its former one; and that the wire of the micrometer H must always be set to the tabular error belonging to every dot, when we end one interval and begin another. The eight courses of the sector will have carried us through

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than $\frac{30''}{128} = 0''\cdot23$; and most probably this kind of error will on some intervals amount to double that quantity. It therefore becomes matter of prudent precaution to examine every interval previous to making the divisions; and, where necessary, to adjust the sector, so that its arc may exactly measure the corresponding interval as corrected by the tabulated errors.

part of the circle, 11° 15′, and during this time, the roller will have proceeded through half a revolution; for its close contact with the limb of the circle does not allow it to return with the sector when the latter is set back at every course. Having in this manner proceeded, from one interval to another, through the whole circle, the micrometer at last will be found with its wire, at *zero*, on the dot from which it set out; and the sector with its 16th division, coinciding with the wires of its microscope.

Having now given a faithful detail of every part of the process of dividing this circle, I wish to remind the reader that, by verification and correction at every interval, any erroneous action of the roller is prevented from extending its influence to any distant interval. It will be further observed, that the subdividing sector magnifies the work; that by means of its adjustable arc, it makes the run of the roller measure its corresponding intervals upon the circle; and, without foreign aid, furnishes the means of reducing the bisectional intervals to the usual division of the circle. Furthermore, the motion of the wire of the micrometer H, according to the divisions of its head and corresponding table of errors, furnishes the means of prosecuting the work with nearly the same certainty of success, as could have happened had the 256 points been (which in practice is quite impossible) in their true places.

Now, the whole of my method of dividing being performed by taking short measures with instruments which cannot themselves err in any sensible degree, and, in as much as those measures are taken, not by the hand, but by vision, and the whole performed by only looking at the work, the eye must be charged with all the errors that are committed until we come to cut the divisions; and, as in this last operation the hand has no more to do than to guide an apparatus so perfect in itself, that it cannot be easily made to deviate from its proper course, I would wish to distinguish it from the other methods by denominating it, *dividing by the eye.*[*]

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[*] I must here remark, that Smeaton has represented the greatest degree of accuracy that can be derived from vision, in judging of the coincidence of two lines, at the 4,000th part of an inch. From this it may fairly be inferred that he had not cultivated the power of the sight, as he had done that of the touch; the latter of which, with that ability which appeared in all his works, he rendered sensible to the 60,000th part of an inch. Were materials infinitely hard, no bounds could be set to the precision of contact; but taking things as they are, the different degrees of hardness in matter, may be considered as a kind of magnifying power to the touch, which may not unaptly be compared with

The number of persons at all capable of dividing originally have hitherto been very few; the practice of it being so limited, that, in less than twice seven years, a man could hardly hope to become a workman in this most difficult art. How far I shall be considered as having surmounted these difficulties, I know not; but if, by the method here revealed, I have not rendered original dividing almost equally easy with what copying was before, I have spent much labour, time, and thought, in vain. I have no doubt indeed, that any careful workman who can divide in common, and has the ability to construct an astronomical instrument, will, by following the steps here marked out, be able to divide it, the first time he tries, better than the most experienced workman, by any former method.

If, instead of subdividing with the roller, the same thing be performed with the screw, it will not give to dividing by the eye any very distinctive character: I have practised this on arcs of circles with success, the edge being slightly racked, the screw carrying forward an index with the requisite apparatus, and having a divided micrometer head; the latter answers to the subdividing sector, and, being used with a corresponding table of errors, forms the means of correcting the primitive points: but the roller furnishes a more delicate action, and is by far more satisfactory and expeditious.

It is known to many that the six-feet circle, which I am now at work upon for our Royal Observatory, is to be divided upon a broad edge, or upon a surface at right angles to the usual plane of division: the only alterations, which will on

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the assistance which the eye receives from glasses. It is now quite common to divide the seaman's sextant to 10″, and a good eye will estimate the half of it; which on an eight-inch radius, is scarcely the 10,000th of an inch. This quantity, small as it is, is rendered visible by a glass of one inch focal length; and such is the certainty with which these quantities are seen, that a seaman will sometimes complain that two pair of these lines will coincide at the same time; and that may happen, and yet no division of his instrument err, by more than the 20,000th part of an inch. All this is applicable to judging of the coincidence of lines with each other, and furnishes not the most favourable display of the accuracy of vision. But with the microscopes here described, where the wire bisects the image of a dot, or a cross wire is made to intersect the image of a line, by an eye practised in such matters, a coincidence may undoubtedly be ascertained to the 50,000th part of an inch. I am of opinion that as small a quantity may be rendered visible to the eye, as can by contact be made sensible to the touch; but whether Mr. Smeaton's 60,000th and my 50,000th be not the same thing, I will not determine; the difference beween them, however, is what he would no more have pretended to feel, than I dare pretend to see.

that account be required, are, that the roller must act upon that plane which is usually divided upon; which roller, being elevated or depressed, may be adjusted to the commensurate radius without being made conical, as was necessary in the other case. The apparatus, similar to the other, must here be fixed immoveably to the frame which supports the circle; its position must be at the vertex, where also I must have my station; and the instrument itself must be turned round its axis, in its proper vertical position, as the work proceeds. The above may suffice, for the present, to gratify those who feel themselves interested upon a subject which will be better understood, if I should hereafter have the honour of laying before the Royal Society a particular description of the instrument here alluded to; a task which I mean to undertake, when, after being fixed in the place designed for it, which I hope will be effected at no very distant period, it shall be found completely to answer the purposes intended.

Should it be required to divide a circle according to the centesimal division of the quadrant, as now recommended and used in France, we shall have no difficulty. The 100° of the quadrant may be conveniently subdivided into 10 each, making 4000 divisions in the whole round. The 256 bisectional intervals, the two tables of errors, and the manner of proceeding and acting upon them, will be exactly the same as before, until we come to cut the divisions; and for this purpose we must have another line divided upon the sector. For $\frac{1}{4000}$th part of the circle being equal to 5′·4 of the usual angular measure $\frac{1^\circ\,24'\,22''\cdot 5}{5'\cdot 4} = 15\frac{5}{8}$ths divisions; and just so many will be equivalent to one of the intervals of the circle. The value of one of the great divisions of the sector will be 1° 26′ 24″, and that of the $\frac{1}{8}$th parts, which are to be annexed to the right and left as before, will be 10′ 48″, therefore divisible by the engine. Should any astronomer choose to have both gradations upon his instrument, the additional cost would be a mere trifle, provided both were done at the same time.

It must already have been anticipated, that dividing by the eye is equally applicable to straight lines as it is to circles. An apparatus for this purpose should consist of a bar of brass, three quarters of an inch thick, and not less than three inches broad; six feet may do very well for the length; it may be laid upon a deal plank strengthened by another plank screwed edgewise on its lower surface. The bar should be planed, on both its edges and on its surface, with the greatest exactness:

and it will be better, if it has a narrow slip of silver, inlaid through its whole length for receiving the dots. An apparatus nearly similar to the other should slide along its surface, carrying a roller, whose circumference is 12·8 inches, and turned a little conical for the sake of adjustment. The roller may be divided into 32 parts, each of which when transferred to the bar will give intervals of 0·4 of an inch each: the angle of the subdividing sector should of course be 11° 15′, and subdivided into four parts, which will divide the inch into tenths: the surface may also receive other lines, with subdivisions suited to the different purposes for which it may be wanted. The revolutions of the roller and its $\frac{1}{32}$ parts must be dotted upon the bar; taking care, by sizing the roller, to come as near the true standard measure as possible: when this is done, compare the extent of the greater bisectional number that is contained in the length; *i. e.* 128 intervals of 51·2 inches with the standard measure; noting the difference as indicated by the micrometer heads; the examination and construction of the table of errors may then be conducted just as was done for the circle.

Being now ready for the performance of its work, the scale to be divided must be laid alongside of the bar, and the true divisions must be cut upon it by an appeal, as before, to the erroneous dots on the bar, corrected by a corresponding table of errors. The apparatus, remaining entire in the possession of the workman, with its primitive dots, the table of errors, &c. is ready for dividing another standard, which will be precisely similar to others that have been, or may be, divided from it. It may be considered, indeed, as a kind of engine; and, as it is not vitiated by the coarse operation of racking with a screw, but performed by only looking at the work, the method will command about three times the accuracy that can be derived from the usual straight-line dividing engine. Should it be asked, if any engine thus appointed would succeed for dividing circles? I answer, Yes; but I would not recommend it; because, beyond a certain extent of radius, it is not necessary; for the errors, which would be introduced into the work by the violence of racking a large wheel, are sufficiently reduced by the comparative shortness of the radius of such instruments as we divide by that method: and, what is still more to the purpose, the dividing engine is four times more expeditious, and bears rough usage better. I cannot quit the subject of dividing straight lines without observing, that I never had my apparatus complete. The standard which I made for Sir George Shuckburg Evelyn in 1796, was done by a mere make-shift contrivance, upon the principle of dividing by the eye; how I succeeded may be seen in Sir George's papers on Weights and Measures (Philosophical Transactions for 1798.) I made a second, some years after, for Professor Pictet of Geneva, which became the subject of comparison with the new measure of France, before the National Institute; and their report, drawn up by Mr. Pictet, has been ably re-stated and corrected by Dr. Young, as published in the Journals of the Royal Institution. I made a third for the magistrates of Aberdeen. I notice the two latter, principally to give myself an opportunity of saying that, if those three scales were to be compared together, notwithstanding they were divided at distant periods of time, and at different seasons of the year, they would be found to agree with each other as nearly as the different parts of the same scale agree.

I hope I may here be allowed to allude to an inadvertency which has been committed in the paper mentioned above; and which Sir George intended to have corrected, had he lived to conclude his useful endeavours to harmonize the discordant weights and measures of this country. The instruments which he has brought into comparison are, his own five-feet standard measure and equatorial; General Roy's forty-two inch scale; the standard of Mr. Aubert; and that of the Royal Society. The inadvertency is this: in his equatorial, and the standard of the Royal Society, he has charged the error of the most erroneous extent, when compared with the mean extent, alike to both divisions; *i. e.* he has supposed one of the divisions, which bound the erroneous extent to be too much to the right, and the other too much to the left, and that by equal quantities. This is certainly a good-natured way of stating the errors of work; and perhaps not unjustly so, where the worst part has been selected; but in the other three instances, namely, in General Roy's, Mr. Aubert's, and his own standard, he has charged the whole error of the most erroneous extent to one of the bounding lines.

I was well confirmed in my high opinion of the general accuracy of Bird's dividing, when, last winter,* I measured the chords of many arcs of the Greenwich quadrant: that instrument has indeed suffered both from a change in its figure, and from the wearing of its centre; but the graduation, considering the time when it was done, I found to be very good. Sir George in his paper upon the equatorial, (Philosophical

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* This paper was written in June, 1808.

Transactions for 1793,) after some compliments paid to the divider of his instrument, says, " The late Mr. John Bird seems to have admitted a probable discrepancy in the divisions of his eight-feet quadrant amounting to 3″ ;" and he refers to Bird on the construction of the Greenwich quadrant. This quantity being three times as great as any errors that I met with, I was lately induced to inquire how the matter stood. Bird, in the paper referred to, says, " In dividing this instrument I never met with any inequality that exceeded one second. I will suppose that in the 90 arch this error lay towards the left hand, and in the 96 arch that it lay towards the right, it will cause a difference between the two arches of two seconds ; and if an error of one second be allowed to the observer in reading off his observation, the whole amount is no more than three seconds, which is agreeable to what I have heard," &c. Sir George's examination of his own equatorial furnishes me with the means of a direct comparison : in his account of the declination circle, we find an error + 2″·35, and another —1″·5 ; to these add an error of half a second in each, for reading off, which Sir George also admits ; we shall then have a discrepancy of 4″·85 ; but as the errors of reading off are not errors of division, let them be discharged from both, and the errors will then stand, for the quadrant 2″, and for the circle 3″·85. As the radius of the former, however, is four times greater than that of the latter, it will appear by this mode of trial, that the equatorial is rather more than twice as accurately divided as the quadrant. In doing justice to Bird in this instance, I have only done as I would be done by ; for, should any future writer set me back a century on the chronological scale of progressive improvement, I hope some one will be found to restore me to my proper niche. I now subjoin a re-statement of the greatest error of each of the instruments that are brought into comparison by Sir George, after having reduced them all by one rule ; viz. allowing each of the two points which bound the most erroneous extent to divide the apparent error equally between them. They are expressed in parts of an inch, and follow each other in the order of their accuracy.

Sir George Shuckburg's 5-feet standard . . .	·000165
General Roy's scale of 42 inches	·000240
Sir George's equatorial, 2-feet radius	·000273
The Greenwich quadrant, 8-feet radius . . .	·000465
Mr. Aubert's standard, 5 feet long	·000700
The Royal Society's standard, 92 inches long* .	·000795

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* This is the same which Mr. Bird used in dividing his eight-feet mural quadrants, and was presented to the Royal Society by Bird's executors.

For the justness of the above statement I consider my name as pledged; requesting the permission to say, that if on the result of each respective examination, as here presented, there could have been more than one opinion, it would not have appeared here. I am further prompted to add, that the above comparative view presents one circumstance to our notice, which cannot do less than gratify every individual who is at all conversant in these matters; I mean the high rank which general Roy's scale takes in the list; that scale having been made the agent in measuring the base line of our national trigonometrical survey.

To return, finally, to the dividing of circles; I must state, as matter of precaution, that great care should be taken during the turning of the outer edge, to have the circle of the same temperature; for one part may be expanded by heat, or contracted by cold, so much more than another, as to cause the numbers in the tables of errors to be inconveniently large. A night is not more than sufficient for allowing the whole to take the same temperature, after having been handled by the workmen; and the finishing touch should be given within a short space of time. But, if the effects of temperature are to be regarded in turning a circle, it is of tenfold more importance to attend to this circumstance, while the examination of the larger arcs of the instrument is carried on; for it is absolutely necessary that, during the time, the whole circle should be of the same heat exactly. Few workmen are sufficiently aware of this: they generally suppose the expansion of metals to be a trifle which need not be regarded in practice; and wonder how the parts of a circle can be differently heated without taking pains to make it so. One degree of Fahrenheit's thermometer indicates so small a portion of heat that, in such places as workmen are usually obliged to do their business in, it is not very easy to have three thermometers attached to different parts of a large instrument, showing an equality of temperature within that quantity: yet so necessary is correctness in this respect, that if a circle has the vertex one degree warmer than its opposite, and if this difference of temperature be regularly distributed from top to bottom, the upper semi-circle will actually exceed the lower by 2″: and, if such should happen to be the case while the examination of the first dot of the third quadrant is made, the regularity of the whole operation would thereby be destroyed.

It may not be improper to remark, that dividing by the eye does not require a more expensive apparatus than the operation of dividing by hand; and, indeed, less so when the scale of inches is deemed necessary. The method by adjustment is still more expensive, requiring whatever tools Bird's method requires, and in addition to these, a frame and microscopes, somewhat similar to those for dividing by the eye.

It is somewhat more difficult to give a comparative estimate of the time which the different methods of dividing require. I known that thirteen days of eight hours each are well employed in dividing such a circle by my method; about fifty-two days would be consumed in doing the same thing by Bird's method; and I think I cannot err much when I state the method by adjustment, supposing every dot to be tried, and that two-thirds of them want adjusting, to require about one hundred and fifty of such days.

The economy of time (setting side the decided means of accuracy) which the above estimate of its application offers to view, will, I think, be considered of no little moment. By the rising artist who may aspire at excellence, it will at least, and I should hope, with gratitude, be felt in the abbreviation of his labours. To me, indeed, the means of effecting this became indispensable; and it has not been without a sufficient sense of its necessity, that I have been urged to the progressive improvement and completion of those means, as now described. It is but little that a man can perform with his own hands alone; nor is it on all occasions, even in frames of firmer texture than my own, that he can decisively command their adequate, unerring use. And I must confess, that I never could reconcile it to what I hold as due to myself, as well as to a solicitous regard for the most accurate cultivation of the science of astronomy, to commit to others an operation requiring such various and delicate attentions, as the division of my instruments.

That my attentions on this head have not failed to procure for me the notice and patronage of men whose approbation make, with me, no inconsiderable part of my reward, I have to reflect on with gratitude and pleasure: and as I look with confidence to the continuance of that patronage so long as the powers of execution shall give me the inclination to solicit it, I cannot entertain a motive which might go to extinguish the more liberal wish of pointing out to future ingenuity a shorter road to eminence; sufficiently gratified by the idea of having, in the present communication, contributed to facilitate the operations, and to aid the progress of art (as far as the limited powers of vision will admit) towards the point of perfection.

TABLE OF APPARENT ERRORS.

Name of the dot.	1st. Quadrant.	2d Quadrant.	3d Quadrant.	4th Quadrant.	1st Quadrant.	2d Quadrant.	3d Quadrant.	4th Quadrant.	Name of the dot.
° 0·0	0	+12·2	— 6·9	+17·9	+ 4·6	+17·1	— 4·4	+17·3	° 1·4
45·0	—21·3	— 8 9	16·7	—29·6	— 5 2	— 9·7	8·9	— 6·4	4·2
22·5	1·6	2 2	1·0	2·7	0 0	3·8	1·0	4·7	7·0
67·5	+ 1·0	+15 6	0·0	+13·7	+ 1·0	+ 3 5	5·1	5·5	9·8
11·2	—16·6	—20 2	22·6	—30·3	— 5·5	— 1·6	0·0	+ 1·2	12·7
33 7	4·0	4·2	13·2	23·1	7·6	7·6	4·2	— 2·3	15·5
56·2	16·9	22·2	17·0	22·7	9·4	3·9	0 0	5·3	18·3
78 7	30 8	16·6	31·3	30 3	+ 1·1	+12·1	+ 4·2	+ 4·3	21·1
5·6	2·7	8 6	4·1	10 1	12·3	0·9	6·2	14 4	23·9
16·9	11·5	11·3	11 2	16·1	— 5·7	— 6·2	1·1	—11·2	26 7
28·1	9·0	7·4	5·8	14·3	+ 1·5	3 5	— 6·3	4 2	29·5
39·4	9 3	8·2	5·8	13·1	0 0	7·0	7 7	+ 1·4	32 3
50 6	4 2	6·6	8·2	4·4	1·5	+ 9·0	+ 3·0	4·3	35·2
61·9	4·3	8·4	12·5	4·4	— 8·6	— 5·9	— 2·0	— 6·7	38·0
73·1	7·6	10·0	13·6	9 7	3·3	+ 2·7	4 9	1·5	40 8
84·4	18·0	+ 6·0	16·3	7·1	+ 4·0	3 1	3 5	+ 1·0	43·6
2·8	3 4	— 7 5	8·9	2·1	13·5	10 5	+16·0	11 9	46·4
8·4	0·0	5 0	4·6	5 7	2·1	0·0	1 7	— 3·5	49 2
14·1	6·6	8·2	5·6	4·8	— 5·0	—10 7	— 2·9	1·5	52·0
19·7	1·6	2 4	+ 1 0	2·5	4 2	7·9	2·2	7 2	54·8
25·3	3 7	8 2	— 2 9	2 5	1·0	3 0	2·5	1·0	57 7
30 9	+ 2·4	7·1	7·0	0 0	7·3	+ 6·2	6 1	1·5	60·5
36·6	— 5·9	+ 1·0	2·5	1·5	3·2	—10·1	5·6	12 7	63 6
42·2	+ 3 1	1·9	5·8	+ 2 5	1·4	7·2	3·9	+ 2·2	66·1
47·8	7 1	5 2	+ 2·1	. 4 8	+11·2	+11·9	+21·2	7·2	68·9
53·4	— 5·6	— 6·0	— 5·0	— 6·1	— 7·1	— 1·0	— 8·9	—11·7	71·1
59 1	10·7	+ 1·0	3·0	+ 1·4	5·3	1·2	6·6	2·7	74·5
61·7	7·9	—18 0	10·7	— 9 0	7·2	9 9	+ 1·0	5·9	77 3
70·3	2·7	7·4	1·5	9 0	6·5	1·8	5·3	2·6	80 2
75 9	1 2	5·2	2.2	4·7	+ 4·4	+ 1·4	— 2·2	4 ·3	83 0
81·6	1·6	+ 1·7	0·0	2·0	—20·8	— 0·0	11·4	+ 1·0	85·8
87·2	13·7	6·0	3·5	+ 5·6	+ 2·1	+11 0	4·0	9·5	88·6

TABLE OF REAL ERRORS.

Name of the dot.	1st Quadrant.	2d Quadrant.	3d Quadrant.	4th Quadrant.	1st Quadrant.	2d Quadrant.	3d Quadrant.	4th Quadrant.	Name of the dot.
o 0·0	0·0	+ 8·8	— 6·9	+14·4	—16·9	— 8·0	—13·4	—22·4	o 45·0
1·4	— 1·8	— 0·6	16·0	5·9	8·7	5·5	9·7	16·1	46·4
2·8	10·2	9·3	24·0	— 2·9	14·3	9·6	17·4	22·3	47·8
4·2	13·8	15·1	28·3	12·8	22·3	17·9	19·9	33·8	49·2
5·6	13·7	12·5	23·3	16·1	26·0	21·6	26·7	31·9	50·6
7·0	15·9	16·8	28·7	19·4	25·5	26·0	23·6	28·9	52·0
8·4	17·6	19·6	32·0	27·0	32·0	27·8	30·3	38·3	5 ·4
9·8	21·4	16·1	35·5	30·7	34·0	27·3	29·1	35·2	54·8
11·2	21·6	16·7	31·5	26·5	26·8	22·1	24·0	32·6	56·2
12·7	27·9	21·6	32·2	28·6	29·6	24·5	29·7	29·8	57·7
14·1	31·1	26·8	37·5	34·4	33·7	17·7	27·2	24·6	59·1
15·5	28·5	22·7	30·2	26·8	30·2	15·6	29·3	26·5	60·5
16·9	27·3	20·5	32·4	32·7	19·2	15·3	24·1	19·4	61·9
18·3	29·9	18·2	24·2	25·7	21·5	14·6	18·8	23·7	63·3
19·7	20·2	13·5	20·6	22·2	19·0	21·5	22·4	17·4.	64·7
21·1	22·4	5·9	22·1	24·0	18·8	19·9	22·8	17·1	66·1
22·5	10·0	1·8	10·9	6·7	3·0	+ 8·2	+ 0·7	+ 2·5	67·5
23·9	8·8	12·2	16·0	11·9	9·8	— 2·8	— 2·5	—13·0	68·9
25·3	19·8	15·5	20·2	24·0	15·7	10·2	13·7	19·2	70·3
26·7	21·7	16·1	20·0	33·0	21·9	7·0	21·8	25·8	71·7
28·1	22·1	12.8	23·8	36·4	23·0	13·9	25·1	23·0	73·1
29·5	17·1	15·8	28·9	35·0	27·1	14·3	25·3	26·8	74·5
30·9	22·1	18·0	31·4	37·0	26·6	20·1	26·6	30·7	75·9
32·3	24·7	19·3	33·3	37·7	33·3	21·1	22·7	31·1	77·3
33·7	17·4	9·1	25·1	37·6	27·9	16·0	28·8	29·1	78·7
35·2	22·7	8·0	25·1	35·7	35·5	14·5	18·5	28·7	80·2
36·6	27·3	11·9	27·4	41·8	29·3	9·0	22·4	27·3	81·6
38·0	26·5	15·6	26·9	40·6	21·0	6·6	17·5	21·4	83·0
39·4	26·4	16·7	24·8	43·1	27·5	5·4	21·0	21·6	84·1
40·8	25·4	7·2	25·1	33·6	31·0	7·9	15·4	12·6	85·8
42·2	18·5	10·4	24·7	30·2	23·0	0·1	6·8	5·2	87·1
43·6	13·6	10·0	24·6	31·7	16·3	3·7	15·9	6·4	88·6
45·0	16·9	8·0	13·0	22·4	+ 8·8	·9	+ 14·4	0·0	90·0

On an Improvement in the Manner of dividing astronomical Instruments.

The great inconvenience and difficulty in the common method of dividing, arises from the danger of bruising the divisions by putting the point of the compass into them, and from the difficulty of placing that point mid-way, between two scratches very near together, without its slipping towards one of them ; and it is this imperfection in the common process. which appears to have deterred Mr. Troughton from using it, and thereby gave rise to the ingenious method of dividing described in the preceding article. This induced me to consider, whether the above-mentioned inconvenience might not be removed, by using a beam compass with only one point, and a microscope instead of the other ; and I find, that in the following manner of proceeding, we have no need of ever setting the point of the compass into a division, and consequently that the great objection to the old method of dividing is entirely removed.

In this method, it is necessary to have a convenient support for the beam compass : and the following seems to me to be as convenient as any. Let CCC, fig. 1, plate LXXVIII, be the circle to be divided, BBB a frame resting steadily on its face, and made to slide round on it with an adjusting motion to bring it to any required point : *d* δ is the beam compass, having a point near δ, and a microscope *m* made to slide from one end to the other. This beam compass is supported at *d*, in such manner as to turn round on this point as a centre, without shake or tottering ; and at the end δ it rests on another support, which can readily be lowered, so as either to let the point rest on the circle, or to prevent its touching it. It must be observed, however, that as the distance of *d* from the centre of the circle must be varied according to the magnitude of the arch to be divided, the piece on which *d* is supported had best be made to slide nearer to, or further from, the centre; but the frame must be made to bear constantly against the edge of the circle to be divided, so that the distance of *d* from the centre of this circle, shall not alter by sliding the frame.

This being premised, we will first consider the manner of dividing by continued bisection. Let F and *f* be two points on the limb which are to be bisected in ϕ. Take the distance of the microscope from the point nearly equal to the chord of *f* ϕ, and place *d* so that the point and the axis of the microscope shall both be in the circle in which the divisions are to be cut. Then slide the frame BBB till the wire of the microscope bisects the point F; and having lowered the support at δ, make a faint scratch with the point.

Having done this, turn the beam compass round on the centre *d* till the point comes to D, where it must rest on a support similar to that at δ; and having slid the frame till the wire of the microscope bisects the point *f*, make another faint scratch with the point, which if the distance of the microscope from the point has been well taken, will be very near the former scratch: and the point mid-way between them will be the accurate bisection of the arch F*f*; but it is unnecessary, and better not to attempt to place a point between these two scratches.

Having by these means determined the bisection at φ, we must bisect the arches F φ and *f* φ in just the same manner as before, except that the wire of the microscope must be made to bisect the interval between the two faint scratches instead of bisecting a point.

It must be observed, that when the arch to be bisected is small, it will be necessary to use a bent point, as otherwise it could not be brought near enough to the axis of the microscope; and then part of the rays, which form the image of the object seen by the microscope, will be intercepted by the point; but I believe, that by proper management this may be done without either making the point too weak, or making the image indistinct; but if this cannot be done, we may have recourse to Mr. Troughton's expedient of besecting an odd number of contiguous divisions.

It must be observed too, that in the bisections of all the arches of the same magnitude, the position of the point *d* on the frame remains unaltered; but its position must be altered every time the magnitude of the arch is altered.

It is scarcely necessary to say, that the bisections thus made are not intended as the real divisions, but only as marks from which they are to be cut. In order to make the real divisions, the microscope must be placed near the point, and the support *d* must be placed so that *d* δ shall be a tangent to the circle at δ. The wire of the microscope must then be made to bisect one of these marks, and a point or division cut with the point, and the process continued till the divisions are all made.

It is plain that in this way, without some further precaution, we must depend on the microscope not altering its position in respect of the point during the operation; for which reason I should prefer placing the axis of the microscope at exactly the same distance from the centre of motion *d*, as the point; but removed from it sideways, by nearly the semi-diameter of the object-glass; so that having made the division, we may move the beam compass till the division comes within the field of the microscope, and then see whether it is bisected by the wire, and consequently see whether the microscope has altered its place.

In the operation of bisection, as above described, it may be observed, that if the two scratches are placed so near together, that in making the second the point of the compass runs into the burr raised by the first, there seems to be some danger that the point may be a little deflected from its true course; though in Bird's account of his method, I do not find that he apprehends any inconvenience from it. One way of obviating this inconvenience, if it does exist, would be to set the beam compass not so exactly to the true length, as that one scratch should run into the burr of the other; but as this would make it more difficult to judge of the true point of bisection, perhaps it might be better to make one scratch extend from the circle towards the centre, and the other from it.

It is clear, that the entire arc of a circle cannot be divided to degrees, without trisection and quinquesection; and I do not know whether our artists have recourse to this operation, or whether they avoid it by some contrivance similar to Bird's, namely, that of laying down an arch capable of continued bisection; but if the method of quinquesection is preferred, it may be performed by either of the three following methods.

FIRST METHOD.

Let *a* α (fig. 1) be the arch to be quinquesected. Open the beam compass to the chord of one fifth of this arch; bring the microscope to *a*, and with the point make the scratch *f*; then bring the microscope to *f*, and draw the scratch *e*; and in the same manner make the scratches *d* and *b*. Then turn the beam compass half round, and having brought the microscope to α, make the scratch β; and proceeding as before, make the scratches δ, ε and ϕ. Then the true position of the first quinquesection will be between *b* and β, distant from β by and place *d* so that the point and the axis of the microscope shall both be in the circle in which the divisions are to be cut. Then slide the frame BBB till the wire of the microscope bisects the point F; and having lowered the support at δ, make a faint scratch with the point.

Having done this, turn the beam compass round on the centre *d* till the point comes to D, where it must rest on a support similar to that at δ; and having slid the frame till the wire of the microscope bisects the point *f*, make another faint scratch with the point, which if the distance of the microscope from the point has been well taken, will be very near the former scratch: and the point mid-way between them will be the accurate bisection of the arch F*f*; but it is unnecessary, and better not to attempt to place a point between these two scratches.

Having by these means determined the bisection at ϕ, we must bisect the arches F ϕ and *f* ϕ in just the same manner as before, except that the wire of the microscope must be made to bisect the interval between the two faint scratches instead of bisecting a point.

It must be observed, that when the arch to be bisected is small, it will be necessary to use a bent point, as otherwise it could not be brought near enough to the axis of the microscope; and then part of the rays, which form the image of the object seen by the microscope, will be intercepted by the point; but I believe, that by proper management this may be done without either making the point too weak, or making the image indistinct; but if this cannot be done, we may have recourse to Mr. Troughton's expedient of besecting an odd number of contiguous divisions.

It must be observed too, that in the bisections of all the arches of the same magnitude, the position of the point *d* on the frame remains unaltered; but its position must be altered every time the magnitude of the arch is altered.

It is scarcely necessary to say, that the bisections thus made are not intended as the real divisions, but only as marks from which they are to be cut. In order to make the real divisions, the microscope must be placed near the point, and the support *d* must be placed so that *d* δ shall be a tangent to the circle at δ. The wire of the microscope must then be made to bisect one of these marks, and a point or division cut with the point, and the process continued till the divisions are all made.

It is plain that in this way, without some further precaution, we must depend on the microscope not altering its position in respect of the point during the operation; for which reason I should prefer placing the axis of the microscope at exactly the same distance from the centre of motion *d*, as the point; but removed from it sideways, by nearly the semi-diameter of the object-glass; so that having made the division, we may move the beam compass till the division comes within the field of the microscope, and then see whether it is bisected by the wire, and consequently see whether the microscope has altered its place.

In the operation of bisection, as above described, it may be observed, that if the two scratches are placed so near together, that in making the second the point of the compass runs into the burr raised by the first, there seems to be some danger that the point may be a little deflected from its true course; though in Bird's account of his method, I do not find that he apprehends any inconvenience from it. One way of obviating this inconvenience, if it does exist, would be to set the beam compass not so exactly to the true length, as that one scratch should run into the burr of the other; but as this would make it more difficult to judge of the true point of bisection, perhaps it might be better to make one scratch extend from the circle towards the centre, and the other from it.

It is clear, that the entire arc of a circle cannot be divided to degrees, without trisection and quinquesection; and I do not know whether our artists have recourse to this operation, or whether they avoid it by some contrivance similar to Bird's, namely, that of laying down an arch capable of continued bisection; but if the method of quinquesection is preferred, it may be performed by either of the three following methods.

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Then, in subdividing these arches, and striking the true divisions, the wire of the microscope, instead of bisecting the interval between the two scratches, must be brought four times nearer to β than to b. But in order to avoid the confusion which would otherwise proceed from this, it will be necessary to place marks on the limb opposite to all those divisions, in which the interval of the scratches is not to be bisected, showing in what proportion they are to be divided; and these marks should be placed so as to be visible through the microscope, at the same time as the scratches. Perhaps the best way of forming these marks, would be to make dots with the point of the beam compass contiguous to that scratch which the wire is to be nearest to, which may be done at the time the scratch is drawn.

Perhaps an experienced eye might be able to place the wire in the proper manner, between the two scratches, without further assistance; but the most accurate way would be to have a moveable wire with a micrometer, in the focus of the microscope, as well as a fixed one · and then having brought the fixed wire to b, bring the moveable one to β, and observe the distance of the two wires by the micrometer; then reduce the distance of the two wires to one fifth part of this, and move the frame till the moveable wire comes to β, and then the fixed wire will be in the proper position, that is, four times nearer to β than to b.

It will be a great convenience, that the moveable wire should be made in such manner, as to be readily distinguished from the fixed, without the trouble of moving it.

In this manner of proceeding, I think a careful operator can hardly make any mistake; for if he makes any considerable error in the distance of the moveable wire from the fixed, it will be detected by the fixed wire not appearing in the right position in respect of the two scratches; and as the mark is seen through the microscope, at the same time as the scratches, there is no danger of his mistaking which scratch it is to be nearest to, or at what distance it is to be placed from it.

To judge of the comparative accuracy of this method with that of bisection, it must be considered that the arches $a\,\beta$, $\beta\,\delta$, &c. though made with the same opening of the compass will not be exactly alike, owing partly to irregularities in the brass, and partly to other causes. Let us suppose, therefore, that in dividing the arch $a\,a$ into five parts, the beam compass is opened to the exact length, but that from the above-mentioned irregularities, the arches $\alpha\,\beta$, $\beta\,\delta$, $\delta\,\epsilon$, and $\epsilon\,\phi$, are all too long by the small quantity ϵ, and that the arches *af*, *fe*, *ed*, and *d b* are all too short by the same quantity, which is the supposition the most unfavourable of any to the exactness of the operation; then the error in the position of $\beta = \epsilon$, and the point *b* errs $4\,\epsilon$ in the same direction, and therefore the point assumed as the true point of quinquesection, will be at the distance of $\frac{3\,\epsilon}{5}$ from β, and the error in the position of this point $= \epsilon \times 1\frac{2}{5}$.

By the same way of reasoning, the error in the position of the point taken between *d* and $\delta = \epsilon \times 2\frac{2}{5}$.

In trisecting the error of each point $= \epsilon \times 1\frac{1}{3}$; and in bisecting, the error $= \epsilon$; and in quadrisecting, the error of the middle point $= 2\,\epsilon$.

It appears therefore that in trisecting, the greatest error we are liable to, does not exceed that of bisection in a greater proportion than that of 4 to 3; but in quinquesecting the error of the two middle points is $2\frac{2}{5}$ times greater than in bisecting. It must be considered, however, that in the method 'of continued bisection, the two opposite points must be found by quadrisection, and the error of quinquesection exceeds that of quadrisection in no greater proportion than that of six to five; so that we may fairly say, that if we begin with quinquesection, this method of dividing is not greatly inferior, in point of accuracy, to that by continued bisection.

SECOND METHOD.

This differs from the foregoing, in placing dots or scratches in the true points of quinquesection and trisection, before we begin to subdivide. For this purpose, we must have a microscope placed as in page 33 second par. at the same distance from the centre of motion as the point is; and this microscope must be furnished with a moveable wire and micrometer, as in page 34; and then having first made the fixed wire of this microscope correspond exactly with the point, we must draw the scratches *b* and β, *d* and δ, &c. as before, and bring the fixed wire to the true point of quinquesection between *b* and β, in the manner directed in page 34, and with the point strike the scratch or dot; and if we please, we may, for further security, as soon as this is done, examine, by means of the moveable wire, whether this intermediate scratch or dot is well placed.

The advantage of this method is, that when this is done, we may subdivide and cut the true divisions, by making the wire of the microscope bisect the intermediate scratches, instead of being obliged to use the more troublesome operation of placing it in the proper proportion of distance between the two extremes.

This method certainly requires less attention than the former, and on the whole seems to be attended with considerably less trouble; but it is not quite so exact, as we are liable to the double error of placing the intermediate point and of subdividing from it.

As in this method the intermediate points are placed by means of the micrometer, there is no inconvenience in placing the extreme scratches b and β, &c. at such a distance from each other, that the intermediate one shall be in no danger of running into the burr raised by the extremes.

THIRD METHOD.

Let $a\ \alpha$ (fig. 3) be the arch to be quinquesected; lay down the arches $a\ b$, $b\ d$, and $d\ e$, as in the first method; then turn the beam compass half round, and lay down the arches $\alpha\ \beta$ and $\beta\ \delta$; then, without altering the frame, move the moveable wire of the microscope till it is four times nearer to δ than to e, and having first rubbed out the former scratches, lay them down again with the compass thus altered; but as this method possesses not much, if any, advantage over the second, in point of ease, and is certainly inferior to it in exactness, it is not worth while saying any thing further about it.

It was before said,* that the centre of motion of the beam compass is to be placed, so that the point and axis of the microscope shall both be in the circle in which the divisions are made; but it is necessary to consider this more accurately. Let $A\ \delta$ (fig. 4) be the circle in which the scratches are to be made, δ the point of the beam compass, which we will suppose to be exactly in this circle, d the centre on which it turns, and $M\ m$ the wire in the focus of the microscope, and let m be that point in which it is cut by the circle; and let us suppose that this point is not exactly in the line $d\ \delta$, then when the beam compass is turned round, the circle will cut the wire in a different point μ, placed as much on one side of $d\ \delta$, as m is on

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* Page 31.

the other, so that if the wire is not perpendicular to *d* δ, the arch set off by the beam compass, after being turned round, will not be the same as before; but if it is perpendicular, there will be no difference; for which reason, care should be taken to make the wire exactly perpendicular to *d* δ, which is easily examined by observing whether a point appears to run along it, while the beam compass is turned a little on its centre. It is also necessary to take care that the point δ is in the arc of the circle, while the bisection is observed by the microscope, which may most conveniently be obtained, by placing a stop on the support on which that end of the beam compass rests. If proper care, however, is taken in placing the wire perpendicular, no great nicety is required either in this or in the position of *d*.

Another thing to be attended to, in making the wire bisect two scratches, is to take care that it bisects them in the part where they cut the circle; for as the wire is not perpendicular to the circle, except in very small arches, it is plain, that if it bisects the scratches at the circle, it will not bisect them at a distance from it.

There are many particulars in which my description of the apparatus to be employed will appear incomplete; but as there is nothing in it which seems attended with difficulty, I thought it best not to enter further into particulars, than was necessary to explain the principle, and to leave the rest to any artist who may choose to try it.

It is difficult to form a proper judgment of the conveniences or inconveniences of this method, without experience; but, as far as I can judge, it must have much advantage, both in point of accuracy and ease, over that of dividing by the common beam compasses; but it very likely may be thought that Mr. Troughton's method is better than either. Whether it is or is not, must be left for determination to experience and the judgment of artists. Thus much, however, may be observed, that this, as well as his, is free from the difficulty and inaccuracy, of setting the point of a compass exactly in the centre of a division. It also requires much less apparatus than his, and is free from any danger of error, from the slipping or irregularity in the motion of a roller; in which respect his method, notwithstanding the precautions used by him, is perhaps not entirely free from objection; and, what with some artists may be thought a considerable advantage, it is free from the danger of mistakes in computing a table of errors, and in adjusting a sector according to the numbers of that table.

On a method of examining the Divisions of Astronomical Instruments.

The papers relative to the division of instruments, which will be closed by the present article, form a series of singular ingenuity and value. The subject is of immense importance; for it is intimately connected with the progression of astronomy. of the art of navigation, and the diversified pursuits requiring the practical application of the mathematics. Here, as well as in the two preceding papers, and many others of this Class, the form of writing and expression adopted by the Author are entirely retained, as best adapted to convey with perspicuity the whole of his ideas.

To the Astronomer Royal.

St. Ibbs, August 27. 1808.

Dear Sir,

I am persuaded that you must feel, in common with myself, how unpleasant it is to make use of an instrument in astronomical observations requiring extreme accuracy, whose exactness you have no adequate means of ascertaining, but are obliged to depend for it in a great measure upon the abilities and integrity of the artist. It is in vain that we observe with so much nicety, and read off with so much precision, if we are still uncertain whether there may not be an error in the instrument itself of much greater magnitude, than those which we are endeavouring to prevent; and that our best instruments must be liable to such errors, no person can possibly doubt, who has paid due attention to the sources from whence they may arise. I have estimated, as accurately as I could, the amount to which they may accumulate in Bird's method of dividing by continual bisections, and have satisfied myself that they are much more considerable than is generally apprehended: but as I cannot obtain such precise information as I could wish, respecting the exactness with which a bisection can be performed, or a length taken from the scale of equal parts and laid upon the instrument, I will not trouble you with the deduction which I have made. It is understood indeed, that Bird's method is now generally laid aside, and that each artist employs one, which he considers in many respects as peculiar to himself:

but I presumed that there would still be such a connexion betwixt Bird's method and those which have been substituted in its stead, as to render them in some degree liable to the same errors to which it was subject; and the reports which I have uniformly received from persons, who have had an opportunity of examining some of the modern instruments, have fully convinced me that my opinion was just. But whatever may be the nature of the methods which are now in use, or whatever their advantages over Bird's, I never could persuade myself that it would be safe to trust to an instrument, without a previous examination. To discover the means of accomplishing this object, is what I have for some time been anxious to effect, and though I fear my endeavours have not been very successful. I will nevertheless take the liberty of presenting you with the result.

You are aware, I believe, that I use a circular instrument for observing both in altitude and azimuth, which was made for me by Mr. Cary in the Strand; that the radius of both the altitude and the azimuth circle is one foot, and that each is divided into parts containing ten minutes. The construction of this instrument does not differ materially from that of other similar instruments, with which you are well acquainted, and I shall not therefore waste your time by giving you a particular description of it. For the purpose of examining the divisions upon the two circles, I procured an apparatus to be prepared by Mr. Cary, which will be very easily explained. To the face of the rim which surrounds the azimuth circle, and with its left end close to the stand which supports the micrometer on the east side, an arc of brass, concentric with the circle itself, and a little more than 90° in length, an inch in breadth, and one-eighth of an inch in thickness, is firmly fixed by screws, so as to have the plane parallel to the plane of the circle, and a small portion of its lower surface resting upon the extreme part of the rim. The screws pass through a brass arc, which is fastened to this at right angles, and lies with its broad side against the face of the rim. Upon the first mentioned arc, a strong upright piece of brass about six inches in length, is made to slide, the lower part of it embracing the arc as a groove, and having a clamping screw underneath, for the purpose of fixing it firmly to the arc at any point required. To the top of the upright piece of brass is attached a microscope, with a moveable wire in its focus, pointing down to the division upon the circle, not directly, however, but with an inclination to the left of about 30°.

This inclination is given to it, in order to make it point to the same division upon the circle, which is immediately under the micrometer itself, when it has been moved up as near to the micrometer as it is capable of approaching. The microscope has attached to it a small graduated circle of brass, and an index, by which the seconds, and parts of a second, moved over by the wire, are determined.

To the vertical circle there is likewise an arc applied, of the same length and breadth as the former, but somewhat thicker, and of a radius exceeding that of the circle by about two inches. This greater thickness is given to it, on account of its being supported in a manner which renders additional strength necessary. It is fixed with its broad convex side downwards upon two brass pillars, screwed fast to the plane of the azimuth circle, and standing in a line parallel to the plane of the vertical circle at the distance of about four inches from it, and on the right side of the pillars which support the micrometers belonging to this circle. The pillar, to which the left end of the arc is fastened, is placed close to the lower micrometer of the vertical circle, and the other contiguous to the elevated rim, in which the divisions of the azimuth circle are cut. The right end of the arc reaches beyond this pillar about ten inches. The pillars are of such a height, and so proportioned to each other, that whilst the left end of the arc, which lies horizontally, is raised to within about two inches of the height at which the lowest point of the vertical circle is placed, the whole arc runs parallel to the circle through an extent of something more than 90°. Upon the arc a microscope, with a moveable wire in the focus, is made to slide as in the former case, and to point to the divisions upon the vertical circle, not directly, but with an inclination of about 30° to the left, in order that the same division (which is the lowest upon the circle) may be seen through it, and through the lower micrometer at the same time.

I will now proceed to show you, in what manner the examination of the divisions upon either circle may be performed. The process is precisely the same in both cases, and will of course be described in the same words.

The first point to be examined is that of 180°, which must be done in the usual way, by bringing the points of 0 and 180° to the moveable wires of the opposite micrometers, and then turning the circle half-way round, and bisecting the points again with the moveable wires; and lastly, taking half the difference betwixt the distances of the wires in the two positions of the circle for the error at the point of 180°. Having now bisected the point of *zero* with the moveable wire of the micrometer, which is intended to be used in the rest of the process, (for we shall have no further occasion for both,) we must slide the microscope along the arc, till by moving the wire a little we can bisect the point of 90°, and then the micrometer must be firmly clamped to the arc. The circle must then be turned till the point of 180° is brought to the microscope, and that of 90° to the micrometer, so that we may be able to bisect each by a slight motion of their respective wires. This being done, we must observe, from the positions of the wires, how much the interval betwixt them has increased or decreased in the measurement of the new arc; and this increase or decrease must be noted down with a + or — accordingly. In the same manner we must proceed through the remaining two arcs of 90°, observing and noting down the difference betwixt each and the original arc.

The point of *zero* must now be brought again to the micrometer, and bisected by the moveable wire, and the microscope be made to slide back along the arc, till by moving the wire a little we can bisect the point of 60°, and when this is done, the microscope must be clamped. We must then measure the arc of 60° against every succeeding arc of 60° in the circle, precisely in the same way that we measured the first arc of 90° against the other three. The arc of 45° is next to be measured against every succeeding arc of 45°, and this will complete all that is necessary to be done in the early part of the morning before the heat of the sun can have affected the temperature of the instrument. The rest may be performed at our leisure.

You will immediately perceive the object of this kind of measurement. It enables us to determine, with any degree of accuracy that may be required, the proportion which the first and every succeeding arc of the circle, contained betwixt the micrometer and the microscope, bears to the whole circle, and of course the absolute length of the arcs themselves. Let a denote the real length of the first of these, and $\pm a'$, $\pm a''$, $\pm a'''$, &c. the difference betwixt the first and second, the first and third, &c. respectively; let A represent any other arc whose length is known, and which is a multiple of a, as marked upon the instrument, and let this multiple be expressed by n. Then will $\underline{a + (}a + a') + (a + a'') + (a + a''') + \overline{\&c. \ldots}$ $(a + a'''\ldots{}^{n-1}) = A$, and $a = \frac{A - a' - a'' - \ldots a'''\ldots n-1}{n}$

Hence it is evident, that if there is no error committed in the measurement of any of these arcs, we shall have the value of a, and consequently of $a + a'$, $a + a''$, $a + a'''$, &c. and of any arc, comprehending any number of these, accurately determined. But if there be an error of e in the measurement of the first, of e', e'', e''', &c. in the measurement of the second, third, &c. respectively, then we shall have the following equation for determining a, viz. $a + (a + a' + e + e') + (a + a'' + e + e'') + \&c. \ldots (a + a''''^{\ldots\overline{n-1}} + e + e'''''^{\ldots\overline{n-1}}) = A$, and consequently a will appear to be equal to $\frac{A - a' - a'' - a'''^{\ldots\overline{n-1}}}{n}$ $\frac{-\overline{n-1}\,e - e' - e'' - \ldots e'''''^{\ldots\overline{n-1}}}{n}$, which differs from its true value by $\frac{\overline{n-1}\,e + e' + e'' + \ldots e''''^{\ldots\overline{n-1}}}{n}$. Hence it follows, that the value of the p^{th} arc (p being greater than unity,) as deduced by, this process, will differ from its true value by $\frac{\overline{n-1}\,e + e' + e'' + \cdots e''^{\ldots\overline{p-1}} + e''''^{\ldots p} + \ldots e''''^{\ldots\overline{n-1}}}{n} - e - e'''^{\ldots\overline{p-1}}$, and that if we add any number p of these arcs together, in order to determine the value of the arc which is equal to their sum, we shall have an error in this value (and the expression holds when p is unity, or the first arc only is taken) equal to $p\frac{\overline{n-1}\,.\,e + e' + e'' + \cdots e'''^{\ldots\overline{p-1}} + e''''^{\ldots p} + \ldots e''''^{\ldots\overline{n-1}}}{n} - p - 1\,.\,e - e' - e'' - \ldots e'''^{\ldots p-1} =$ $\frac{\overline{n-p\,.\,e - e' - e'' - \ldots e'''\ldots\overline{p-1}} + p.e'''^{\ldots p} + \overline{e'''\ldots\overline{p+1} + \ldots e'''\ldots\overline{n-1}}}{n}$. Now, if we suppose e to be the greatest error to which we are liable in the measurement of any arc, and each of the succeeding errors to be equal to it, and likewise that $e', e'', \ldots \overline{e'''\cdots} p-1$ are all negative, then it will appear that $\frac{n-p}{n}+2pe$ will be the greatest error that can be committed in determining the value of any arc, by adding together the values of the (p) smaller arcs of which it is compounded. For instance, if the interval betwixt the micrometer and the microscope comprehends an arc of 60°, as marked upon the instrument, and this arc is measured against every succeeding arc of 60° in the whole circle, we shall have the greatest error that can be committed in deducing the arc of 120° from the addition of the two first arcs of 60°, equal to $\frac{6-2}{6} \times 2 \times 2e = 2.66e$. After these remarks, we may proceed to consider how the remaining divisions upon the circle may be examined with the least probable error, and to ascertain the amount of the greatest to which the process can in any case be liable.

Let the arc of 30° be now measured against every succeeding arc of 308° in the first, third, fourth, and sixth arcs of 60°, and let the length of each be determined from a separate comparison with the arc of 60°, in which it is comprehended, and not from a general comparison with all the four. The arc of 15° must then be measured against every succeeding arc of 15° in the first, third, fourth, sixth, seventh, ninth, tenth, and twelfth arcs of 30°, and the value of each deduced from a comparison with the arc of 30°, in which it is contained. When this is done, we shall have determined the length of every succeeding arc of 15°, of the first arcs of 30, 45, 60, 75 (= 60+15,) 90, 105 (=90+15,) 120 (=60+60,) 135 (=90+45,) 150 (=120+30,) 165 (=150+15,) and 180° in each semicircle.

We must next measure the arc of 5° against every succeeding arc of 5° in the whole circle, and deduce the values of the first, and of the sum of the first and second, in each succeeding arc of 15° from a comparison with the arc of 15° in which they are contained. We must then proceed to determine the values of the first arc of 3° in each 15°, and of its multiples the arcs of 6, 9, and 12°. We must also put down the value of the last arc of 3° in each arc of 15°, and then deduce the values of the first and last arcs of 1° in each arc of 15°, from a comparison with the arc of 3° in which they are respectively contained.

We shall now have measured in each arc of 15° the first arcs of 1, 3, 5, 6, 9, 10, 12°, and by taking the last arc of one degree, which has likewise been determined, from the arc of 15°, we shall obtain the first arc of 14°. The first 7° of this arc being measured against the second, we ascertain the value of the first 7°; and then, by measuring the first 4° of the remaining arc of 8° against the second, we shall get the value of the first 4°, which added to the arc of 7°, before determined, will give us the length of the first arc of 11°. The first 2° of the remaining arc of 4° must then be measured against the second, and we shall get the value of the first 2°, and by adding this arc to the arc of 11°, we shall obtain the value of the arc of 13°. By taking away the first arc of 1° from the arc of 15°, we get the remaining arc of 14°, and then having determined the length of the first 7° of this arc, by measuring them against the second, we must add it to the arc of 1°, and we shall obtain the arc of 8°. The length of the first 4° of this arc will then be easily known, by measuring them against the second, as will afterwards that of the first 2° in the arc of 4° itself by measuring them against the second in the same arc.

We have still to ascertain the lengths of all the first arcs of 10, 20, 30, 40, and 50 minutes, contained in each degree, for I shall only consider the case in which the circle is divided into parts of 10 minutes. Now the length of the first arc of 30′ will be obtained by measuring it against the second, and the lengths of the first and second arcs of 20′ (whose sum will give the arc of 40′) by measuring the first against each of the remaining arcs. The length of the third arc of 20′ must likewise be put down, and then the first arc of 10′ being measured against the second of the arc of 20′, in which it is included, and also against the two arcs of 10′ contained in the last arc of 20′, its own value, and that of the last 10′ in the degree, will be determined from a comparison with the arcs of 20′, in which they are respectively comprehended. The length of this last arc of 10′ being taken from that of the whole degree, will give us the length of the first 50′, and complete the operation.

In order to ascertain the greatest possible error to which we are liable in the examination, let ϵ denote in parts of a second the greatest that can be committed in bisecting any point upon the limb; then, since this error may occur at each end of the arc, it is evident that e in the expression deduced above $\left(\frac{n-p}{n} \times 2pe\right)$ will become 2ϵ, and the expression itself $\frac{n-p}{n}$

$\times\ 4p\varepsilon$. Hence the possible error will be $\frac{2-1}{2}4\varepsilon = 2\varepsilon$ at 180° $\frac{2\varepsilon}{2}+\frac{2-1}{2}\times 4\varepsilon = 3\varepsilon$ at 90°; $\frac{2\varepsilon}{3}+\frac{3-1}{3}\times 4\varepsilon = 3.33\varepsilon$ at 60°; $\frac{2}{3}\times 2\varepsilon+\frac{3-2}{3}\times 4\times 2\varepsilon = 4\varepsilon$ at 120°. The greatest error must therefore lie betwixt 90 and 120°, and nearer to the extremity of the latter than of the former arc. At 105° it will be 5.50ε; at 111° it will be $5.50\varepsilon-\frac{2}{5}.\ 1{,}5\varepsilon+\frac{5-2}{5}\times 4\times 2\varepsilon = 9{,}70\varepsilon$; and at 111° 10′ it will be $9{,}70\varepsilon-\frac{1}{6}.\ 1{,}04\varepsilon$ (the excess of the error at 111° above that at 112°) $3+3.33\varepsilon = 12.85\varepsilon$, which will be found to be the greatest error betwixt 105 and 120°, and of course the greatest in the first semi-circle. In the other semi-circle, the process being the same, the possible errors must necessarily be the same at the same distances from the first point, reckoning the contrary way upon the circle.

The magnitude of the quantity ε will of course vary upon circles of the same radius, according to the excellence of the glass employed, and the accuracy of the examiner's eye. It will seldom, however, exceed one second upon a circle, whose radius is one foot: and in general it will not amount to so much. I find that I can read off to a certainty, within less than three fourths of a second, and hence I conclude, that I could examine the divisions of my circle without being liable to a greater error than 9.63 seconds, and those of a circle of three feet radius without the risk of a greater error than 3.21 seconds.

To those people who are accustomed to entertain such exalted notions of the accuracy with which astronomical instruments can with a certainty be divided, this error, I dare say, will appear very considerable: but for my part, I am perfectly satisfied that it bears but a small proportion to the accumulated error which may take place, in spite of the utmost vigilance of the artist, in an instrument divided according to any method which has hitherto been made public. I need not, however, remark upon the very great improbability that the error of examination should ever attain or approach, to its extreme limit, as this must be sufficiently obvious to any person who is in the least degree conversant with the doctrine of chances; but it may be proper to observe, that we have it in our power (and in this respect the examiner possesses a most important advantage over the divider of an instrument) to diminish its probable amount, as much as we please, by bringing the moveable wires of the micrometer and microscope several times to bisect their respective points in the measurement of every arc, and taking a mean of the different *readings-off* for the true position of the wire at the real bisection of the point. The wire may be moved in this manner eight or ten times at each point (if such a degree of caution should be thought necessary,) and the mean taken in little more than a minute, so that the time of performing the work will not be so much increased, as might perhaps have been apprehended, and when it is completed, we may reasonably presume that the distance of every point from zero (whilst the temperature of the circle continues uniform) will have been determined with sufficient exactness for every practical purpose.

Of the time necessary for the examination, a pretty correct idea may be formed by considering how many measurements are required, and allowing about a minute and a half for each; *i. e.* a quarter of a minute for bringing the extreme points of the arc to the micrometer and the microscope, and a minute and a quarter for making the several bisections. Now, in dividing the whole circle into arcs of 15° each, it will appear that forty-four measurements must be performed; and to examine every point in each arc of 15°, there will be 161 required, making in all 3908 measurements; and consequently the time necessary for completing the whole work will be 5862 minutes, or about 98 hours.

The time and labour required for this examination are, no doubt very considerable; but it ought to be recollected, that it will render any great degree of precision, in dividing the instrument totally unnecessary. Whoever indeed employs this method of examination will be virtually the divider of his own instrument, and all that he will ask of the artist, is to make him a point about the end of every five or ten minutes, whose distance from zero he will determine for himself, and enter in his book to be referred to when wanted. We may likewise observe, that by this examination we shall not only be secured against the errors of division, but against those which arise from bad centering, and from the imperfect figure of the circle, and which in general are of too great a magnitude to be neglected.

It will, I dare say, have occurred to you, that whenever we are desirous that an observation should be particularly exact, we may guard it against the effects of unequal expansion or contraction in the metal, by means of the apparatus which I have described: for we have only to measure the arc which has been determined by the observation against the whole circle, or against the multiple of it, which approaches nearest to the circle, and from thence to deduce its value in the manner explained above, and we shall either have entirely excluded the error which we apprehended, or have rendered it too small to be of any importance. Suppose, for instance, that the arc determined by the observation was 48°; then by measuring it against the whole circumference increased by an arc of 24°, we shall obtain a result free from any greater error of unequal temperature, than one-eighth of the increase or decrease of this arc of 24° beyond a due proportion to that of the circle itself.

This expedient gives us all the advantages of the French circle of repetition, without the inconvenience arising from being obliged to turn the instrument, and move the telescope, so many times in the course of the observation. Nay, I am persuaded that the result may be made more accurate in this way, than by the French method, because not only can the object be more frequently observed, but the contacts or bisections, it may be presumed, will be more exact when the observer is not disturbed by the hurry attendant upon the use of the repeating circle; and with respect to any error in the instrument, from whatever cause it may arise, it will be as effectually excluded by the process which I recommend, as by moving the telescope round the circle. Besides, this method is applicable either to the azimuth or altitude circle, or indeed to any circle which turns upon its own axis, whereas the French method can never be applied to the azimuth circle, nor to any other circle which does not turn both upon its own axis, and upon one which is perpendicular to it.

After all, however, it is possible that the process which I have been explaining to you may be no new discovery, and that you may be already acquainted with it. If this should be the case, you will be kind enough to inform me; at any rate indeed, I should esteem myself greatly obliged, if you would favour me with your sentiments upon the subject, as soon as you can do it with perfect convenience to yourself.

I am, dear Sir,

Yours, &c.

WILLIAM LAX.

Farey's elliptograph.

An Instrument for drawing Ellipses.

An instrument of this description has long been a desideratum in the art of drawing, as all the methods hitherto in use are liable to objections, either for want of neatness in their performance, or in the extent of application. The present instrument is completely general in its properties, being capable of describing ellipses of any possible dimensions or proportions of diameter, within the size to which it is made, and it is equally applicable to engraving and drawing. .The general size of the instrument is twice as large as the drawings in plate LXXIX: when it is used, it is placed upon the paper, or surface where the ellipses is to be described, and the square frame held fast by one hand, while the moving circles are turned round by the other, to trace the curve by means of a drawing pen, properly situated for that purpose.

Fig. 1 represents the whole instrument, looking down upon its plan; fig. 2 is an elevation, to show the thickness of its several parts; and fig. 3 is a cross section.

The moving parts of the instrument consist of two brass circles (AB) of equal dimensions, so fitted together that they will slide one upon another, by means of the pinion K, to separate their centres to any required distance within the extent of their radii; the centres have no central bar, but instead thereof have two bars, *a a,* parallel to each other, and at some distance from the centre, leaving an open space between them, in which the drawing pen or tracing point is situated; there are also crooked arms, *b b,* proceeding from the bars *a a* to the circular rim, to give them sufficient strength, and these being all the bars across the circle, leaves them sufficiently open to see the curve as it is traced beneath by the drawing pen.

The circles are united by screws at *c c,* screwed into the lower circle, and the two bars *a a* of the upper circle are included between them; this keeps the two together, but at the same time admits of sliding them one upon the other in the manner of the figure. At *e e* are two other screws, tapped into the other circle, and retaining the bars of the lower one in the same manner. The centre pin for the pinion K is fixed on one of the arms of the lower circle, and acts upon a rack *d,* screwed to the upper circle, so that it separates the two when turned round by the finger and thumb, applied to the milled head K, upon it, but the circles are fitted together so tight by the screws, that they will not separate from each other except by the power of the pinion, and may, in the motion of the instrument, be considered as firmly united together, but capable of having any degree of eccentricity given to them by means of the pinion K.

The circles are turned round in their square frames, by means of six small handles, *f f f f f f*, fixed in the rim of the upper circle; to any two of these the thumb and finger of the right hand are applied.

The frame or fixed part of the instrument consists of four straight rulers DE, and FG; the latter are screwed down upon the former, and are therefore in a plane above them, as is shown by fig. 2, plates of brass being interposed between them, at the angles, to separate them to a proper distance.

The lower circle 4, is fitted in between the two lower rulers, DE, and slides freely to the direction of their length, but has no shake sideways; in like manner the upper circle B is included between the edges of the rulers FG, and therefore moves in a right line, in a direction perpendicular to the former; thus the frame forms two grooves at right angles to each other, in which the circles revolve, with an eccentric motion, the upper circle sometimes hanging over the lower rulers, and the lower circle passing under the lower rulers, as is shown in the figure.

The result of this motion is, that a tracer placed on any part of the circles when they are rendered eccentric, will describe an ellipsis on the surface beneath, but the only tracer which is used for drawing, is situated between the bars *a a*; into this space a small carriage or frame *g* is fitted to slide freely from one end of the opening to the other, by means of a rack *h* screwed to one side of it, with a millet head and a pinion L turning on a centre-pin fixed into the upper circle BB. The frame has a brass socket, H, moving on a centre-pin fixed across it, and having a hole in it for the reception of the leg of a pair of common drawing compasses, M, which stand as in fig. 2, when in use, the pen tracing the curve upon the paper; but they admit of being lifted up on the centre-pin of the socket H, and then for the convenience of setting the instrument, the circles can be turned about without making any marks.

The transverse section, fig. 3, shows the frame *g g*, and the manner in which it is fitted into the bars *a a* of the circles, also the socket H, moving on its centre-pin, and the two pair of racks and pinions, K *d*, and L *h*, the former for the purpose of separating the circles, and the latter for moving the frame *g* along between them; the frame *g* is so fitted that it continues at the same point, with respect to the upper circle B, when the centre of the two are separated from each other by the motion of the pinion K, and may therefore be considered as immoveable when the lower circle only is moved.

To keep the frame of the instrument stationary upon the paper whilst it is used, two sharp pins are fixed in the ruler P, which penetrate the paper, and make it quite fast, when they are held down by the finger and thumb of the left hand applied upon the heads of the nuts, NO ; these are introduced to unite the ruler P with the ends of the two upper rulers FG, but the screws of these nuts passing through grooves in the ruler P, admit the whole instrument to be moved on the paper a small quantity parallel to itself, in the direction of the ruler P, though the friction of the fitting is such that it will not move unless some force is applied for that purpose ; the same screws, where they pass through the ends of the rulers FG, are also received in grooves, so that by unscrewing the nuts, the whole instrument can be moved sideways, a small quantity nearer or farther from the ruler P, but by screwing these nuts fast, the screws become fixed to FG, though they still admit of moving in the grooves of the ruler P.

The reader will now comprehend the structure of the instrument ; the circles are capable of revolving in the frame set with any required degree of eccentricity ; and the tracing point or pen can be removed to any required distance from the centre of the upper circle B ; the compasses M, being opened to the extent of a mark made upon one of the bars of the frame, and then being fixed in the instrument, by pushing them into their socket H, it is ready for use.

In this state, suppose the two circles set by the pinion K exactly concentric with each other, and the pinion L turned till the end of the frame *g* comes into contact with the rim of the instrument, then the point of the pen M will come exactly in the centre of both circles, and the circles being turned round in the frame by their handles, the pen will only mark a small point on the paper, which will be the centre of any curve the instrument may be afterwards made to describe.

By turning the pinion L, the point of the pen may be removed to any distance from the centre, within the radius of the instrument, and it will, when turned round, describe a circle which may be made of any radius, from the smallest point to the size of the circles ; this is the simplest case of the instrument, and may be considered as an ellipsis when the difference of its diameters is infinitely small ; when the circles are rendered eccentric it draws an ellipsis, and by turning the pinion L the breadth of the ellipsis will be determined, and by the other (K) the difference between its breadth and length is regulated.

Suppose the pinion K turned to render circles eccentric without moving the other pinion, the pen therefore remains in the centre of the upper circle ; in this case the pen will describe a straight line, equal in length to twice the eccentricity of the circles : this is evident, because the circumference of the upper circle BB, moving against the straight-edge F and G, its centre must describe a line parallel thereto ; this case may be considered as an ellipsis without breadth, for if the pen is set the smallest quantity out of the centre of the upper circle, it will draw a very narrow ellipsis, and by setting it at different distances from the centre, any required proportion of ellipses may be described.

The conjugate diameter will in all cases be equal to double the distance from the point of the pen to the centre of the upper circle, and the difference of the conjugate and transverse diameters will be always equal to twice the eccentricity of the two circles.

The principle upon which this instrument operates, is the same as the trammel, employed by carpenters and other artificers, for striking ovals, by means of a board with two cross grooves in it, and a beam or radial bar, which has two pins to operate in the grooves, and a third to draw the curve ; to prove this, suppose PP, and QQ, fig. 4, to be the two diameters of the intended ellipsis, then, if the three points *d*, *e*, and *f*, are marked upon an inflexible bar, and the points *d* and *e* constantly applied to the two diameters, PQ, and a tracing point situated at *f* is carried round by the bar, it will describe an ellipsis RR; this is the principle of the trammel, but its defects, as at present constructed, are well known.

First, it will not draw any ellipsis which is less in either of its dimensions than the size of the board or frame containing the cross grooves, representing the two diameters PP, and QQ; nor can it draw much larger, unless the diameters are nearly equal.

Secondly, it is difficult to fix the cross firmly on the paper, or to bring it to the exact point required for the centre of the ellipsis ; and, thirdly, when this is done, the most perfect workmanship in the grooves and sliders, can scarcely ensure its moving freely without shake or improper motions, so as to make an accurate and fair curve.

All these defects are obviated in the present invention, by extending the two points *d* and *e* to become the largest circles, AB, fig. 1, and then the rulers DE, and FG, represent the sides of the grooves, in which the points move; the point of the pen of the compasses M, now represents the point *f* in all its properties of moving along the bar, to enlarge or diminish the ellipsis, but with the advantage that it can be actually brought to coincide with one of the points *d* or *e*, when of course it will draw a straight line, and if brought to agree with both of them, it will describe only a point; therefore this instrument will describe any possible variety of ellipsis within the limits of its radius, either as to size or proportion of its diameter.

DIRECTIONS FOR USING THE INSTRUMENT.

When any ellipsis of given dimensions is to be drawn, the paper is prepared by drawing the two diameters, about four inches long; upon each of these, set off with the compasses the four points where the intended curve is to intersect the lines. This preparation is not essential, but it assists in setting the instrument in its true place: first, fill the drawing pen of the compasses with Indian-ink from a camel-hair pencil, (for common ink soon destroys the steel points of the pen;) then adjust the screw, that the pen may draw a proper line; and fix the compasses into the brass socket H, so that they have no shake or looseness in the fitting; turn the circles about in their frame so that the pen is towards the side marked G; now place the whole instrument in such a position, that the centre of the four rulers coincides with the centre of the intended ellipsis. This may be estimated; or, by previously producing the two diameters, the frame may be set very nearly, taking care to place the upper rulers FG parallel to the greatest diameter. Here fix the instrument, by pressing the two pins or points of the ruler P, into the paper, and hold it fast, by placing the thumb and forefinger of the left hand upon the nuts NO, leaving the other hand at liberty to turn the circles about, by applying the finger and thumb to any opposite two of the small handles *f*. Now, by turning the pinion L, remove the drawing pen to the extent of the shortest diameter of the ellipsis; then turn the circles one half round by the handles, and examine if the point of the pen comes exactly to the opposite end of the shortest diameter; if it does not, adjust the error one half, by moving the pen by turning the pinion L; and the other half, by moving the whole frame on the paper. The screws of the nut NO, will admit this motion, being fitted into grooves in the ruler P, (which should not be disturbed,) but the nuts should not be screwed so tight as to prevent the motion; then, by returning the circles back again, its accuracy will be ascertained; for if it meets the former mark, it proves that the circles are in the right centre, and the compasses are set to the proper diameter for the conjugate axis; now turn the pen towards the length of the ellipsis, and without altering the compasses or pinion L, slide the circles one upon the other by the pinion K, till the point of the pen arrives at the mark made for the length of the ellipsis; turn the circles half round to the opposite end, and if they match the mark made there, the adjustment is correct; if not, one half the error must be corrected by moving the circles with their pinion K, and the other by moving the whole frame on the paper. To do this, the nuts NO must be made slack, and then the frame will be at liberty to move, as before described; but the ruler P must never be removed after the first fixing, and the side D of the frame will of course be a greater or less distance from it.

The adjustments being made in this manner, the pen may be suffered to rest upon the paper, and trace round the curve. The precautions of turning the circles to the opposite sides will be unnecessary, except where great accuracy is required. In turning the circles about, a habit will be easily acquired of pressing with equal force on the two opposite sides of the circles, and then they will turn round pleasantly.

It will save much trouble in adjusting the place of the instrument upon the paper, if the compasses before being put into the socket H, are opened to the extent of the arch struck upon the ruler G: then, when the compasses are put into their socket, and the pinion L turned back as far as it will go, the point of the pen will come exactly into the centre of the ellipsis which it is intended to describe; if, therefore, the centre of the ellipsis is marked upon the paper, and the point of the pen (when opened to the above extent, and the pinion L turned till the end of the frame *g* touches the rim of the circle,) being brought by moving the whole instrument on the paper, to this mark, the instrument is adjusted at once as to its position on the paper, and the other adjustments for the dimensions of the ellipsis required to be drawn, must be made as before directed.

After having draw an ellipsis, if it is required to draw another parallel to it, to show the thickness of a circular plate, set the pen opposite G, fig. 1, and by the screws of the nuts NO, as before mentioned, being fitted in grooves, the frame and the circles may be moved with the longer axis parallel to itself, so as to describe another ellipsis parallel to the former.

Method of transferring Pictures to new Grounds.

The want of an efficient method of transferring to new grounds, pictures which are hastening to decay, or on walls or ceilings which are likely to be pulled down, has often been regretted. The paper we shall here give to the reader, is perhaps the best essay on the subject, that has hitherto been made public. By this process, any paintings on the ceilings, walls, or wainscots of old buildings, however large, on curved or straight surfaces, and of whatsoever shape, may be preserved from ruin and handed down to posterity, when otherwise they would be lost; and this may be done without defacing or injuring them.

The first thing to be attending to, either for paintings on plaster walls or ceilings, or from boards, is, that the place in which they are, be secure from wet or damp. If the paintings are on old walls, in large buildings, and places where this cannot be attained by art, then the summer seasons should be taken for the purpose, as a picture would rarely escape damage, if wet or damp get at it while under the process; at the same time caution should be taken that the room or place be not overheated, which would also produce equally bad effects. These precautions being taken, the next thing is to examine the force of the painting. If there are any holes in the same, they must be carefully filled up with paste, or putty of glue and whiting: this, if the holes are large, should be done twice or thrice, so as entirely to fill up the holes, and to leave the face even and smooth; but if there are any bruised places, with paint still remaining on the face of the bruised parts, then this stopping must not be applied, but the securing canvass, hereafter described, must be pressed down into such places. In the places that are stopped, there will of course appear blemishes, when the picture is transferred: but the process is rendered much more certain by this treatment of the deficiencies.

Attention must next be paid, to lay down any blisters, or places where the paint is leaving the ground; this is done by introducing, between the paint and the ground, some very strong paste made of flour and water; and the face of the blistered paint being damped with a wet sponge or pencil, it may be pressed with the hand home to the ground, to which it will then adhere. All the unsound places being thus secured, care must be taken to clear the face of any grease or dirt, as also of any particles of the paste, that may happen to be left on the surface.

The next thing is to determine the size of the painting meant to be taken off; and if on a plain surface, a board of the size of the picture must be procured, of not less than an inch in thickness, and framed together with well seasoned wood, in small pannels, smooth and flush on one side. This done, a piece of fine open canvass must be provided, such as the finest sort used for hanging paper on. This canvass should be made somewhat larger than the picture, and so sewed together, and the seam pressed, that it may be perfectly smooth and even. It may be called the securing canvass; and being so prepared, it is struck on the face of the picture, with a paste made of strong beer, boiled till it is half reduced, and then mixed with a sufficient quantity of the finest wheaten flour to give it a very strong consistence. To large pictures, on walls or ceilings, the canvass must for sometime be pressed, and rubbed with the hand as smooth as possible, working it from the middle to the outside, so as to make it tolerably tight, and observing, as it dries, to press it with the hand or cloth, into any hollow or bruised places, so that it may adhere to every part of the painting. This done, it is left to dry, which it will mostly do in a day or two. When dry, a second canvass, of a stronger and closer sort, and of the same size as the other, is in like manner to be attached on the top of the first. This last canvass will want very little attention, as it will readily adhere to the first; and, being dry, any small knots or unevenness which appear on it must be removed. Then the whole should be again covered with a thin paste of size and whiting; when dry, the surface should be pumiced over, so as to make it perfectly smooth and even.

The painting being thus secured, the board, already prepared to the size of the picture, is to be put with the smooth side against the face of the uppermost canvass, so as exactly to cover the surface intended to be transferred. The edges of the canvass, which as before directed, are left larger than the painting, are then to be pulled tight over, and closely nailed to the edge of the board. If the painting be large, either on ceilings or walls, the board must, by proper supports, be firmly fixed against the picture, so that it can readily be lowered down when the plaster and painting is detached.

The canvass and board being fixed, the paintings from walls or ceilings are to be freed, together with a certain portion of the plastering; this with proper care and attention may readily be done. If on a ceiling, the first thing is to make some holes through the plastering round the outside of the board and painting, and, with a small saw, to saw the plastering from one hole to another, till the whole is disunited from the other parts of the ceiling. The workman must then get at the upper side of the ceiling, where he must free the plastering from the laths, by breaking off the keys, and with a chisel, cut out the laths, whereby the plastering, together with the picture, will be left resting on the boards and supports. If there be apartments over the ceiling, the readiest way will be to take up a few of the flooring-boards above; if next the roof, means may always be found to get at the back in the same way; and although at first the operation may appear difficult, yet it is presumed, no difficulty will be found by any ingenious workman.

If the painting is on a brick or stone wall, the wall must be cut away at the top, and down the sides of the painting; and then by means of chisels or saws, of different lengths, the wall must be cut away quite behind the painting, which will be left with the plastering resting on the board. This operation may sometimes be done with a saw; or, if the wall be not thick, nor the other side of much consequence, the bricks or stones may be taken out from that side, leaving the plastering and painting as before.

If paintings are on curved surfaces, such as the coves of ceilings, then the only difference of operation is, that some ribs of wood must be cut out and boarded smooth to the curve of the surface of the painting, against which they must be fixed, in place of the before-described bearing board; the painting is then to be freed, and left with the plastering resting on the bearers.

For paintings on wainscot or boards, the same process is exactly followed, only that, as the wainscot or board can always be cut to the size wanted, and laid horizontal, the securing canvass is stretched thereon, and turned over its edges till it is dry; after which the edges are again turned up, and nailed to the board, in the same manner as those from walls.

The paintings being freed from their original places, as above described, the state in which they are obtained, is that of being secured to two thicknesses of canvass, with their faces to the board prepared for that purpose. They may therefore be removed to any room or shop, where they may be finished as follows: Let the room or shop be moderately warm and dry, but by no means overheated; lay the board on a bench or tressels; the back of the picture will then be uppermost, and the plastering, or wood, is to be cleared away, leaving nothing but the body of paint, which will be firmly attached to the securing canvass. To perform this operation of removing the wood or plaster from the back of the painting, a large rasp, a narrow plane, and chisels, will be requisite; the work is difficult to describe, but would soon be learned by any one who makes the attempt; nor is it very tedious with sharp tools. When it is performed, the picture is ready to be attached to new-canvass, as follows:

The painting being cleared, and lying on the board, the back of it is to be painted successively, three or four times over, with any good strong-bodied paint, leaving each coat to dry before the other comes on: a day or two between each will generally be found sufficient. Each of these coats, and particularly the first, should be laid on with great care, taking but a small quantity in the brush at a time, and laying it very thin. This precaution is necessary, to prevent any of the oil or paint from searching through any small cracks or holes that may happen to be in the face of the picture, which would run into the paste, and so attach the securing canvass to the picture as to prevent its being afterwards got off. If any of these holes or cracks are observed, they should be stopped up with the glue and whiting paste and the painting then repeated till a complete coat is formed on the back of the picture. It is now ready for attaching to canvass, which is done by spreading all over the back of the picture, a paste made of copal varnish, mixed with stiff white lead, and a small quantity of any other old fat paint; all which being spread equally over with a pallet-knife, such a canvass as the first securing canvass is laid upon it, and strained and nailed round the edges of the board, in which state it is left till it becomes tolerably dry; and then a second canvass, of a stronger sort, must be in like manner attached on the first, and left till it is perfectly dry and hard. This mostly takes about two months; and the longer it is left, the more securely the painting will be attached to its canvass, and less liable to crack or fly from it. When sufficiently dry, all the four pieces of canvass are to be unnailed from the board, and the edges turned up the reverse way, and nailed to a proper stretching frame. This is done by unnailing from the board a part on each side at a time, and immediately nailing it to the stretching frame, so as never to leave the canvass to rack or partially stretch, which would damage the picture. In this manner, by degrees, the cloths are entirely detached from the board, and firmly fixed on the stretching frame. The superfluous canvass left larger than the frame, may then be cut off, and the wedges put in the frame, and moderately tightened up.

There remains now only to clear the face of the painting from the securing canvass, which is done by repeatedly washing the face with a sponge dipped in moderately warm water. In doing this, no violence or force must be used : with frequent and gently washings, the paste will all be worked out with the sponge; the outer canvass being cut round the edges, is then to be stripped off, and the other next the face of the picture is to be done in the like manner. It will then only remain to clear the paste off entirely, and repair any defects; and the picture will be as strong as if it had been originally painted on the canvass to which it is transferred.

. For taking pictures off walls, without taking the walls down, or cutting away more than the plastering, the following process is proposed :—The face of the picture to be first secured with canvass, in every respect, in the manner before-described : then instead of the plain board, a bearer should be prepared, with a convex surface, composed of ribs, boarded over, so as to form part of a cylinder, of not less than five feet radius, and as long as the height of the picture. This bearer being prepared, in order to apply it, a floor or platform should be erected, and placed horizontally, with its surface level, and its edges immediately in contact with the bottom of the picture meant to be transferred. The use of this platform is for the above-described bearer to rest and move upon; the bearer should be set on its end, with one edge in contact with the wall, at one side of the picture; consequently the other edge will be at some distance from the wall, according to the size of the picture and convexity of the bearer. Being thus placed, the superfluous edge of the securing canvass should be turned over, and nailed to that edge of the bearer that is next to the wall; then the operation of cutting away the plastering should be commenced; it may be done with the corner and end of a short saw, by sawing between the brick-work and plastering, leaving the thickness, or part of the thickness of the plastering, on the painting fastened to the bearer; and when this edge of the picture is freed, the whole height for nine or ten inches under the edge of the bearer that is furthest from the wall, must be gently forced nearer; consequently the other edge, together with the painting and plaster that is freed, will leave the wall, and give an opportunity of introducing the saw behind, and cutting away the same to a certain distance further under; and by repeating this, the whole of the picture will at last be freed, and left on the bearer. Each time the bearer is removed, and in effect rolled on the vertical surface of the wall, care must be taken to turn and nail the securing canvass on the top and bottom edges of the bearer, so as to secure the freed part of the plastering and picture from moving about; and, lastly, before the bearer and painting be moved, care must also be taken to nail the other edge of the picture in the same way, which will secure the whole to the bearer. This done, the picture and bearer are at liberty to be moved to a proper place, in order to be freed from the plaster taken from the wall; the edges may then be unnailed, and the painting and canvass slipped from this bearer on to a plain board; the new canvass must then be put on, and remain till dry, as in other cases.

It may appear that the bending of the canvass and plastering to the convex bearer, will crack the plaster, and damage the painting; but it will be found in practice, that to the curve mentioned, or even a less radius, plastering will bend, without any visible crack, even on its exterior; and that part next the bearer, not having occasion, in bending, to extend its parts, will consequently be much less liable to be disturbed by such bending.

Method of preserving and repairing the Defects of the Canvass of Oil Paintings.

1st. Separate the canvass from the pannel, or straining frame, and lay it on a smooth table, with the painting downwards, and nail it securely,

2nd. Take a piece of tin-foil, larger than the canvass, and spread it evenly on a very smooth table. Then melt some Salisbury glue in the same manner as for cabinet-makers' use.

3rd. Warm the tin-foil before the fire, and lay it again on the table, then wash it over with the glue, and place it on the back of the canvass, secured as above, as quickly as possible; smooth it perfectly with the hand, and let it remain in a warm room to dry.

4th. To repair the cracks of the canvass, in an old oil painting, lay it on a smooth table, the subject downwards; then with a brush or fine linen, cover the convass with some melted white wax, and, with a warm flat smoothing iron, rub over the wax, and press it hard, which will draw the colours up to the canvass.

5th. To varnish the painting, clean it well, take some white wax, and spirits of turpentine, with a small quantity of linseed-oil, and sugar of lead; melt them over the fire, dip a fine linen rag therein, with which wash the painting; then, with a fine linen rag, rub over the varnish, till it begins to be polished; let it remain till next day, and then rub it over with a fine waxed cloth, and afterwards with a soft linen cloth, using them alternately, by which means the painting will receive a very fine polish.

By the above means the cracks and small holes in old paintings may be closed and repaired, and a coat of tin-foil may be afterwards glued on the back of the canvass, as above-mentioned.

A foot square of the tin-foil costs about sixpence; when wanted of a larger size it will cost considerably more in proportion. It may be procured in sheets of three or four feet if wanted.

Preparation of colourless Ox-gall for Painters in Water-colours.

Ox-gall, deprived of its tendency to putridity, and its colouring matter, so detrimental to all delicate colours, is prepared in the following manner:

To a pint of fresh ox-gall, boiled and skimmed, put one ounce of alum, finely powdered; continue it on the fire until combined; when cold put it into a bottle, and cork it moderately close.

To another pint of fresh ox-gall, also boiled and skimmed, put one ounce of common salt, and continue it on the fire until combined; when cold, put it into another bottle, and cork it moderately close.

Gall, thus prepared, will keep perfectly free from putridity, or any offensive smell.

When the above preparations have stood in a room, of a moderate temperature, for about three months, they will deposit a thick sediment, become clear, and fit for ordinary purposes, but as they contain a large portion of yellow colouring matter, tinging blue of a greenish hue, reds, brown, and sullying purples; they are unfit for general use in painting in water-colours. For their further purification, therefore, after they have been decanted, let them be combined in equal proportions; a thick coagulum is instantly formed of the yellow colouring matter, which precipitates, leaving a clear liquid, namely, the colourless ox-gall.

After the combination of the two first preparations, the process may be assisted by filtering the liquid through paper. Age renders this preparation more brilliantly clear, and seems even to give it an agreeable scent; nor has it been observed to contract, at any time, an unpleasant smell, or lose its useful properties, which we shall now proceed more particularly to notice.

This preparation possesses all the valuable properties of ox-gall, as applicable to painting in water-colours, with the superior advantages of being deprived of all tendency to putridity, and of all colouring matters.

It combines with, and fixes, all water-colours, as they are usually prepared, either by being mixed with them, or washed over them after they are laid upon the paper, &c. It renders blue, purple, red, green, and all other delicate colours, more bright and durable; and if a small portion of it be added to any of the colours, it causes them to wash more freely and evenly over the surface of the paper, ivory, &c.

Combined with gum-arabic, it gives depth of tint, without any unpleasant glossiness upon the surface of the drawing, and prevents the gum from cracking; and the colours are so completely fixed in the paper itself, that subsequent tints can be washed over them without any risk of their becoming foul, or forming improper combinations with the under colours.

Combined with fine lamp-black and gum water, it forms a complete substitute for Indian-ink.

If it be floated over the surface of drawings, made with chalks, or black-lead pencil, it fixes them firmly; and they may then be washed over with any water-colours, previously mixed with a small portion of it, without in the least degree disturbing the chalks or black-lead.

For miniature painting, being washed over the surface of the ivory, it completely removes its greasiness; and being mixed with the colours, it cause them to float freely thereon, and tints may be laid on after tints, the colours being struck into the ivory.

For transparencies, oiled paper, being first washed over with the refined ox-gall, and permitted to dry; water-colours, mixed with some of it, will lie freely, and perfectly smooth upon it, and be so fixed, as not to wash up by the repetition of different glazings of colours, over each other, thus producing depth of colour.

In short, the valuable properties this refined ox-gall possesses, makes it equally applicable to historical, landscape, botanical, and natural history painting, as well as to colouring prints in general; and by its readily combining with all the vehicles used in the preparation of water-colours, and having no colour in itself, it enables the artist to paint with ease on surfaces otherwise unfavourable, at the same time rendering the colours more bright and durable.

Method of prepaiing Ox-gall for the Use of Painters.

It has long been a desideratum to find out a method of preparing ox-gall for the use of painters, so as to avoid the disagreeable smell which it contracts by keeping in a liquid state, and at the same time to preserve its useful properties. The following method of doing it is very economical, and will be, to those who use ox-gall, a great saving, as it will prevent it from putrifying, or breeding maggots:

Take a gall fresh from the ox, and put it in a basin; let it stand all night to settle, then pour it off from the sediment into a clean earthen mug, and set it in a sauce-pan of boiling water over the fire, taking care that none of the water gets into the mug. Let it boil till it is quite thick, then take it out and spread it on a plate or dish, and set it before the fire to evaporate; and when as dry as you can get it, put it into small pots, and tie papers over their tops to keep the dust from it, and it will be good for several years.

In this concentrated state, the ox-gall is very convenient for use, as a small cup of it may be placed in the same box which contains other colours.

The general qualities of gall are well known to artists in water-colours, particularly to those who colour prints, as many colours will not, without gall, work freely on such paper, on account of the oil that is used in the printing ink.

The artists who make drawings in water-colours, also use gall in the water which they mix their colour with, as it clears away that greasiness which arises from moist hands upon paper, and makes the colour work clear and bright.

Gall is also useful to housekeepers, sailors, and others, to clean woollen cloths from grease, tar, &c.

For all these purposes, the ox-gall, prepared as above directed, is as useful as the freshest gall that can be procured, and much cheaper on account of its durability. It is rendered fit for use in a few minutes, by dissolving it in the proportion of the size of a pea to a table-spoonful of water.

Method of preparing Oil-colour Cakes.

Take of the clearest gum mastic, reduced to fine powder, four ounces; of spirits of turpentine, one pint; mix them together in a bottle, stirring them frequently till the mastic is dissolved: if it is wanted in haste, some heat may be applied, but the solution is best when made cold. Let the colours to be made use of, be the best that can be procured, taking care that, by washing, &c. they are brought to the greatest degree of fineness possible. When the colours are dry, grind them on a hard close stone (porphyry is the best) in spirits of turpentine, adding a small quantity of the mastic varnish; let the colours so ground again become dry; then prepare the composition for forming them into cakes in the following manner:—Procure some of the purest and whitest spermaceti: melt it over a gentle fire, in a clean earthen vessel; when fluid, add to it one-third of its weight of pure poppy oil, and stir the whole well together.

These things being in readiness, place the stone on which the colours were ground on a frame or support, and by means of a charcoal fire under it, make the stone warm; next grind the colour fine with a muller; then, adding a sufficient quantity of the mixture of poppy oil and spermaceti, work the whole together with the muller to a proper consistence; take then a piece, of a fit size for the cake you intend to make; roll it into a ball, put it into a mould, press it, and it will be complete.

When these cakes are to be used, they must be rubbed down in poppy or other oil, or in a mixture of spirits of turpentine and oil, as may best suit the convenience and intention of the artist.

The colours prepared according to this process, have the valuable property of drying without a skin on the surface; they work as freely at the same time as common oil-colours; and one artist, in his trials of them, observed, that the red-lead appeared to be better preserved from changing, by this mode of preparing it, than by any other.

It may be observed, that the Inventor's colours in bladders, are prepared with a mixture of spermaceti, and differ only from the cakes by having a larger proportion of oil.

Process for producing the Lights in stained Drawings.

The difficulty of preserving the lights in stained drawings with freedom and precision, is so universally felt by those who cultivate that branch of the arts, the practice of which is every day growing more extensive, that the statement of this circumstance alone is sufficient for the introduction of the following process, by which that difficulty is removed, and by which all the effect of body colour may be obtained, without any of its inconveniences or defects. It is applicable to every subject, to the richness of foliage, of rocks, or of fore-grounds; and in ruins, their most picturesque appendages of hanging shrubs, weeds, &c. may be expressed by it with the utmost sharpness, and with all the lightness and freedom with which body colour, or oil-painting is susceptible.

The principle of this process consists in covering the places, where the touches of light are intended to be, with a composition not liable to be displaced by washing over it with the colour, and such as may be afterwards removed by a fluid in which the colours used in water are not soluble.

This composition, or stopping mixture, is made by dissolving bees' wax in spirits of turpentine, in the proportion of one ounce of wax to five ounces of the spirits; and as near the time of using it as may be convenient, grind with the pallet-knife as much flake-white or white lead, in spirits of turpentine, as may be wanted at one time; dilute it with the above solution until it will work freely with the pencil, and appear on the paper, when held between the eye and the light, to be opake. It is necessary to observe this, or the first touches will not be sufficiently visible, after being washed over with the colours, to ascertain the places of the second. It is also necessary to use a frame instead of the drawing-board, or to paste the paper on the frame of the drawing-board, so as to remove the pannel; because the first and second touches must be put on with the drawing placed between the eye and the light, as they will be most visible in that situation. On this frame paste the paper wet, so as to dry firm: when quite dry, draw the outline, and proceed as follows:

1st. With a fine small hair-pencil, and the stopping mixture, cover those places where the clear whiteness of the paper may be wanted, except the sky: let it dry a few minutes; then wet the paper on both sides, and while it is wet wash the sky.

The shadows of the clouds, distances, and general breadths of shadow, must be put in with the grey tint; and over the places of the light wash the tints of the brightest light; those will be generally yellow ochre, or light red.

The light of the clouds may be preserved sharp by pressing on that part a piece of tissue paper, previous to the washing of the sky; this, by absorbing the superfluous moisture, will prevent the colour from spreading further than is desired. Suffer the whole to be very dry; and

2dly. Touch with the stopping mixture the sharp and prominent parts of the brightest lights; let them dry a few minutes, then wash over them with the tints of the next degree of light.

3dly. Stop with the mixture the second order of touches, and wash over them with the middle tints; strengthen also at the same time the breadths of shadow.

4thly. Stop with broad touches of the mixture the places of the middle tint, uniting them to the former touches, and extending them so as to graduate the middle colours into the shadow; strengthen the shadows, making them nearly as dark as they are intended to be, and let the whole be perfectly dry.

Then take spirits of turpentine, and with a sponge, or hog's hair pencil, wash over the places where the mixture has been used, rubbing it with the brush until it is dissolved: clear it away with a linen rag, and wash it with more spirits of turpentine so long as any white lead appears; then let it dry.

Warm the drawing; then with a soft brush, and highly rectified spirits of wine, wash the places where the spirits of turpentine have been used, to clear away the remainder of the latter; rub the drawing lightly on the face, but sponge it well on the back.

When dry, tint down the lights where it may be wanted; harmonize the colouring, and cut the shadows to effect, with still darker tints as may be necessary.

If other touches of light should afterwards be wanted in the shadowed parts, the colour may be easily removed by a pencil formed of sponge, with water, sufficiently to produce them with as much strength as can be desired; then stop them with the mixture; wash the shadow over the touches, bringing it to the colour taken off; and when dry, remove the mixture with the spirits of turpentine and spirits of wine.

A Sinical Octant for taking Altitudes.

This instrument will be extremely useful to the sailor; it will enable him to produce the answer to any question that may be proposed in trigonometry, plain, Mercator's middle latitude, or parallel sailing; also to determine the bearing and distance of any known place, almost instantaneously. In short, it comprises all the properties of the tables of latitude and departure, either in points or degrees, and qualifies the sailor to keep the ship's account completely, without the help of scales or tables.

This instrument consists of a flat, angular piece of hard wood BAC, plate LXXVIII, fig. 5, of an equal thickness throughout, having upon its face either lines and figures as below described, cut into the wood itself, or printed upon a paper from an engraved copper-plate, and cemented upon its surface, which must be afterwards varnished; and of a moveable limb AD, turning upon a pin A, screwed into two brass plates riveted into the piece BAC as an axis: this limb is made bevelling towards its fiducial edge, the better to read off the divisions.

The advantages of this contrivance consist in its simplicity, its easy adaptation to the uses of the mariner, and its very great cheapness; in fact, it might be very readily constructed by any one in the least degree acquainted with geometry, for his own use, by merely drawing the lines upon paper, and cementing them upon the board and limb. Its merit, however, will be better understood, by a description of its geometrical construction, and a few examples of its uses.

This octant is the sector of a circle BAC. The vertical angle A contains 45°, being the eighth part of a circle, as its name implies, or of 360°.

The leg AB is graduated into 90 equal parts, which may represent miles, leagues, &c.; through the points of division lines are drawn, perpendicular to AB, to meet the opposite side AC, or the arc BC; and for the facility of numbering or reckoning, every 10th perpendicular line from A is made stronger than the intermediate ones.

Another series of lines are drawn at the same distances, parallel to AB, to meet the leg AC, or the arc BC, and every 10th line from AB is also made stronger than the intermediate nine lines, for the reason before given.

The arc BC is graduated into 45°. A moveable limb or rule AD, is attached at A to the instrument, and moveable round the same point A; the thin edge AD of the rule is graduated into a scale, the same as the side AB of the octant.

By this construction, a right-angled triangle may be formed in any given proportion, and to any extent that the limits of the instrument will admit of.

The scale AB is numbered from A to B, and the scales on every 10th perpendicular to AB are numbered from the line AB towards AC. The arc BC is numbered from B towards C.

In forming any right-angled triangle, it is to be understood that there must always be two given parts, and that a side of the triangle must always be one of these parts, conformable to the rules of plain trigonometry. The parts that are thus given, may be either two sides, or one side and an angle. These two sides may either be the two legs, or the hypothenuse and one of the legs. When an angle is one of the given parts, it must be concerned either with the hypothenuse, or with one of the legs.

The most usual data is an angle and the hypothenuse; though the other data forming the different cases, may be useful upon certain occasions.

In navigation, any distance measured upon the meridian between any two points or places, is called the difference of latitude of these points or places. But if a vessel do not sail directly north or south, but makes the same angle with every meridian she comes to, whether towards the north or towards the south, the distance from the place she sailed from, and to the place she arrives at, is simply called her distance: and the angle which she forms with the meridians, is called her course. The perpendicular distance between the point from which she arrives, and the first meridian from which she sailed, is called her departure; and the distance intercepted by this perpendicular on the original or first meridian, to the place she set sail from on the same meridian, is her difference of latitude; and thus, by only giving particular names to the parts of the triangle, instead of the general ones, as the course for the given angle, and the distance run for the hypothenuse; one of the legs is her departure, which is always opposite to the course, and the other her difference of latitude, which is one of the legs that form the course.

If it happen that the course contains a greater angle than 45°, it must be subtracted from 90°, so that, in this case, her difference of latitude will be opposite the given angle, instead of her departure; that is, opposite the angle made at A, by the moveable rule AD and the side AB of the octant.

The use of this instrument will be best explained by an example or two.

EXAMPLE I.

Suppose the course to be 10°, and the distance nearly 80 miles, the departure and difference of latitude are required.

Bring the fiducial edge of the limb upon the course 10°: observe which of the perpendiculars, opposite the angle A, is cut by the moveable limb; then the departure will be found upon that perpendicular, to be 14 miles from the line AB to the point 80, upon the edge of the rule AD; and the difference of latitude to be 78 and about two-thirds, upon the side AB of the octant from A to the point cut by the perpendicular from 80, or the nearest within 80 in the edge AD of the limb.

EXAMPLE II.

Suppose the course to be 75°, and the difference of latitude 33 miles; the distance run and departure are required.

Subtract 75° from 90°, and there remains 15°, which gives the angle opposite the difference of latitude; bring the fiducial edge of the limb AD upon 15° on the arc BC, observe the point on the edge of the limb AD, cut by that perpendicular from AB, which just contains 33 miles: and the distance intercepted between A and this perpendicular, on the side AB of the octant, is the departure as required.

EXAMPLE III.

Suppose the course to be 62°, and the departure 74 miles; the distance run and the difference of latitude are required.

Subtract 62° from 90°, and there remains 28°, for the angle opposite the difference of latitude. Bring the fiducial edge to 28° then from 75 on the side AB, observe the length of the perpendicular, or the next nearest perpendicular towards the centre A, from AB, to the edge AD, of the limb; which will give 40 for the difference of latitude.

EXAMPLE IV.

Suppose the difference of latitude to be 68 miles, and the departure 28 miles, the course and distance are required.

Take the point 68 upon the side AB, then upon the perpendicular from 68 number 28 miles; bring the fiducial edge to the point 28 on the perpendicular, then the distance 73½ intercepted upon the fiducial edge of AD, from A, to the point 28 on the perpendicular, is the distance run; and the angle 22⅛° contained by the fiducial edge, and the side AB of the octant, is the course. In addition to the divisions above mentioned, there is likewise an arc divided into four principal divisions, and these again subdivided into halves and quarters, answerable to the points of the mariner's compass in the octant, or eighth part of a circle, which leaves it in the mariner's power either to take points or degrees, according to the accuracy of the operation required.

A Centro-linead, for drawing Lines towards inaccessible Vanishing Points.

This elegant instrument, called by the Inventor a Centro-linead, is designed to remove the difficulties which occur in drawing lines to inaccessible vanishing points in perspective, an operation hitherto found very troublesome to perform, especially where the distance of such points from the drawing exceeds the distance of the walls of the apartment, and even in offices, where the distance is only ten or twelve feet. It will be found in its application more easy to handle, to require less attention, and to perform with greater facility, than a heavy rule of the same length, which takes up the whole of the room, thus only admitting one person to draw at a time. The inventor having experienced its efficacy in teaching Architecture and Perspective, for more than twelve months past, can speak with confidence of its performance. The idea of it occurred to him more than twenty years ago, when he had a model made sufficient to explain its properties, though not sufficiently accurate for use.

In fig. 1, plate LXXX, let AB and CD be two bars so regulated by the following contrivance, that the straight edge CD of the bar CD in motion may always cut a straight line AB, passing through the middle of the bar AB, at rest. For this purpose let E and F be two points in the line AB, and let EI and FK be two other bars, so that the lines FK and EI passing longitudinally through their middle may be parallel: AG is another bar, of which a line HG passing through the middle is parallel to the line EF passing through the middle of the bar AB; then EFGH will be a parallelogram: Now let the points I and K be in the line CD; then suppose E to be a fixed point in the bars AB and EI; F a fixed point in the bars AB and FK; G a fixed point in the bars FK and GH; H a fixed point in the bars EI and GH; I a fixed point in the bars EI and CD; and K a fixed point in the bar FK, but not in the bar CD; suppose the bar AB fixed, and the other parts put in motion according to this construction, the points I and K will describe similar arcs, and the bar CD will always cut the line through the middle of AB at the same distance from either of the points E or F.

In order to effect this motion, PQ is a groove parallel to the right edge CD; NO is a slider; K is a point common to the slider NO and to the bar FK, so that when the instrument is in motion the point K will always be in the edge CD.

The bar FK is so contrived that it may be lengthened or shortened to certain limits, so as to make the vanishing point on the one side or the other as may be required, in the following manner.

The bar FK is made double. The lower part FG is fixed to AB and GH, and the upper part LK has a longitudinal slit to slide upon a pin G passing through the bars GH and FG. In the line FK at M is another pin, in order to keep the middle of the slit in the straight line FK, and to fix or unfix the two parts of LK and FG at pleasure.

To show the truth of what has been asserted, let AB and CD, fig. 2, be the two bars of which AB is fixed; then if CD be moved according to the preceding regulation, the line CD will always pass through the same points in the line AB produced.

For though IR be drawn parallel to AB, so that EFRI will be a parallelogram: then because of the similar triangles KRI and IES, KR, : RI : : IE : ES; but since IR, RI, IE, are given lengths, the fourth proportion ES will therefore be invariable, whatever angles the instrument makes in its revolution.

-To set the instrument so as to tend to the same point in which, if two straight lines AB and TU, fig. 3. would meet if produced, lay the edge of the instrument AB upon the straight line AB, then suppose the parts of the diagram as expressed by the similar letters to those in fig. 1, to be the elements of the instrument, the middle of the bar AB be laid upon AB; move the other parts so that the point I may meet the line TU in V, unscrew the nut of the lengthening and contracting bar FK, and revolve the line CD round I, which is fixed so that ID may fall upon VU, then screw the nut tight, and the instrument will be set as required.

There must always be an index or line on the fixed bar AB, so as to set it to a given point in the vanishing or other line, and that the instrument may be removed when necessary, and set to its place again with the same accuracy as before.

An instrument for drawing Lines towards an inaccessible Centre.

This instrument, like the preceding, will be found extremely useful in making perspective drawings, by giving an artist the means of making a drawing upon a board or table of moderate dimensions, though the vanishing points fall at ever so great a distance; it is quite general in its properties, being capable of drawing parallel lines, which may therefore be considered as converging to a point at an infinite distance, or it may in a moment be altered to draw to a point within a few inches distance.

The first instrument of this kind, the Inventor made in the year 1807, and he has had it in constant use ever since, as it applies with advantage to almost every perspective drawing; the simplicity and cheapness of this instrument will, in some cases, give it a preference to the centro-linead, particularly where a picture requires to have two or three of the instruments in use at once, for as many different vanishing points which fall beyond the limits of the drawing-board. Two or more may be used at once, without any inconvenience, because it has no attachment to the drawing-board, and may therefore be removed in an instant to apply any other rules, &c. which the drawing requires.

It may be used indifferently to draw to a point, either on the right or left side. To set against these advantages, it is not so readily adjusted to the direction required, as the instrument described in the last article, but when once done, it is not liable to be deranged.

This instrument acts upon the drawing-board, or table, on which the paper is fastened, with as much facility and as little attention as a T-square does, when drawing parallel lines, and will be found extremely useful to those who draw buildings, &c. in perspective, as the points to which the lines for such drawings should converge, will often fall at a distance of 12 and 15 feet from the picture, so as to render it impracticable to employ rulers of sufficient length to reach the points, and there is, except this instrument and Nicholson's above-described, no other practicable method of drawing such lines.

The instrument consists of three rulers, AB and D, fig. 4, plate LXXX, which are united by a common centre-screw *a*, and have a thumb-screw *d*, which fixes them fast at any angle at which they may be placed; EF are two fixed weights, or rests, against the edges of which the rulers AB are applied, when the instrument is used; or pins fixed into the table will answer the same end very conveniently. By sliding the instrument against these stationary points, as shown in the figures, the ruler D will draw converging lines, as shown by the dotted lines, which all converge to a common centre, the distance of which will depend upon the angle of the ruler AB, and the situation of the points EF; the edge of the ruler D, must in all cases be made to bisect the angle formed between the other two, otherwise the lines which it draws will not converge to a common centre, but will form a tangent to a circle of small radius, described round the intended centre-point; this indeed is a case which geometricians may sometimes find useful, but for artists, who require the lines to converge to one point, the thin edge of D must bisect the angle formed between A and B. The manner of setting the instrument for any particular case, is thus:—Suppose we have given the two extreme lines *r w r* and *s w s* (dotted) which converge to the intended point; suppose it is required to draw a number of others to the same point, the pins or weights EF, must be set upon these lines, but at equal distances from the centre or point where the lines would intersect: to find the situation proper for these points, place the leg of a pair of compasses upon some point situated between the two lines, *r s*, and find experimentally by repeated trials, that when a circle (as shown at *w w*) is described by the other point of the compasses, the two lines *r s* will form tangents to it; from this point, which suppose at *n*, with a sufficient opening of the compasses, mark off two points as at EF, by striking an arch EF across the lines, and these will be equidistant from the centre. The pins being placed in these points, apply the instrument to them, with the clamp-screw *d* loose, then slide the rulers AB against the pins, till the ruler D comes to one of the lines, as *r*, and here incline the rulers on their centre-points, till the edge of D corresponds with it, when A is in contact with the pins; now remove it till the ruler D matches with *r*, and there make a similar adjustment, that B will touch the pins. The clamp-screw being now fastened, fix the rulers as they are adjusted; and then on sliding the two rulers A and B against the pins EF, the edge of the third ruler D, will, in all positions, tend to the same centre-point as the lines *r r* and *s s;* the angle or point *a*, in which the rulers AB meet, will, in the motion of the instrument, describe a segment of a circle, as shown by the dotted line *v* E *a* F *v*, and the centre to which the lines tend is a point in the opposite circumference of that circle. This point will be found by bisecting the distance EF upon the dotted arch, and from this point, drawing a line through the centre of the circle *v* E *a* F *v* till it cuts the opposite circumference, and to this point the lines will converge.

If the instrument is required to have a greater range, or to draw more convergent lines than between F *r* and E *s*, other pins must be fixed for its rulers to act against; taking care, that they are placed at the same distance from E or F as these are from each other. Their proper situation will be determined by the rulers AB themselves; thus, by sliding the rulers against the pins, till the angle between them comes to one of the points E or F, the new point must be placed so as to be in contact with the edge of that ruler which overhangs the pins, and at the same distance from the present pins E or F, as it is between them.

The construction of the instrument is apparent, from inspection of the figure; the two rulers AB, have circular parts *m* behind the centre, which apply one upon the other, and a projecting part *l* from the ruler D lies over both; the centre screw *a* passing through all three; an arched groove is cut through both the circular parts *m m*, to admit the screw *d*, which also passes through *l*, and thus fastens them all three together, by screwing into a nut, fitted into the arched groove of the lower one; the ruler D is made of wood or ivory, as shown separate in fig. 5, and screwed to the under side of *l*, so that it comes into the same plane with A and B. The instrument will draw parallel lines like a T-square, when AB are set in a straight line, and if the circular part *m* is graduated, it will make a protractor, to set out angles; fig. 5, is an extra-ruler, to be applied in lieu of D, when the instrument is required to draw lines to a centre, on the opposite side; it is merely reversed to the other, having the hole in *l*, which is for the centre-screw *a* in the line of the opposite edge to that which is shown in use in fig. 4, one being intended to draw lines tending towards the left-hand side, and the other towards the right-hand side.

A Perspectograph, or Instrument for Drawing Objects in Perspective.

In examining the various contrivances that have been invented for the purpose of making perspective drawings by mechanical apparatus, it will be found that none have been brought into general use, although most persons in the habit of making such drawings have expressed a wish that some contrivance might be found possessing simplicity in its form, moderate in its expense, and so small in bulk, that an artist might conveniently carry it to the objects of delineation.

One of the most simple, and perhaps the best contrivance, is described in a work on perspective by Ferguson; this is composed of a brass frame fixed upon hinges, which enables the artist to lift it up and lay it down when the perspective point is obtained. The mode of getting the point is by the intersection of two wires or fine threads, which may be made to cross each other within any part of the frame, but as these must frequently have to cross each other at very acute angles, the precise point must be very difficult to obtain. Besides this objection, the instrument, from the nature of its construction, must of necessity be fixed to a board, which, added to the frame, would render this no very portable object. These were the considerations which gave rise to the present invention, and when the great number of persons are considered, who can draw plans and elevations with neatness and accuracy, but who have no knowledge of the rules of perspective, nor inclination to pass through a series of mathematical problems to obtain a proficiency therein, sufficient to enable them to draw even a simple piece of machinery perfectly, it renders the invention of such an instrument exceedingly desirable; at a time too like the present, when the knowledge of science is so widely diffused, and is still susceptible of considerable improvement, if accuracy of depicted representation keep pace with correctly written information.

The principal objection to all instruments that find the perspective points, or extremes of lines, is the length of time that is necessary for conducting the operation. But let an artist who has all the advantages arising from practical habits of drawing, sit down to delineate a machine, (or any object that may be chosen,) and let a person in the habit of using such an instrument as the present, begin with the same subject at the same time, and tedious as the operation of finding points may appear, I should have no fear but the result would prove in favour of the instrument: at the same time, the superior accuracy produced by it, would appear evident.

It will not be denied, that there are many respectable artists, who have a knowledge of perspective sufficient to answer most cases in architectural and picturesque delineation, that would greatly object to draw a complex piece of machinery in perspective, there being such a degree of accuracy required in this branch of art, and so many rules to put in practice to obtain perhaps only a few lines or points, that it requires the aid of some mechanical invention to abridge the labour and ensure the accuracy of the operation.

It is not in machinery alone that such a rigid degree of accuracy is requisite; scientific subjects in general require it to be continually exercised. By way of example, the Inventor executed with this machine, perspective drawings of crystals, such as appeared most difficult to represent by the common rules of perspective. These subjects are frequently occurring in the science of mineralogy, and present to an artist one of the most difficult tasks in the practice of perspective; but by the application of the instrument, they are rendered comparatively easy, even to those unaccustomed to perspective delineation.

The principal part of this instrument consists of a steel rod, having a small slider, which is capable of moving up and down upon it freely, but remains stationary by the pressure of two small springs acting on the rod. This slider carries a projecting piece of steel, having a small point bent at right angles at its extremity. One end of the rod is screwed fast to an axis, which turns in a brass joint, which has an adjustment for tightening it, so that the rod may be kept in any position.

The brass joint moves on an axis perpendicular to the one attached to the steel rod: this axis serves to unite the to a clamp, which may be fixed to any table or board by a thumb-screw. To the side of the clamp, two small loops are fixed, through which a steel bar slides, carrying the eye-piece, which may be fixed at any distance, and retained by a tightening screw in the loop; the eye-piece may also be elevated or depressed at pleasure, and kept at any height that may be desired by a small thumb-screw.

When the instrument is to be used, the clamp must be screwed tight to a board or table, and the paper upon which the drawing is to be made, must be laid down close to the clamp, and fixed firmly with a few bits of soft wax. The pin or axis upon which the brass joint turns, is then to be pressed firmly through the holes of the clamp, and the steel rod which has the slider upon it will stand perpendicular to the table by the pressure of the spring under it, similar to the joint of a clasp knife, This rod may now be moved from the right hand to the left, generating by its motion an imaginary semi-circular plane, which is to be considered as the plane of the picture; by the union of this motion, and that of the slider upon the bar, the steel point may be brought to any given position in the plane of the picture.

The theory upon which this instrument is formed being understood, the practice will consist in placing the object to be drawn at a convenient distance from the supposed plane of the picture, and having fixed upon the height at which the eye of the spectator shall view the object, next determine the distance the picture shall be from the eye, (or, as it is frequently called, the point of sight.) This being done, the eye of the artist must be applied to the hole in the eye-piece, and the steel point be brought to coincide with the extreme point of any line in the object to be drawn. Having performed this part of the operation with great exactness, the rod may be turned down by moving the brass piece upon its axis (using for this purpose the small handle) until the steel point comes in contact with the paper, when the fore-finger must be pressed upon it till the bent point enters it sufficiently to make a visible puncture, which is the perspective representation of one extreme point of the given line. The same operation is to be repeated to obtain the other, and the two points being joined by a line, it will be the perspective representation of the original line, in the object to be drawn.

When curved lines are the object of delineation, any number of points may be obtained in them by the instrument, which being transmitted to the paper, and carefully drawn through with a steady hand and a fine pencil, the perspective representation of curved objects may be obtained with great ease.

The foundation of this instrument is a brass clamp, see plate LXXX, fig. 6, having a screw at A to fix it to a table, drawing-board, &c.; to the lower part of this clamp two loops are attached, in which the bar B slides, and may be kept at any distance within its range by the binding screw *c*; the bar B has a loop fixed on one end, as shown at *d*, to receive a rod E, at the end of which is placed the sight-piece F; this rod may be retained at any height by the screw G.

To the upper part of the clamp two ears are attached, one of which is seen at *h*; between these the block *g* moves on an axis or taper pin, the end of which is seen coming through the ear at *h*; the block *g* has an axis passing through it a little above, and exactly at a right angle to the taper pin before-mentioned; the one end is seen at *i*, fig. 8, and from the other projects the piece *k* to receive the bar *l*; this bar may be turned from the right hand to the left, and *vice versa*, retaining its position at any angle by the friction on the axis, which may be increased at pleasure, as the block which receives it is divided in two, the upper part being pressed upon the axis by a tightening screw, shown at *m*, fig. 8, which represents an end elevation of the upper part of the clamp.

The slider N moves freely up or down, the bar *l* retaining itself in any situation by the pressure of two small springs inclosed within it, pressing against the bar.

The bar *l*, which is attached to the block by its axis, is kept in a perpendicular position by a spring pressing under the block, exactly in the same manner as the spring of a clasp-knife presses upon the square tongue or shoulder of the blade. The position and action of this is best seen by dotted lines at *o*, in the side elevation of part of the clamp at fig. 7; *s*, in the same figure, shows the under half of the divided brass block.

The slider N, has a projecting piece formed into a point as shown at fig. 9, the end P being used to make a coincidence with any part of the object to be drawn, and the point *q*, which stands at right angles to it, is for the purpose of marking the perspective representation of that point upon the drawing, when the bar and slider are laid down upon the paper, and the point pressed upon by the finger, so as to make a small puncture.

The handle *r*, is for the purpose of elevating or depressing the bar and slider when they have been brought to any position desired, and it prevents the accidental shifting of the bar, which might occur if the hand of the operator was to touch it in laying it down.

Fig. 10, is a plan of the clamp, the letters the same as referred to in the other figures.

When the instrument is to be prepared for use, the brass block or joint *g* is to be fixed in the ears of the clamp by the axis or pin *h*, upon which it turns. This part of the apparatus is then ready to be screwed to a table drawing-board, &c. by the thumb-screw A. The paper upon which the drawing is to be made, may be fastened to the drawing-board on one side, by passing it under the clamp before it is screwed to the board or table, and the other sides may be confined by a few wafers, sealing-wax, &c.

The bar *l*, by the pressure of the spring under the brass block or joint, will stand perpendicular to the drawing-board, and may be turned either to the right or left, generating by such motion an imaginary plane, which, we have before observed, is to be considered as the plane of the picture.

The slider N may be moved up or down upon the bar *e*, when it will be seen, that by the union of the two motions, namely, of the bar upon its axis *i*, and of the slider N upon the bar *l*, the small point fixed to the slider may be placed any where in the supposed plane of the picture.

The rod B, is to be placed in the loops on the side of the clamp, the eye-piece F fixed in it at any height or distance that may be considered most convenient for veiwing the object to be drawn, and the instrument is ready for use. The method of obtaining the perspective representation of right lines and curved objects having been before described, it will be unnecessary to repeat it; we have only to observe, that the whole instrument can be packed up in a case 12 inches long, 3 inches wide, and 2½ inches deep.

Application of Steatites, or French Chalk, to the Imitation of Engraving and Carving on precious Stones, &c.

The stone which mineralogists call *steatites*, but which is in this country commonly called *French chalk*, bears in its composition a very strong resemblance to unbaked china-ware. It consists of extremely fine particles, and has a very close texture; it is susceptible of receiving a flinty hardness by exposure to heat, and after having been hardened, the most delicate lines and mouldings which have been made in it while soft, retain all their original sharpness and force. In this respect it is much superior to glass, paste, china-ware, or any other material which is wrought in its soft state, for the purpose of being afterwards hardened. It has been applied, with complete success, to the imitation of agate, and other stones.

Steatites, in its natural state, is sufficiently soft to be cut with great facility by means of the graver, a file, or in a lathe, and admits of a very fine surface being left after the operation of the tool. When, therefore, the artist has produced the effect he desires, whether a cypher for a seal, or a portrait, &c. either sunk or in relief, the next operation is that of hardening his work. For this purpose, the steatites must be put into a crucible, to which must be adapted a tile, or any suitable cover, and the juncture luted with a mixture of equal parts of fine sand and clay, or any ordinary fire-lute. The crucible should then be put into a coke or charcoal fire, the heat of which should be gradually raised; and after having remained in a white heat for two or three hours, it should be taken from the fire, and suffered gradually to cool. The steatites will now be found perfectly hardened.

As the natural colours of steatites vary, so do the shades of the specimens which have been thus fired: some are of a milky white, others gray or brownish; but whatever shade of colour is known to be the result of burning a particular specimen of steatites, that shade, or indeed the colour altogether, may be agreeably changed by the use of a variety of agents. Where the natural colour of the stone is not such that it will become white by firing, the effect of different agents can only be determined with precision by experiment.

Colours which dissolve in amber varnish, such as verdigris, ochre, &c. communicate their tints to steatites which has been fired; those which dissolve in spirit of turpentine give a brighter hue. The steatites, when the colours dissolved in either of these menstrua are applied to it, should be hot, and it is safest to use a charcoal fire in heating it, to avoid the metallic or sulphurous fumes which, as well as smoke, might arise from a fire of pit-coal. This stone may, in like manner, when heated, be stained by both acid and alkaline solutions of colours. In this way, the sulphuric acid is one of the most efficacious menstrua; the hue, for example, given by the sulphate of indigo, is very pleasing, and admits of much diversity of tint by differences in the intensity of the solution; the general tendency, however, of the blue colour communicated by this solution, is to greyness.

As it has been observed, that steatites in its natural state may be considered as a kind of unbaked china-ware, or porcelain, it may justly be inferred that the most brilliant and durable colours may be communicated to it, by employing similar means and agents to those used in staining and painting upon porcelain: but those colours which are not in a state of complete solution, will seldom be proper, because they would defeat the intention of preserving all the sharpness and beauty of effect produced by the tool: they may perhaps be employed for back-grounds with advantage, although, it must be admitted, they are scarcely manageable without the use of an enameller's furnace.

Among the most useful metallic solutions for staining steatites, are those of gold and silver: the nitro-muriatic solution of gold affords different shades of purple, according to its strength; and muriate of silver along with sulphuric acid, affords a black colour. When the steatites, stained by either of these metallic solutions, is exposed to a considerable heat, it acquires a metallic splendour, resembling the metal employed.

Solutions in spirit of wine of carthamus, gamboge, logwood, dragon's blood, or Indian red, may be employed to colour steatites, which receives their respective tints, by being immersed in them for a sufficient time; generally an immersion of a few hours will suffice, but the colours thus communicated want force, and are not so durable as those afforded by means of heat.

Steatites is incapable of fusion by itself; there is therefore no danger of destroying it in the firing: but as it acquires by heat a degree of hardness which enables it to resist the file, it is obviously advantageous to give it, while in its soft state, all the smoothness of surface it is intended to possess. This may be done, by using successively emery or grit-stone, pumice-stone, tripoli, and putty of tin. Emery of successive degrees of fineness will polish it in its hard state, but not so expeditiously; the putty of tin is used merely in giving the last and highest lustre to the work, and this lustre may be made such as to equal that of the agate. A brush revolving in a lathe will be found an easy method of giving it a fine polish, to such surfaces particularly, as cannot be reached with sufficient effect by other means.

The Report of the Committee appointed by the Royal Society to consider of the best Method of adjusting the fixed Points of Thermometers; and of the Precautions necessary to be used in making Experiments with those Instruments.

It is universally agreed by all those who make and use Fahrenheit's thermometers, that the freezing point, or that point which the thermometer stands at when surrounded by ice or snow beginning to melt, is to be called 32°; and that the heat of boiling water is to be called 212°; but for want of further regulations concerning the manner in which this last point is to be adjusted, it is placed not less than two or three degrees higher on some thermometers, even of those made by our best artists, than on others. The two principal causes of this difference are, first, that it has never been settled at what height of the barometer this point is to be adjusted;* and secondly, that so much of the quicksilver in the thermometer as is contained in the tube, is more heated in the method used by some persons, than in that used by others. To show that

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* Fahrenheit found that the heat of boiling water differed according to the height of the barometer; but supposed the difference to be much greater than it really is. Mr. De Luc has since, by a great number of experiments made at very different heights above the level of the sea, found a rule by which the difference in the boiling point, answering to different heights of the barometer is determined with great exactness. According to this rule, the alteration of the boiling point by the variation of the barometer from 29½ to 30½ inches is 1°.59 of Fahrenheit.

this last circumstance ought by no means to be disregarded, suppose that the ball of a thermometer be dipped into boiling water as far as to the freezing point, and consequently, that the length of the column of quicksilver in that part of the tube which is not immersed in the water be 180°; and suppose that the heat of that part of the column of quicksilver be no more than 112°. If the thermometer be now entirely immersed in the water, the heat of this column will be increased 100°; and consequently its length will be increased by $\frac{100}{11500}$ parts of the whole, as quicksilver expands $\frac{1}{11500}$ part of its bulk by each degree of heat; and consequently the thermometer will stand $\frac{180 \times 100}{11500}$ or rather more than $1\frac{1}{2}$° higher than it did before.

Another thing to be considered in adjusting the boiling point is, that if the ball be immersed deep in the water, it will be surrounded by water which will be compressed by more than the weight of the atmosphere, and on that account will be rather hotter than it ought to be.

We are of opinion, that the quicksilver in the tube ought, if possible, to be kept of the same heat as that in the ball, and that the ball ought not to be immersed deep in the water. These two requisites may be obtained by using a vessel covered so as to allow no more passage than what is sufficient for carrying off the steam; form then, if the thermometer be inclosed in this vessel in such manner that the boiling point shall rise but a little way above the cover, almost all the quicksilver in the tube will be surrounded by the steam of the boiling water, and consequently will be nearly of the same heat as the water itself: we therefore made some experiments to determine how regular the boiling point would be when tried in such vessels, both when the ball was immersed in the water, and when it was exposed only to the steam, as recommended by Mr. Cavendish.*

The vessel used in these experiments is represented in fig. 1, plate LXXXI. AB *b a* is the pot containing the boiling water; D *d* is the cover; E is a chimney for carrying off the steam; M *m* is the thermometer fastened to a brass frame; this thermometer is passed through a hole F *f* in the cover, and rests thereon by a circular brass plate G *g* fastened to its frame, a piece of woollen cloth being placed between G *g* and the cover, the better to prevent the escape of the vapours.

There were two pots of this kind used by us; one five inches in diameter and nine deep; the other $4\frac{1}{4}$ in diameter

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* Phil. Trans. vol. LXVI, p. 380.

and 23 deep. Two of the thermometers principally used were short ones, the brass plate (G *g*) being placed only 3¼ inches, above the top of the ball, and the boiling point rising not much above that plate: the third thermometer was much longer, the plate G *g* being 17 inches above the ball. They were all three quick; the first containing only 2½ degrees to an inch; the second 5°; and the third 10°. The first had a cylinder instead of a ball 1½ inch long and $\frac{4}{10}$ in diameter;* the two others had spherical balls, about ¾ of an inch in diameter.

On trying these thermometers in the above-mentioned vessels, with the water rising two or three inches above the top of the ball, we found some variations in the height according to the different manner of making the experiment, but not very considerable; for the most part there was very little difference, whether the water boiled fast or very gently; and what difference there was, was not always the same way, as the thermometer sometimes stood higher when the water boiled fast, and sometimes lower. The difference, however, seldom amounted to more than $\frac{1}{10}$th of a degree, unless a considerable part of the sides of the pot were exposed to the fire; but in some trials which we made with the short thermometers in the short pot, with near four inches of the side of the vessel exposed to the fire,† they constantly stood lower when the water boiled fast than when slow, and the height was in general greater than when only the bottom of the pot was exposed to the fire. This difference, however, was not perceived in the trials of the long thermometer in the deep pot, as there seemed very little difference in the height whether the water boiled fast or slow, or whether more or less of the side of the pot was exposed to the fire. The greatest difference observed in the same thermometer, on the same day and in the same water, according to the different manner of trying the experiment, was half a degree.

We made some trials with the long thermometer in the deep pot, to determine how much the height of the boiling point was affected by a greater or less depth of water above the

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* In the two short thermometers the quicksilver would have descended into the ball when cold, had not the tube been swelled a little, close to the ball, in order to prevent it.

† In all our experiments, the water was boiled over a portable black-lead furnace, covered with an iron plate, which had a hole cut in it just big enough to receive the bottom of the pot; so that, by passing the bottom through this hole to a greater or less depth, we could expose more or less of the sides to the fire. In other experiments, not more than one inch of the sides was ever exposed to the fire.

ball. By a mean of the experiments it stood 66 of a degree higher when the water rose 16 inches above the ball, than when it was only three inches above the ball; so that increasing the depth of water above the ball by 11 inches, raised the thermometer .66 of a degree, that is .06 for each inch.

We would by no means infer however from hence, that it is a constant rule, that the height of the boiling point is increased .06 of a degree by the addition of each inch in the depth of the water above the ball; as perhaps the proportion would be found very different in greater depths of water or in wider vessels.

If this rule was constant, it would show that, when the pressure on that part of the water which surrounds the ball is increased by increasing the depth of water above the ball, the height of the boiling point is not altered thereby more than half as much as by an equal increase of pressure produced by an alteration in the weight of the atmosphere: for the pressure on that part of the water which surrounds the ball is as much increased by an alteration of 11 inches in the depth of the water above the ball, as by an increase of $\frac{11}{13\frac{1}{2}}$ of an inch in the height of the barometer; and such an alteration in the height of the barometer is sufficient to raise the boiling point 1°.3.

It seems as if the height of the boiling point was in some measure increased by having a great depth of water below the ball, as in general the short thermometers stood higher when tried in the deep pot than in the short one; this effect however, did not always take place. In the former of these cases, the depth of water below the ball was about 18 inches, in the other only 4; but the depth of water above the ball was the same in both cases.

It must be observed, that when there was a great depth of water in the vessel, either above or below the ball, the experiments were much more irregular, and the quicksilver in the tube remained much less steady, than when it was small. When the depth of water in the vessel is great, it is apt to boil in gusts, which seems to be the cause of this irregularity; though we could not perceive any regular connexion between these gusts and the risingof the thermometer.

In the experiments made with the water not rising so high as the ball, so that the thermometer was exposed only to the steam, we very seldom found any sensible difference whether the water boiled fast or slow, but whenever there was any, the greater height was when the water boiled fast; the difference, however, never amounted to more than $\frac{1}{20}$th of a degree.

There was scarcely ever any sensible difference whether the short thermometers were tried in the short pot or the deep one, though in the former case the ball was raised very little above the surface of the water, and in the latter not less than 14 inches: neither did we find any sensible difference in trying them in the tall pot, whether there was a greater or less depth of water in the vessel.

As it was nevertheless suspected, that the heat of the steam might possibly be less near the top of the pot than lower down (for in these experiments the ball of the thermometer was always at the same depth below the cover, though its height above the surface of the water was very different) we made two holes in the side of a pot four inches deeper than the deepest of the foregoing, one near the top of the pot, and the other not far from the bottom, and passed the ball of the thermometer through one or the other of these holes, taking care to stop up both holes very carefully, so that no air could enter into the pot by them: no sensible difference could be perceived in the height, whether the thermometer was placed in the upper or lower hole, though in one case the ball was only three inches, and in the other 21 inches, below the cover.

The heat of the steam therefore appears to be not sensibly different in different parts of the same pot; neither does there appear to be any sensible difference in its heat, whether the water boil fast or slow; whether there be a greater or less depth of water in the pot; or whether there be a greater or less distance between the surface of the water and the top of the pot; so that the height of a thermometer tried in the steam, in vessels properly closed, seems to be scarce sensibly affected by the different manner of trying the experiment.

Though, as was before said, there was scarcely any difference in the height of the quicksilver, whether the water boiled fast or slow, yet when the water boiled slow the thermometer was a great while before it rose to its proper height; and when it boiled very slow, it seemed doubtful whether it would have ever risen to it, especially if the ball was raised a great way above the surface of the water: but when, by making the water boil briskly, the thermometer had once risen to its proper height, the water might then ye suffered to boil very gently, even for a great length of time, without the thermometer sinking sensibly lower.*

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* The reason of this seems to be that, while any air is left in the pot, the steam cannot acquire its full degree of heat; and that when the water boils

All three thermometers were found to stand, in general, from 30 to 65 hundredths of a degree higher when the ball was immersed a little way in the water (neglecting those observations in which much of the sides of the pot were exposed to the fire) than when it was tried in steam: at a medium they stood $\frac{48}{100}$ higher, which is equal to the difference produced by a variation of $\frac{3}{10}$ths of an inch in the barometer; so that the boiling point, adjusted at a given height of the barometer, with the ball immersed a little way in the water, will in general agree with that adjusted in steam, when the barometer is $\frac{3}{10}$ths of an inch higher.

It must be observed, that in all these experiments a piece of flat tin plate was laid loosely on the mouth of the chimney E, so as to leave no more passage for the steam than what was sufficient to prevent the tin plate from being lifted up. In trying the thermometers in steam, this is by no means unnecessary; for, if the cover of the pot does not fit very close, the thermometers will immediately sink several degrees on removing the tin plate; but when their balls are immersed in the water, the removal of the tin plate has no sensible effect.

If this cover to the chimney had been heavy, the included steam might have been so much compressed thereby, that the water and steam might have acquired a considerably greater heat than they ought to have done; but as this plate lay loose on the chimney, and as its weight was not greater than that of a column of quicksilver, whose base is equal to that of the mouth of the chimney, and whose altitude is $\frac{1}{30}$th of an inch, the excess of the compression of the included steam above that which it would suffer in an open vessel, could not be greater than that which would be caused by an increase of $\frac{1}{30}$th of an inch in the height of the barometer, which is too small to be worth taking notice of; for, if the excess of compression was greater than that, the tin plate must necessarily be lifted up so much as to afford a sufficient passage for the steam to escape fast enough, though urged by no greater force than that.

Though in the different trials of the same thermometer in steam, on the same day, and with the same water, so little difference was observed, according to the different manner of trying the experiment; yet there was a very sensible difference between the trials made on different days, even when reduced

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very gently, the air is not easily entirely expelled from the pot. That the steam will not acquire its full degree of heat while any air is left in the pot, will appear from the next paragraph but one.

to the same height of the barometer, though the observations were always made either with rain or distilled water. The difference, however, never amounted to more than a quarter of a degree, except in one thermometer, in which there were three observations out of eighteen which differed more than that; one of them differed so much as 0.65° from some of the rest. In the observations made with the ball immersed a little way in the water, there was a greater difference between the observations of different days, even neglecting those in which much of the sides of the pot were exposed to the fire. In two of the thermometers the different observations differed about $\frac{35}{100}$ of a degree from each other; but in the other thermometer they varied $\frac{8}{10}$ths.

We do not at all know what this difference could be owing to, especially in the observations in steam. It could not proceed entirely from some unknown difference in the water; for, if it did, the difference between the different thermometers should have been always the same, which was not the case, though in general, on those days in which one thermometer stood high, the others did also, especially in the trials in steam. Moreover, as far as can be perceived from our experiments, there seems to be very little difference between different waters with respect to the heat which they acquire in boiling. We could not be sure that there was any difference between rain and distilled water and pump water, provided the latter had boiled long: neither did any difference seem to arise from the water containing such substances as are disposed to part readily with their phlogiston; for, on trying the thermometers in the steam of distilled water, their height was not sensibly altered by pouring in a small quantity of a solution of liver of sulphur, or of iron filings imperfectly rusted. The thermometer, however, seemed to stand sensibly lower in pump water beginning to boil, than in the same water long boiled, but the difference scarcely exceeded $\frac{1}{10}$th or the one $\frac{1}{5}$th of a degree.

We made some experiments to determine the heat of water boiling in open vessels. In general, when the vessel was almost full, and the water boiled fast, and the ball of the thermometer was held from three-quarters to two or three inches under water, and also in that part of the vessel where the current of water ascended upwards, that is, in the hottest part of the water, its heat was not much different from that of the steam of water boiling in closed vessels, varying only from a quarter of a degree more than that, to as much less; but if the water boiled gently, its heat would frequently be half or three quarters of a degree cooler than the steam. If the experiment was tried in the deep pot, with such a quantity of water in it that the surface was at least 14 or 15 inches below the top of the pot, so that though the vessel was open, yet the water was not much exposed to the air, its heat then seemed scarcely less than when boiled in closed vessels.

In making these experiments we chiefly made use of the two short thermometers, in which, as the quantity of quicksilver contained in the tube was small, the error arising from that part of the quicksilver being not heated equally with that in the ball, could be but small: for example, in the second of the short thermometers, the number of degrees contained in that part of the tube between the circular plate G *g* and the ball, was 18°. In the experiments in steam, this part of the tube was heated to the same degree as the ball. Suppose now, that in open vessels it was heated only to 122°, or was 90° cooler than the ball, it is plain, that the thermometer would stand only $\frac{18 \times 90}{11500}$, or $\frac{1}{7}$th of a degree lower than it did in steam, provided the heat of the quicksilver in the ball was the same in both cases. In the other short thermometer, as there were only half as many degrees to an inch, the error was only half as great.

In several of the experiments, however, we made use of the long thermometer; but then it was necessary to make an allowance on account of the quicksilver in the tube being not heated equally with that in the ball. The better to enable us to do this, we made use of a thermometer tube, filled with quicksilver in the same manner as a thermometer, only without any ball to it, or a thermometer without a ball, as we may call it. A small brass plate was fixed to the tube near the top of the column of quicksilver, to show the heat as in a common thermometer. In all our experiments with the long thermometer in open vessels, this tube without a ball, was placed by its side; whence, as the quicksilver in the tube of the long thermometer could hardly fail of being nearly of the same heat as that in the tube without a ball, we knew pretty nearly the heat of the quicksilver in the tube of the former, and consequently how much higher it would have stood, if the quicksilver in its tube had been of the same heat as that in the ball. For example, on October 19, the long thermometer tried in an open vessel, the water boiling fast, stood 1°.65 lower than it did when tried in the same day, the quicksilver in the tube without a ball ng at the same time at 109°: we may therefore conclude, that the heat of the quicksilver, in that part of the tube of the long thermometer which was not immersed in the water, was also 109°; and consequently, as that part of the tube contained about 170°, the thermometer stood $\frac{170 \times 103}{11500}$, or 1°.52 lower than it would have done if the quicksilver in the tube had been of the same heat as that in the ball; and consequently the quicksilver in the ball of the thermometer was in reality .07 cooler than when tried in steam.

We examined the boiling points of several thermometers. made by different artists, by trying them in steam when the barometer was at 30.1, and finding what division on the scale the quicksilver stood at. The difference of the extremes was 3¼°; but by a mean of all, it was found to stand at 213°.1, and consequently would have stood at 212°, if the barometer had been at 29.4; so that if the boiling point was to be adjusted, either in steam, when the barometer is at 29.4, or with the ball immersed two or three inches in water, when the barometer is at 29.1, it would agree best with the mean of the above-mentioned thermometers. But as it seems to be of no great signification to make the boiling point agree very nearly with the mean of the thermometers made at present, when the extremes differ so widely; and as we apprehend that it will be more convenient to the makers that some height should be chosen which differs less from the mean, as thereby they will more frequently have an opportunity of adjusting the boiling point without the trouble and danger of mistakes which attend the making a correction, we recommend, that the boiling point should be adjusted when the barometer is at 29.8, if the person chuses to do it in steam; or when the barometer is at 29½, if he chuses to do it in close vessels, with the ball immersed to a small depth under the water. Our reason for pitching upon this precise height is, that thereby the boiling point will differ from Mr. De Luc's boiling point, by a simple fraction of the degrees of his common scale, namely, three-quarters of a degree higher.

We are informed by Mr. De Luc, that the method he used in adjusting the boiling point, though he forgot to mention it in the *Récherches sur les Modifications de l' Atmosphere*, was to wrap rags round the tube of the thermometer, and to try it with the ball immersed in water in an open vessel, of the form described in the above-mentioned book, while boiling water was poured at different times on the rags, in order that the quicksilver in the tube might be heated, if possible, to the same degree as that in the ball. As well as we can judge from the above-mentioned experiments in open vessels, and from the few trials we have made of this method, we are inclined to think, that the boiling point adjusted this way will in general differ but little from that adjusted in steam at the same height of the barometer, especially if the thermometer be not very long, and do not extend a great way below the freezing point;[*] consequently, as Mr. De Luc's boiling point was adjusted when the barometer was at 27 Paris or 28.75 English inches, it will stand lower than that adjusted in the manner recommended by us, by three-quarters of a degree of his scale; or 80¾° on De Luc's thermometer, will answer to 212° on Fahrenheit's adjusted in the manner proposed.

Though the boiling point be placed so much higher on some of the thermometers now made than on others, yet we would not have the reader think that this can make any considerable error in the observations of the weather, at least in this climate; for an error of 1½° in the position of the boiling point, will make an error of only half a degree in the position of 92°, and of not more than a quarter of a degree in the point of 62°. It is only in nice experiments, or in trying the heat of hot liquors, that this error in the boiling point can be of much signification.

There is another circumstance that we have not yet taken notice of, which, in strictness, causes some error in thermometers, namely, the difference of expansion of the glass tube and the scale. But this error is in almost all cases so small as not to be worth regarding; we have, however, in the note below given a rule for computing the value of it.[†]

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[*] In order to see how much the quicksilver in the tube of the thermometer would be heated in this method of adjusting the boiling point, we took the above-mentioned tube without a ball, wrapped it round with rags, and poured boiling water on it as above described: the heat of the quicksilver therein was found to be about 21° less than that of boiling water; and, therefore, the boiling point of a thermometer, adjusted in this manner, supposing the thermometer to be dipped into the water as far as to the point of 32°, should stand about one-third of a degree lower than it would do if the quicksilver in the tube was heated equally with that in the ball.

[†] The usual way of adjusting thermometers, is, to mark the boiling and freezing points on the glass tube, and not to set off those points on the scale till some time after, when the tube and scale may both be supposed to be nearly of the temper of the air in the room; consequently, when the thermometer is exposed to a greater heat than that, the scale, if of brass, will expand more than the glass tube, and the divisions on it will be longer than they ought to be; but, if the scale bc of wood, it will expand less than the glass tube, and the

Adjustment of the fixed points of thermometers.

In making experiments with thermometers, it evidently is equally necessary that the quicksilver in the tube should be of the same heat as that in the ball, as it is in adjusting the boiling point: for this reason, in trying the heat of liquors much hotter or colder than the air, the thermometer ought, if possible, to be immersed as far as to the top of the column of quicksilver in the tube. As this, however, would often be very difficult to execute, the observer will frequently be obliged to content himself with immersing it to a much less depth. But then as the quicksilver, in a great part of the tube, will be of a different heat from that in the ball, it will be necessary where any degree of accuracy is required, to make a correction, on that account, to the heat shown by the thermometer. If the heat of the quicksilver in the tube be known, the correction may readily be made by the help of the annexed table ; the only difficulty lies in estimating what that heat may be. In all probability the heat of the quicksilver in the tube will not be very different from that of the air which surrounds it ;* but as

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divisions will be too short. Let now the heat of the air, when the divisions were set off on the scale, be called A ; let the degree of heat which the thermometer stands at in the experiment be called D ; and let the degree answering to that point of the scale in which the thermometer is fastened to the scale be called F. Then, if all parts of the thermometer and scale are heated equally, and the scale is of brass, the thermometer will appear to stand lower than it ought to do by the $\frac{D—F \times D—A}{165000}$ part of a degree, observing that if D—F × D—A is negative, it will stand higher than it ought to do ; but if the scale is of wood, it will stand higher than it ought to do by the $\frac{D—F \times —A}{216000}$ part of a degree. If the thermometer be fastened to the scale by the ball, or any part of the tube lower than the observed heat, the error will be the same, whether that part of the tube and scale, which is above the observed degree, be of the same heat as the ball or not : but if the thermometer is fastened to the scale by the top of the tube, as is frequently done, then the error will vanish whenever that part of the tube and scale, which is above the observed degree, is not much heated. This rule is founded on Mr. Smeaton's experiments, who found that white glass expands $\frac{1}{100}$th of an inch in a foot by 180° of heat ; that brass wire expands $\frac{232}{10000}$; and that wood expands scarce sensibly.

* This must evidently be the case, unless the quicksilver in the tube is considerably heated by its contact with that in the ball. To see whether this was the case, some sand was heated in a small copper dish over a lamp to the heat of about 212°, and the above mentioned tube, without a ball, laid horizontally with the end extending about half an inch over the sand ; but, to prevent its being heated thereby, a piece of wood, about a quarter of an inch thick, was laid between the sand and it. After it had remained a sufficient time in this situation, the division which the quicksilver stood at was observed. The

that air will be affected by the steam of the liquor, and the fire by which it is heated, it will commonly be of a very different heat from the rest of the air of the room in which the experiment is made; but as no great nicety is required in estimating the heat of the quicksilver in the tube, insomuch that a mistake of 25° therein will cause an error of only half a degree in the correction, when the number of degrees in that part of the tube which is not immersed in the liquor is not more than 220°, it will commonly be not difficult to guess at the heat of the quicksilver in the tube as near as is required.* But if the

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piece of wood was then removed, and the end of the tube laid in the sand, which was heaped over it so that above half an inch of the column of quicksilver was entirely surrounded by the hot sand, and must therefore be heated to nearly the same degree as it. The quicksilver in the tube rose very little higher than before, and seemingly not more than might be owing to the expansion of the half inch of quicksilver which was surrounded by the sand; so that it should seem, that heating one end of the column of quicksilver does not communicate much heat to the rest of the column; and consequently, that, when the ball of a thermometer is immersed in hot liquor, the quicksilver in the tube will not be much hotter than the surrounding air.

* The better to enable the reader to guess at the heat of the quicksilver in the tube, in cases of this kind we tried how much the quicksilver in the above-mentioned tube, without a ball, would be heated when held over a vessel of boiling water. It is true, that these experiments cannot be of any great service towards this purpose, as the tubes will be very differently heated, according to the degree of heat of the fluid, and the quantity of steam which it furnishes, and according to the nature of the fire by which it is heated; yet as the experiments may perhaps serve in some measure to rectify our ideas on this head, we will give the result. When the above-mentioned tube without a ball,† the length of the column of quicksilver in which was 15 inches, was held perpendicularly over the vessel of boiling water, with its bottom even with the surface of the water, the heat of the quicksilver was in all the trials we made from 68 to 28° hotter than the air of the room. If the tube was held inclined to the horizon, in an angle of about 30°, with the bottom of the column of quicksilver reaching not more than three-quarters of an inch within the circumference of the pot, so that the column of quicksilver was as little heated by the steam as could easily be done, it was from 30 to 7° hotter than the air. When a shorter tube of the same kind, in which the column of quicksilver was seven inches, was used, the quicksilver was from 62 to 44° hotter than the air, when held perpendicularly, and from 49 to 36° hotter when held inclined. The water in these trials frequently boiled pretty fast, but never very violently. It was in general heated over a portable black-lead furnace placed in the middle of the room; but it was once heated over an ordinary chafing-dish, when the quicksilver in the long tube, held perpendicularly, was found to be 64° hotter than the air. When the experiments were tried without doors, the heat of the quicksilver in the tube would vary very much, according as the wind blew the steam and hot air from or towards the tube, but it sometimes rose as high as it did within doors.

The most convenient method we know of making these tubes without a ball is, to fill a thermometer in the usual manner, and heat the ball till there is a

† See page 89, line 27.

observer is desirous of more accuracy, he may find the heat of the surrounding air by holding the ball of a small thermometer near the tube of the thermometer with which he tries the heat of the liquor; or, what will be much better, he may have a tube without a ball, such as is above described, fastened to the frame of the thermometer, on one side of the tube; or if he has two such tubes, of different lengths, it will be still more accurate.

To avoid the inconvenience of this correction, perhaps it may be thought, that both in adjusting the boiling point and in trying the heat of liquors, it would be better, that not much more than the ball of the thermometer should be immersed, and that the tube should be held inclined in such manner as to be heated as little as possible; as it may be said, that by this means you will find the heat of liquors pretty nearly, without the trouble of making any correction; and that, though in strictness a correction would be required in observing the heat of the air with such thermometers, yet the heat of the atmosphere never differs so much from the mean heat, as to make that correction of much consequence.* But, on the other

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proper quantity of quicksilver in the tube, and then to make the column of quicksilver separate at the neck of the ball, and run to the extremity of the tube, so as to leave a vacuum between the ball and the column of quicksilver, as is expressed in fig. 2, plate LXXXI, where the shaded part AD represents the column of quicksilver, and BA that part in which there is a vacuum. The tube must then be sealed somewhere between B and A, as at E, and cut off there; after which it must be held with the end D upwards, so as to make the column of quicksilver run to the extremity E: by this method of filling it is plain, that no sensible quantity of air can be left between E and the column of quicksilver; but yet the quicksilver will be apt not to run sufficiently close to the extremity E, as the weight of the column will be scarcely sufficient to force it into the narrow space which will commonly be left in sealing the tube, especially when held nearly horizontal: for this reason it will be proper to open the tube at D, so as to let in the air, and then seal it again. It must be observed, that the space left between D and the column of quicksilver, ought not to be less than the tenth part of the length of the column of quicksilver, as otherwise the included air might be too much compressed by the expansion of the quicksilver when much heated.

* The degrees on all thermometers are intended to answer to equal portions of the solid contents of the tube; and, consequently, if the quicksilver in the tube is kept constantly of the same heat as that in the ball, the degrees will answer to equal increments of bulk of the whole quantity of quicksilver in the thermometer, that is of a given weight of quicksilver. But if only the quicksilver in the ball is heated, and that in the tube is kept always of the same heat, the degrees will answer to equal increments of a given bulk of quicksilver; so that the scale of the thermometers will be really different in these two methods of proceeding, and in high degrees the difference will be very considerable: for

hand, this method of making and using thermometers is much less exact than the former, and therefore is unfit for nice experiments; and, besides, a correction would be as necessary with this kind of thermometer in trying the heat of air, artificially heated, or in finding the heat of large quantities of hot liquors, in which it would be difficult to prevent the quicksilver in the tube from being heated by the steam, as it is in finding the heat of liquors with the other thermometer, whenever the ball is not immersed to a sufficient depth; so that, on the whole, the former method of making and using thermometers seems much the best.

A much better way of avoiding the trouble of making a correction, would be to have two sets of divisions made to such thermometers as are intended for trying the heat of liquors; one of which should be used when the tube is immersed almost to the top of the column of quicksilver; and the other, when not much more than the ball is immersed, in which last case the observer should be careful that the tube should be as little heated by the steam of the liquor as conveniently can be. It is difficult to give rules for constructing this second set of divisions, as the heat of the quicksilver in the tube will be very different according to the temperature of the air in the room, quantity, and nature of the fluid whose heat is to be tried, the manner in which it is heated, and the other circumstances of the experiment: but, on the whole, we think that given in the following table would be as proper as any:

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example, let two thermometers be made, and in the first of them let care be taken, both in adjusting the fixed points and in trying the heat of liquors, that the quicksilver in the tube shall be of the same heat as that in the ball; and in adjusting the fixed points of the second, and in trying the heat of liquors with it, let care be taken that the quicksilver in the tube shall remain always of the same invariable heat, and let the freezing and boiling points be marked 32 and 212 on both of them: then will the degree of 620 on the first, answer to that of 600 on the second; that of 406 to 400; that of 302 to 300; and that of 119.7 to 120; that is, a liquor which appears to be of 620 of heat by the first, will appear to be of 600 by the second, &c. It appears from hence, that it would be improper to employ the latter method of adjusting and using thermometers for ordinary purposes, and the former for nice experiments.

Adjustment of the fixed points of thermometers.

	Degree answering to that point of the tube which is two inches above the ball.										
	+ 75	+ 50	+ 25	0	—50	— 100	— 200	— 300	— 400	— 500	
—500										— 500	0
—400									—400	—396.6	0
—300								—300	—297.4	—294.8	0
—250								—248.9	—246.7	—244.6	0
—200							—200.	—198.3	—196.4	—194.8	0
—150							—149.3	—148.	—146.7	—145.4	0
—100						—100.	— 98.9	— 97.7	— 96.6	— 95.5	30
— 50					—50	—49.7	— 49.	— 48.3	— 47.6	— 46.9	30
0				0	+0.2	+ 0.3	+ 0.6	+ 0.9	+ 1.2	+ 1.5	35
+150	149.5	149.4	149.	148.7	148.4	147.3					75
+200	198.8	198.5	198.3	198.	197.5	197.					85
+250	247.5	247.1	246.8	246.4	245.7						85
+300	295.8	295.3	294.9	294.4	293.4						85
+350	343.7	343.1	342.5	342.							85
+400	391.1	390.4	389.7	389.1							85
+450	438.1	437.3	435.5	435.7							85
+500	484.7	483.8	482.9	482.							85
+600	576.5	575.4	574.3	573.2							85

To make use of this table, seek in the uppermost horizontal line the degree of the thermometer answering to that point of the tube which is two inches above the ball; and in the left hand column seek the degrees of the second set of divisions; the corresponding numbers in the table are the corresponding degrees of the first set, or the degrees which they must be set opposite to.

The right-hand perpendicular column shows the heat which the quicksilver in the tube was supposed to be of in forming this table.

Though this second set of divisions be far from accurate, yet it is at least as much so as a thermometer adjusted in the latter method can be; so that this double set of divisions possesses all the advantages which can be expected from that method of adjusting thermometers, without the inconveniences.

A TABLE FOR CORRECTING THE OBSERVED HEIGHT OF A THERMOMETER, WHENEVER THE QUICKSILVER IN THE TUBE IS NOT OF THE SAME HEAT AS THAT IN THE BALL.

Diff. of Heat.	Degrees not immersed in the liquors.														
	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750
50	.2	.4	.7	9.	1 1	1.3	1.5	1.7	2.	2.2	2.4	2 6	2.8	3.1	3.3
100	.4	.9	1.3	1.8	2.2	2.6	3.0	3.5	3.9	4.4	4 8	5 2	5.7	6.1	6 6
150	.7	1.3	2.0	2.6	3.3	3.8	4.6	5 2	5.9	6.5	7.2	7.9	8 4	9.2	9.8
200	.9	1.8	2.6	3.5	4.4	5.1	6 1	7.0	7.8	8.7	9 6	10	11	12	13
250	1.1	2.2	3.3	4.4	5.5	6.4	7.6	8 7	9.8	11	12	13	14	15	16
300	1.3	2.6	3.8	5.1	6.4	7.7	9.1	10	12	13	14	16	17	18	20
350	1.5	3.0	4.6	6.1	7.6	9.1	11	12	14	15	17	18	20	21	23
400	1.7	3.5	5.2	7.0	8.7	10	12	14	16	17	19	21	23	24	26
450	2.	3.9	5.9	7.8	9.8	12	14	16	18	20	22	24	25	27	29
500	2.2	4.4	6.5	8.7	11	13	15	17	20	22	24	26	28	31	33
550	2.4	4.8	7.2	9.6	12	14	17	19	22	24	26	29	31	34	36

To make use of this table, in the left-hand perpendicular column look for the number of degrees contained in that part of the tube which is not immersed in the fluid whose heat is to be tried, and in the upper horizontal line seek the supposed difference of heat of the quicksilver in that part of the tube from that in the ball, the corresponding number in the table is the correction, which must be added to the observed heat when the quicksilver in the tube is cooler than that in the ball, and subtracted when it is warmer: for example, let the observed heat of the fluid be 475°, let the thermometer be immersed in the fluid as far as to the degree of 25°, or to that part of the tube which should be marked 25° if the divisions were centinued long enough; then is the number of degrees in that part of the tube which is not immersed in the fluid 450; and let the heat of the quicksilver in that part of the tube be supposed 100°: and consequently, the difference of heat of the quicksilver in that part of the tube from that in the ball, 375; then in the left-hand perpendicular column seek the number 450, and in the upper horizontal line the number 375; the corresponding number in the table, or the correction, is 15°, and therefore the true heat of the fluid is 490°.

This correction may be had very easily without the help of the table, only by multiplying the number of degrees not immersed in the fluid by the supposed difference of heat, dividing the product by 10000, and diminishing the quotient by one-eighth part of the whole.

In the following pages we have thrown together the practical rules which we would recommend to be observed in adjusting fixed points of thermometers.

RULES TO BE OBSERVED IN ADJUSTING THE BOILING POINT.

The most accurate way of adjusting the boiling point is, not to dip the thermometer into the water, but to expose it only to the steam, in a vessel closed up in the manner represented in fig. 4, plate LXXXI, where AB *b a* is the vessel containing the boiling water, D *d* the cover, E a chimney made in the cover intended to carry off the steam, and M *m* the thermometer passed through a hole in the cover. Those who would make use of this method must take care to attend to the following particulars.

1st. The following point must be adjusted when the barometer is at 29.8 inches; unless the operator is willing to correct the observed point in the manner directed below.

2dly. The ball of the thermometer must be placed at such a depth within the pot, that the boiling point shall rise very little above the cover; for otherwise part of the quicksilver in the tube will not be heated, and therefore the thermometer will not rise to its proper height. The surface of the water in the pot also should be at least one or two inches below the bottom of the ball; as otherwise the water, when boiling fast, might be apt to touch the ball: but it does not signify how much lower than that, the surface of the water may be.

3dly. Care must be taken to stop up the hole in the cover through which the tube is inserted, and to make the cover fit pretty close, so that no air shall enter into the pot that way, and that not much steam may escape. A piece of thin flat tin plate must also be laid on the mouth of the chimney, so as to leave no more passage than what is sufficient to carry off the steam. The size of this plate should be not much more than sufficient to cover the chimney, that its weight may not be too great;

and the mouth of the chimney should be made flat, that the plate may cover it more completely. It must be observed, that when the tin plate is laid on the mouth of the chimney, it will commonly be lifted up by the force of the steam, and will rattle till it has slipped aside sufficiently to let the steam escape without lifting it up. In this case it is not necessary to put the plate back again, unless by accident it has slipped aside more than usual. If the artist pleases, he may tie each corner of this plate by a string to prongs fixed to the chimney, and standing on a level with the plate, as thereby it will necessarily be kept always in its place;* but we would by no means recommend having it made with a hinge, as that might be apt to make it stick, in which case the included vapour might be so much compressed as to cause an error. We would also by no means advise lining the tin plate with leather, or any other soft substance, for the sake of making it shut closer, as that also might be apt to make it stick. The chimney also ought not to be made less than half a square inch in area: for though a smaller chimney would be sufficient to carry off the steam, unless the vessel is much larger than what we used, yet the adhesion which is apt to take place between it and the tin plate when wet, might perhaps bear too great a proportion to the power which the included steam has to lift it off, if it was made much less. It is convenient that the chimney be not less than two or three inches long, as thereby the observer will be less incommoded by the steam; but it would be improper to make it much longer, for the longer the chimney is, the greater disposition has the air to enter into the pot between it and the cover.

It is most convenient not to make the cover fit on tight, but to take on and off easily; and to wrap some spun cotton round that part of the cover which enters into the pot, in order to make it shut closer; or, what seems to answer rather better, a ring of woollen cloth may be placed under the cover, so as to lie between the top of the pot and it. These methods of making the cover shut close can be used more conveniently when the cover is made to enter within the pot, as in the figure, than when it goes on the outside.

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* Fig. 3, plate LXXXI, is a perspective view of the chimney and tin plate; ABCD is the plate; E the chimney; F*f*, G*g*, M*m*, and N*n*, the prongs fastened to the chimney, to which the four corners of the plate are to be tied by the strings AF, BG, CM, and DN; the ends F, G, M, and N, of the prongs must be on a level with the plate, and the strings should not be stretched tight.

There are various easy ways by which the hole in the cover, through which the tube of the thermometer is passed, may be stopped up, and by which the thermometer may be suspended at the proper height. The hole in the cover may be stopped up by a cork, which must first have a hole bored through it, big enough to receive the tube, and be then cut into two, parallel to the length of the hole. Another method, more convenient in use, but not so easily made, is represented in fig. 6, plate LXXXI, which exhibits a perspective view of the apparatus; A *a* is the cover; H the hole through which the thermometer is passed; B *b* a flat piece of brass fixed upon the cover; and D *d* E *e* a sliding piece of brass, made so as either to cover the hole H, or to leave it uncovered as in the figure, and to be tightened in either position by the screw *s* sliding in the slit M *m*; a semi-circular notch being made in the edge B *b*, and also in the edge D *d*, to inclose the tube of the thermometer; pieces of woollen cloth should also be fastened to the edges B *b* and D *d*, and also to the bottom of the sliding piece D *d* E *e*, unless that piece and the cover are made sufficiently flat to prevent the escape of the steam. In order to keep the thermometer suspended at the proper height, a clip may be used like that represented in fig. 7, which by the screw *s* must be made to embrace the tube tightly, and may rest on the cover. That part of the clip which is intended to bear against the tube, had best be lined with woollen cloth, which will make it stick tighter to the tube, and with less danger of breaking it. Another method, which is rather more convenient, when the top of the tube of the thermometer is bent into a right angle, in the manner frequently practised at present for the sake of more conveniently fixing it to the scale, is represented in the same figure; G *g* F *f* is a plate of brass, standing perpendicularly on the cover, and, L *l* N *n* a piece of brass, bent at bottom into the form of a loop, with a notch in it, so as to receive the tube of the thermometer, and to suffer the bent part to rest on the bottom of the loop; this piece must slide in a slit K *k*, cut in the plate L *l* N *n*, and be tightened at any height by the screw T.

4thly. It is best making the water boil pretty briskly, as otherwise the thermometer is apt to be a great while before it acquires its full heat, especially if the vessel is very deep. The observer too should wait at least one or two minutes after the thermometer appears to be stationary, before he concludes that it has acquired its full height.

5thly. Though, as we said before, this appears to be the most accurate way of adjusting the boiling point; yet, if the operator was to suffer the air to have any access to the inside of the vessel, he would be liable to a very great error; for this reason we strongly recommend it to all those who use this method, not to deviate at all from the rules laid down, without assuring themselves by repeated trials with a pretty sensible thermometer, that such alteration may be used with safety. But the covering the chimney with the tin plate ought by no means to be omitted; for though, if the cover of the pot fits close, it seldom signifies whether the plate is laid on or not, yet, if by accident the cover was not to fit close, the omitting the tin plate would make a very great error. Making the chimney very narrow would not answer the end properly; for, if it was made so small as to make the vessel sufficiently close when the water boiled gently, it would not leave sufficient passage for the escape of the steam when the water boiled fast.

Another way of adjusting the boiling point is, to try it in a vessel of the same kind as the former, only with the water rising a little way, namely, from one to three or four inches above the ball, taking care that the boiling point shall rise very little above the cover, as in the former method. In this method there is no need to cover the chimney with the tin plate; and there is less need to make the cover fit close, only it must be observed, that the closer the cover fits, the less the operator will be incommoded by the steam. The height of the barometer at which the boiling point should be adjusted, when this method is used, is 29½ inches, or three-tenths of an inch less than when the former method is used.

It will be convenient to have two or three pots of different depths; for if a short thermometer is to be adjusted in the same pot which is used for a long one, it will require a great depth of water, which, besides taking up more time before it boils, makes the observation rather less accurate, as the heat seems to be less regular when the depth of water in the pot is very great, than when it is less.

Perhaps some persons, for the sake of heating the water more expeditiously, may be inclined to use an apparatus of such kind that the fire shall be applied to a considerable part of the sides of the pot as well as to the bottom; we would, however, caution them against any thing of that kind, as the observations are considerably less regular than when little more than the bottom of the pot is heated. If the pot is heated over a chafing-dish or common fire, we apprehend that there can seldom be any danger of too much of the sides being heated; but if the operator should be apprehensive that there is, it is easily prevented by fastening an iron ring an inch or two broad round the pot near the bottom. This precaution is equally necessary when the thermometer is adjusted in steam, especially when there is not much water in the pot.

The greatest inconvenience of this method of adjusting the boiling point is the trouble of keeping a proper depth of water in the pot, as to do this it is necessary first to find the height of the boiling point coarsely by trying it in an open vessel, and then to put such a quantity of water into the pot that it shall rise from one to three or four inches above the ball, when the thermometer is placed at such a depth within the pot that the boiling point shall rise very little above the cover. The operator must be very careful that the quantity of water in the pot be not so small as not entirely to cover the ball.

A third way of adjusting the boiling point is, to wrap several folds of linen rags or flannel round the tube of the thermometer, and to try it in an open vessel, taking care to pour boiling water on the rags, in order to keep the quicksilver in the tube as nearly of the heat of boiling water as possible. The best way is to pour boiling water on the rags three or four times, waiting a few seconds between each time, and to wait some seconds after the last time of pouring on water before the boiling point is marked, in order that the water may recover its full strength of boiling, which is in good measure checked by pouring on the boiling water.

In this method the boiling point should be adjusted when the barometer is at 29.8 inches, that is, the same as when the first method is used; the water should boil fast, and the thermometer should be held upright, with its ball two or three inches under water, and in that part of the vessel where the current of water ascends.*

Whichever of these methods of adjusting the boiling point is used, it is not necessary to wait till the barometer is at the proper height, provided the operator will take care to correct the observed height according to the following table:

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* In a vessel of boiling water, one may almost always perceive the current of water to ascend on one side of the vessel, and to descend on the other.

Adjustment of the fixed points of thermometers.

Height of the barometer when the boiling point is adjusted according to,		Correction in 1000ths of the interval between 32° and 212°.		Height of the barometer when the boiling point is adjusted according to,		Correction in 1000ths of the interval between 32° and 212°.	
1st or 3d method.	2d method.			1st or 3d method.	2d method.		
	30.64	10	lower.	29.69	29.39	1	higher.
	53	9		58	28	2	
30.71	41	8		47	17	3	
59	29	7		36	06	4	
48	18	6		25	28.95	5	
37	07	5		14	84	6	
25	29.95	4		03	73	7	
14	84	3		28.92	62	8	
03	73	2		81	51	9	
20.91	61	1		70	——	10	
80	50	0		59	——	11	

To make use of this table, seek the height which the barometer is found to stand at in the left-hand column, if the boiling point is adjusted either in the first or third method, and in the second column if it is adjusted in the second method; the corresponding number in the third column shows how much the point of 212° must be placed above or below the observed point, expressed in thousandth parts of the interval between the boiling and freezing point: for example, suppose the boiling point is adjusted in steam when the barometer is at 29 inches, and that the interval between the boiling and freezing points is 11 inches; the nearest number to 29 in the left-hand column is 29.03, and the corresponding number in the table is 7 higher, and therefore the mark of 212° must be placed higher than the observed point by $\frac{7}{1000}$ of the interval between boiling and freezing, that is, by $\frac{11 \times 7}{1000}$, or .077 of an inch.

This method of correcting the boiling point is not strictly just, unless the tube is of an equal bore in all its parts; but the tube is very seldom so much unequal as to cause any sensible error, where the whole correction is so small. The trouble of making the correction will be abridged by making a diagonal scale, such as is represented in fig. 5.

It is not very material what kind of water is used for adjusting the boiling point, so that it is not at all salt; only, if any kind of hard water is used, it is better that it should be kept boiling for at least ten minutes before it is used. But we would advise all those desirous of adjusting thermometers in the most accurate manner for nice experiments, to employ rain or distilled water, and to perform the operation in the first-mentioned manner, that is, in steam.

ON THE FREEZING POINT.

In adjusting the freezing as well as the boiling point, the quicksilver in the tube ought to be kept of the same heat as that in the ball. In the generality of thermometers, indeed, the distance of the freezing point from the ball is so small, that the greatest error which can arise from neglecting this precaution is not very considerable, unless the weather is warmer than usual: but as the freezing point is frequently placed at a considerable distance from the ball, the operator should always be careful either to pile the pounded ice to such a height above the ball, that the error, which can arise from the quicksilver in the remaining part of the tube not being equally heated with that in the ball, shall be very small; or he must correct the observed point, upon that account, according to the following table:

Heat of the air.	Correction.	Heat of the air.	Correction.
42°	.00087	72°	.00348
52	.00174	82	.00435
62	.00261		

The first column of this table is the heat of the air, and the second is the correction expressed in 1000th parts of the distance between the freezing point and the surface of the ice; for example, if the freezing point stands seven inches above the surface of the ice, and the heat of the room is 62, the point of 32° should be placed 7 × .00261, or .018 of an inch lower than the observed point. This correction also would be made more easy by the help of a diagonal scale, similar to that proposed for the boiling point.

ON THE PRECAUTIONS NECESSARY TO BE OBSERVED IN MAKING OBSERVATIONS WITH THERMOMETERS.

In trying the heat of liquors, care should be taken that the quicksilver in the tube of the thermometer be heated to the same degree as that in the ball; or, if this cannot be done conveniently, the observed heat should be corrected on that account; but for this we refer to the former part, p. 91, 92.

Methods of grinding and polishing Glasses and Mirrors for Telescopes, Microscopes, and other Optical purposes.[*]

Among those who are fond of mechanical pursuits, and who have large portions of leisure at their command, or the perseverance to render many small portions of leisure considerable by the accumulated effects of their active use, there are many who cannot prudently gratify themselves in their favourite pursuits at a great expense. When persons thus situated, have a predilection for optical and astronomical recreations, they immediately perceive that the effective parts of instruments of the most valuable and costly description consist of materials of very little value: a few bits of glass, in their original state, not worth accepting as a gift; a little metal, not intrinsically worth more than a table-bell, are rendered by the labour bestowed upon them, of the highest estimation. They are anxious to know in what manner their labour must be directed to be equally successful, and they feel that even their zeal for science would be increased, if they could examine the phenomena of Creation with the mechanical productions of their own hands. To these it may be gratifying to learn, that the apparatus which will suffice for the purpose of grinding and polishing lenses and specula, is not more simple and economical in its purchase, than the objects which its productions will enable them to contemplate are grand and interesting. Several essays of real value have been written on the subject, but it has happened that these essays have had a very limited circulation, and some of them seem to have been entirely confined to the publications in which they first appeared; not certainly for want of great intrinsic merit, but perhaps because the compilers of books are not often practical men, and the subject is such that those who felt no interest in it would scarcely venture to appreciate an essay written for its elucidation. These original papers, we shall give at length; by this means we shall embrace a variety of details, which will give the reader better hold of the subject, and render him more easily conversant with manipulations, the suc-

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[*] A glass which will either enlarge or diminish the visible appearance of an object, is by opticians called a *lens;* and a mirror, designed for any optical use, is called a *speculum.*

cess of which depends much upon minuteness of attention. In conclusion, we shall make a variety of remarks, drawn from actual experience, as well as information derived from sources not wholly confined to this subject, but containing applicable hints.

ESSAY I.

The Method of Grinding and Polishing Glasses for Telescopes.

The ground-work of this essay was supplied by the posthumous papers of a friend of its first Editor, who by the following advertisement explained the cause and the authority of the additions he made to it:

1. This ingenious and honourable Author, (Molyneux,) out of his great regard for the improvement of astronomy, by perfecting the methods of making telescopes both by refraction and reflection, did not only collect and consider what had been written and practised by others, but also made several new experiments of his own contriving, after he had procured a most complete apparatus of all sorts of instruments for that purpose. But in the midst of these thoughts, being appointed a Lord Commissioner of the Admiralty, he became so engaged in public affairs, that he told me he had not leisure to pursue these inquires any farther. Then it was that he gave me the following papers, and was pleased to invite me to make use of his house and apparatus of instruments, in order to finish what he had left imperfect. But he died soon after, and so I lost that opportunity, and a most worthy friend. Having therefore seen nothing of the practice of grinding glasses, I durst not venture to add any thing of my own relating to it; but have supplied from Mr. Huygens what was left unfinished by our honourable Author. And as Mr. Huygens's treatise is esteemed the best of any yet extant, I have taken care that nothing material therein contained should pass unobserved. If I have mistaken his meaning anywhere, it is the more excusable, considering the difficulty of the subject, and that it was a posthumous treatise, written originally in Dutch, and translated into Latin by another hand. To distinguish Mr. Molyneux's papers from what I have translated from Mr. Huygens, the initials of their names are placed at the beginning of every piece.

OF MAKING AND POLISHING THE TOOLS.

2. It is easier to make an object-glass of equal convexities than of any other figure; because the same tools will serve for forming both its surfaces. And a glass of this figure will make as perfect an image in its focus as any other, because the aberrations of the rays caused by the sphericalness of the figures of the surfaces, whatever be the proportion of their semi-diameters, are inconsiderable in long telescopes, in comparison to the aberrations caused by the different refrangibility of the rays; and these latter aberrations are the same whether the semi-diameters of the surfaces be equal or unequal, supposing the aperture and focal distance to be the same. If it be proposed then to make a glass of equal convexities, that shall have a given focal distance, the radius of the spherical surface will be found by taking it in proportion to the given focal distance as 12 to 11, putting the sine of incidence to the sine of refraction out of the air into glass as 17 to 11, as Sir Isaac Newton has accurately determined it. The focal distance of the glass being given, its aperture may be found by tables usually inserted in optical treatises; and because its figure cannot be formed exactly true to the very edges, the breadth of the glass may be taken about half an inch more than the diameter of its aperture, or even three-quarters or a whole inch more, if its focal distance be between 50 and 200 feet.

3. Mr. Huygens directs in general to make the breadth of the concave tool, (or plate, dish, or form,) in which an object-glass must be ground, almost three times the breadth of the glass. Though in another place, he speaks of grinding a glass whose focal distance was 200 feet, and breadth 8¾ inches, in a plate only 15 inches broad. But for eye-glasses, and others of lesser spheres, the tool must be broader in proportion to the breadth of these glasses, to afford room enough for the motion of the hand in polishing. Mr. Huygens made his tools of copper or cast brass; which, for fear they should change their figures by bending, can hardly be cast too thick; nevertheless he found by experience that a tool 14 inches broad, and half an inch thick, was strong enough for forming glasses to a sphere of 36 feet diameter; when the tool was strongly cemented upon a cylindrical stone an inch thick, with hard cement made of pitch and ashes.

4. In order to make moulds for casting such tools as are pretty much concave, he directs that wooden patterns should be turned in a lathe, a little thicker and broader than the tools themselves. But for tools that belong to spheres above twenty or thirty feet diameter, he says, it is sufficient to make use of flat boards turned circular to the breadth and thickness required. When the plates are cast, they must be turned in a lathe, exactly to the concavity required. And for this purpose it is requisite to make a couple of brass gauges in the manner following.

5. *M.*—Take a wooden pole, a little longer than the radius of the spherical surface of the glass to be formed, and through the ends of it strike two small steel points, at a distance from each other equal to the radius of the sphere intended; and by one of the points hang up the pole against a wall, so that this upper point may have a circular motion in a hole or socket made of brass or iron fixed firmly to the wall. Then take two equal plates of brass or copper, well hammered and smoothed, whose length is somewhat more than the breadth of the tool of cast brass; and whose thickness may be about a tenth or a twelfth of an inch, and whose breadth may be two or three inches. Then having fastened these plates flat against the wall in a horizontal position, with the moveable point in the pole strike a true arch upon each of them. Then file away the brass on one side exactly to the arch struck, so as to make one of the brass edges convex and the other concave; and to make the arches correspond more exactly, fix one of the plates flat upon a table, and grind the other against it with emery. These are the gauges to be made use of turning the brass tools exactly to the sphere required.

6. *H.*—But if the radius of the sphere be very great, the gauges must be made in this manner: Imagine the line AE, plate LXXXII, fig. 1, drawn upon the brass plate, to be the tangent of the required arch AFB, whose radius for example is 36 feet and diameter 72 feet. From A set off the parts AE, EE, &c. severally equal to an inch, and let them be continued a little beyond half the breadth of the tool required. Then as 72 feet or 864 inches is to 1 inch, so let 1 inch be to a fourth number; this will be the number of decimal parts of an inch in the first line EF, reckoning from A. Multiply this fourth number successively by the numbers 4, 9, 16, 25, &c. the squares of 2, 3, 4, 5, &c.; and the several products will be the number of parts contained in the 2nd, 3d, 4th, 5th EF respectively. But because these numbers of parts are too small to be taken from a scale by a

pair of compasses, subtract them severally from one inch, represented by the lines EG, and the remainders being taken from a scale of an inch divided into decimal parts and transferred by the compasses from G to F, will determine the points F, F, &c. of the arch required. And the same being done on the other side of the line AD, the brass plate must be filed away exactly to the points of this arch, and polished as before.

7. To apply the brass tool to a turning lathe in order to turn the concave surface of it exactly spherical, let fig. 2 represent a view of some part of the lathe, taken from a point directly over it; and here let *a b* represent a strong flat disk of brass, half an inch thick at least, having a strong iron screw-pin fixed firmly in the centre of it, and standing out exactly perpendicular to one side of it; by which it may be screwed into the end *c* of the mandrel or axis of the lathe, represented by *c d*. This disk is represented separately in fig. 3, and must be well soldered to the back side of the tool *e f*, which, therefore, in the middle of it must be made plane, and exactly parallel to the circumference of its opposite surface; to the intent that the circumference may be carried round the axis of the lathe in a plane perpendicular to it. The mandrel or axis *c d* turns upon a point *d* in the puppet-head of the lathe, and in a collar at *s t*, as usual.

Let *g h i k* represent a board nailed fast upon the other puppet-head; and let the concave guage *g h* be laid upon this board, with its concave arch parallel to the concavity of the tool *e f*, and be screwed down to the board with flat-headed screws sunk into the brass. Let *l m n o* represent such another board lying upon the former, with the convex guage *l m* screwed to the under side of it, so that by moving this upper board, the arch of the convex guage may be brought to touch the concave one and slide against it. The turning tool *p q* is laid upon this moveable board, and is held fast to it by a broad-headed screw at *r*, to be turned or unturned by the hand upon occasion. To know whether the concave guage be exactly parallel to the concavity of the tool *e f* screwed fast to the mandrel, direct the point *p* of the turning tool *p q* to touch any point of the tool *e f* near its circumference; then having fixed the turning tool *p q* by the screw *r*, turn the brass tool *e f* half round, and move the upper board till the point *p* of the turning tool be brought over against the same mark upon the tool *e f*; and if it just touches it as before when the guages coincide, all is right. If not, the position of the head of the lathe may be altered a little by striking it with a mallet. But the best way is to make this examination of the situation of the concave guage, when only one end of it is fixed to the head of the lathe by a single tack or screw, about which it may easily be moved into its true position. And while the tool or plate *e f* is turning, the same examination of its parallelism to the guage must be frequently repeated; otherwise its surface will take a false figure. It is convenient that the upper board *l m n o* should project over both the guages; and to keep its surfaces parallel to that of the under board, two round-headed nails, or a plate of brass, of the same thickness as the guages, must be fixed to its under surface, towards the opposite side *n o*. Care must be taken to drill the holes in the guages, through which they are screwed to the boards, not too near the polished arches, for fear of altering their figure, by the yielding of the brass. The tool and all the parts of the lathe must be fixed very firm, because any trembling motion will cause the graving tool *p q* to indent the brass.* After the tool is well turned, it must be separated from the brass back *a b*, by melting the solder with live coals laid upon it.

It is easy to understand, that by transposing the guages, a convex tool may be turned in the same manner. Fig. 4 is a perspective view of this method of making convex and concave tools.

8. *M.*—Mr. Huygens would have his plates or tools first formed in a turning lathe, and then ground together with emery; that is to say, the concave or convex tool of the same sphere together. But the tools of very large spheres, he would have ground at first quite plane by a stone-cutter; and then ground hollow with a round flat stone and emery to the desired guage. And he prescribes to use for this grinding, first a stone half as broad as the tool, and after that another stone very nearly as broad as the tool; and in this way of forming the tools it is convenient to tie a little frame of thick paper, or rather of thin pasteboard, about an inch high, round about the tool to keep in the emery; and in grinding, the whole must be made extremely firm and stable. And when the tool is to be polished, it must still remain upon the stone pedestal; otherwise it will be in danger of bending a little in the operation.

9. For polishing these tools thus ground, Mr. Huygens takes some soap, and daubs the concave tool therewith; then he takes the last mentioned round stone, somewhat less than the tool, (or the convex tool itself,) and heats it, and then he pours upon it some hot melted cement (made of pitch and fine powdered and sifted ashes as much as he can mix with it) and then he turns over the stone and cement upon the concave tool, into

which also he had poured a good quantity of the same cement, having first laid three little pieces of brass of equal thicknesses on the circumference thereof, in order to press and keep this crust of cement of an exact equal thickness in all its parts; and thus he lets them cool together. Then taking the stone from the tool and turning it up, he sifts upon the cement that sticks to it, a crust of very fine emery, and with a flat iron spatula about one-third of an inch thick, gently warmed, he presses lightly the emery, to stick to and incrustate upon the cement; then he again gently warms the whole stone (or convex tool) cement and emery, and he again replaces it upon the concave tool, and leaves it again to cool; so that he has by this means a crust of emery exactly of the figure of his tool; with this he polishes the tool dry, without the addition of any wet, pressing it down hard on the surface of the tool. And to press it the harder, he places upon it a long pole, a little bent to make it spring, whose upper end is fixed to the ceiling of the room, or else is pressed downwards by a strong iron spring; and he says it will be necessary to have two persons to rub the stone upon the tool. And here it is to be noted that great care must be taken in this and all cases where this way of grinding by a pole is made use of, to fix the point of pressure exactly and truly in the middle, as shall be more particularly explained hereafter when the glass comes to be ground in this tool.

10. It is to be noted that this cement, and indeed all cements for sticking glasses, is made in different manners by different persons. Pere Cherubin says it is usually made of common black pitch and finely sifted vine ashes, but he himself made it of rosin and ochre, or of rosin and Spanish white, pounding the rosin first, and mixing it with a due quantity of the powder, and then sifting the mixture upon hot melted pitch, and while hot, well mixing and incorporating the whole. The cement that Mr. Scarlet uses is made of common pitch, and common coal-ashes sifted fine. In all cases it is harder or softer as more or less of the ashes or other powder is put into it; and in this present case for polishing these tools, it must be made as hard as possible, by putting in as great a quantity of the ashes as is possible; for otherwise, if the cement be not hard enough, the particles of the emery will be loosened by the heat in grinding, and then will only run round upon the tool, and will not work out the little inequalities and roughnesses thereof. If the emery should be found to grow blunt, a very little more of it may be dusted dry upon the tool, by which its sharpness and cutting quality will be a little recovered; but if the cement be sufficiently

OF PREPARING THE GLASSES BEFORE THEY CAN BE GROUND AND POLISHED.

15. *H.*—The pieces of glass above-mentioned, which we directed to be planed to an equal thickness, and polished a little by a glass grinder, should be much broader than the intended object-glass, that there may be room enough for chusing the best part of them. For planing and smoothing those large pieces of glass, I ordered the workmen to make use of plates of cast iron, such as are sold at the ironmongers' shops, after they had been ground and planed in a stone-cutter's engine. Upon the plate of glass, with a diamond-pointed compass, strike a circle representing the circumference of the object-glass; and also another concentric circle with a radius about a tenth or a twelfth part of an inch bigger. And also two other such circles, on the other side of the glass, directly opposite to the former: which may be done by means of a circular glass to be described by and by. The larger parts of the glass may be separated from the outward circle by a red-hot iron, or by a strong broad vice, opened exactly to the thickness of the glass. The remaining inequalities may be taken off by a grindstone, beginning with the largest first, and taking care they do not splinter. Then having warmed the glass, cement a wooden handle to it, and in a common deep tool for eye-glasses, making use of white clear sand and water, grind the circumference of the glass, exactly true to the innermost circle on each side of it.

16. Then having made a great many small cavities with a punch upon one side of a round copper plate, and having fixed the other side of it upon the middle of the round glass, by cement made with two parts of rosin or hard pitch and one part of wax, place the steel point of the springing pole above-described, being fourteen or fifteen feet long, into that cavity of the copper-plate, which lies nearest to the thickest part of the glass. Then work the glass by the pole with sand and water upon a flat plate of cast iron, of a round figure, the plate having been planed with sand and water by a stone-cutter. Then having examined the thickness of the glass in several places by a hand-vice, which is better than a pair of callipers, by repeating the same operation it will soon be reduced to an equal thickness in all its parts.

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the changes which they produce upon the transmitted light, and the distinctness with which they are seen increases as the refractive power of the fluid approaches to that of the solid.

Towards the end of this operation, it is convenient to make use of sifted emery, because the sand will scratch too deep; and then it will also be necessary to place the steel point of the pole exactly over the centre of the under surface of the glass; otherwise that surface will take a cylindrical or a sort of convex figure instead of a plane one, even though it was exactly plane before you began to grind it. The reason of which is well worth observing. And when convex-glasses are to be polished, it is also absolutely necessary to place the point of pressure exactly over the centre of the under surface of the glass.

17. Therefore to bring one of the little cavities in the copper-plate exactly over that centre, we make use of a circular glass formed from a broken looking-glass, the quicksilver being rubbed off; having described upon it with a diamond-pointed compass, eight or ten concentric circles at the distance of about a quarter of an inch from each other, so that the larger circles may be somewhat bigger than the circumference of the glass to be polished. Lay this circular glass upon the surface of the glass to be polished, and move it to and fro till you perceive the circumference of the glass to be polished is exactly parallel to the nearest circle upon the circular glass; then having inverted both the glasses, lay the circular glass upon a table, and having laid a small live coal upon the copper-plate, to make it moveable upon the cement, place one point of a pair of compasses in one of the little cavities, and move the copper till a circumference described with the other point coincides exactly with any one circle upon the circular glass, and the business is done. With starch it is convenient to paste three slender shreds of linen, directly towards the centre of the circular glass, that the other glass may not slide too easily upon it, and that they may not scratch one another.

18. The cavities punched in the copper-plate, and also the point of the pole, should be triangular, to hinder the rotation of the glass; which is still more necessary in perfecting the polish of the glass. And here it must be observed again whether the circumference of the glass remains exactly circular on both sides of it, which must be tried with a pair of compasses; and if it be not, it must be corrected again by grinding it exactly circular in a common tool for making eye-glasses; which will contribute very much to its taking an exact spherical surface when it comes to be ground in proper tool. For if any part of the circumference be protuberant, it will hinder the adjoining parts of the surface from wearing so much as they should do; and by consequence will spoil the spherical figure of the surface.

OF GRINDING THE GLASSES.

19. *M.*—The glass being planed and rounded as above, take away the plate with several cavities, and with some of the same cement fix on a smaller round piece of brass or rather steel, truly flat and turned about the bigness of a farthing, but thicker; having first made in the centre thereof, with a triangular steel punch, a hole about the bigness of a goose-quill, and about the depth of $\frac{1}{12}$ of an inch; and at the very bottom of this triangular hole, a little small round hole must be punched somewhat deeper with a very fine small steel punch. A small steel point of about an inch long must be truly shaped and fitted to this triangular hole, and at the very apex to the small round deeper impression. Nevertheless it must not be fitted so exactly to the same, but that it may have some liberty to move a little to and fro; the apex always continuing to touch and press upon the surface of the round hole below. This steel triangular point must be fixed to the end of a pole, to the other end of which another round iron point must be fixed, of about five or six inches long, to play freely up and down in a round hole in a piece of brass let into a board fixed against the ceiling for that purpose, perpendicularly over the bench, and over the centre of the tool, which must be strongly and truly fixed horizontally thereon. This apparatus is represented by fig. 5, plate LXXXII.

20. Now here it is to be noted, that Mr. Huygens prescribed to fix his brass plate to the glass by means of cement, and takes no notice of any other method whatever: though a very small experience in these affairs will convince any body that it is hardly possible, in this or any other case, to bring the cement to a fluidity sufficient to fix two plane surfaces exactly parallel one to the other, without heating the glass and the brass also to a great degree, and so as to endanger the figure of the glass considerably. To avoid this in fixing glasses to brass or wood or the like, some have done it with plaster of Paris: Mr. Scarlet does it by cementing another intermediate glass to the brass (or wood) and then fixing the glass, to be ground, to the outward surface of the cemented glass with common glue. Without all this trouble, I have done it only with common Icthyocolla or fish glue, which will run very fluid, and will fix the glass and the brass itself strongly together; and round the edges of the brass I stick on some common soft red wax, such as is used for the privy seal, to keep the wet from getting to the glue.

21. For grinding glasses truly plane, upon a plane tool, by this method, Mr. Huygens prescribes this pole to be about fifteen feet long; but in grinding upon a concave plate, the pole had best be made equal to the radius of the sphere of the tool; though I believe it would not be material if made considerably shorter, according as the height of the room will allow.

It is necessary to have lying by one, an ordinary piece of coarse glass, ground in the same tool, called a bruiser, whereby when any new emery is necessary to be laid on the tool in grinding your glass, the said emery is constantly to be first run over and smoothed, for fear any little coarse grains should remain and scratch the glass to be ground.

22. Having these things prepared, together with some pots of emery of various finenesses, take of your roughest sort a small half pugil, wetting the same and daubing it pretty equally on the tool; then lay on your glass and fix up your pole, and continue to grind for a quarter of an hour, not pressing upon the pole, but barely carrying the glass round thereby; then take the like quantity of some finer emery, and work another quarter of an hour therewith; then take the like quantity of emery still finer, and work for the same time; last of all take a less quantity of some of the very finest you have, which will be sufficient for a glass of five inches diameter, and work therewith for an hour and a half, taking away by little and little some of the emery with a wet sponge. Do not keep it too wet nor too dry, but about the consistence of pap; for much depends on this. If it is too dry, your emery will clog and stick and incorporate, so as for the most part to cut little or not at all, unless here and there where its body chances to be broke, and there it will scratch and cut your glass irregularly; and if it is too wet, and too much diluted, it will from the irregular separation of its parts cut in some places more than others, just as in the other case.

23. But Mr. Huygens tells us this method of using various sorts of fresh emery is not good, finding by experience that the surfaces of large glasses are often scratched. And therefore, he says, it is best to take a large quantity of the first or second sort of emery, and so work with the same from the first to the last; taking away by little and little, every half hour, or quarter of an hour, more and more of the emery with a wet sponge; by which means he could bring the glass extremely smooth and fine, so as to see pretty distinctly a candle, or the sash windows well defined, through it; which is a mark when

it is ground enough to be ready to receive a polish. But if the glass has not acquired this degree of transparency, it is certain, says Mr. Huygens, that too much emery remains; and therefore it must still be diminished and the operation continued. He found it best to make use of common well water in this grinding; and he took care to move the glass in circles, taking in an inch beyond the centre of the tool and somewhat beyond the outside of the tool; and he found in a glass of two hundred feet, whose diameter was 8¾ inches, which he ground in a tool of 15 inches diameter, that the figure of the tool in grinding would alter considerably, unless he carried the glass round an inch beyond the centre of the tool one way, and 3¼ inches beyond the skirts of it another way: but if he carried it no more than a straw's breadth beyond the skirts of the tool, and accordingly farther beyond the centre, the glass would always grind falsely, too much being taken off on the outsides, so that he could never after bring the outsides of the glass to a true and fine polish.

24. When you first begin to grind, and the emery begins to be smooth, the glass will stick a little to the tool and run stiff; then fresh emery is to be added. When it afterwards comes to be polished, it will, if large, require a considerable strength to move it, but this inconvenience will happen less in grinding by the pole than in grinding by hand. For the warmth of the hand makes the substance of the glass swell, and not only increases the sticking of the glass, but in some measure may also spoil the figure of it, and also of the tool. When it is ground with the pole, it never sticks very strongly, unless when you take the glass off from the tool and keep it from it for some time, and then apply it to the tool again; and this in large glasses; for by this means, says Mr. Huygens, the glass gets from the air a greater warmth than it had on the tool; and being again applied to the tool, its lower surface is suddenly contracted by the coldness of the tool, and so sticks to it. Wherefore, saith he, you must, in that case, wait till the glass, and the tool come to be of one temper. The like effect is observable in grinding large glasses when there is a fire in the room. Perhaps the cause of these effects may be more truly reduced from the attractive qualities of warm glass. But whatever is the cause, we may from hence perceive the great nicety of grinding large glasses, and the necessity there is of grinding them slowly, and with the greatest caution in the most minute circumstances.

25. The method hitherto described of grinding with emery, is what is recommended by Mr. Huygens. Le Pere Cherubin

prescribes another material, and it is the grit of a hard grindstone well beaten into a fine powder and sifted pretty fine. And here in England the same thing was used to be performed by Mr. Cox with common clean fine white sand, taking away by little and little the said grit and sand as it ground finer and finer. Nay, Mr. Cox was used to continue his grinding till the matter of the sand came to be so fine, and so little of it to remain in the tool, that he could, and frequently did use to polish off his glasses therein, without the use of any other material whatsoever; and I myself have been present, while Mr. Scarlet ground and polished, or dried off, a glass of sixteen feet in this manner. They call this way drying off on sand, because as the matter grows finer and finer, they wet it less and less, till for the last quarter of an hour (the whole work lasting near two hours) they only wet it by breathing upon it, and at the very last not at all.

26. It seems this method is now quite disused: perhaps the violent labour requisite at the last may be a reason of it. A better reason may be the great improbability of grinding or polishing true by this method, by the uncertain and unequal force of the hand, and if this be the true reason of its disuse, I cannot well see but that this method of grinding and polishing out and out in the same tool, and with the same material, viz. white sand, might perhaps be again restored, and greatly improved by adding to the old way Mr. Huygens' method of grinding and polishing with a pole and spring to press down the pole; or some analogous contrivance. And in relation to grinding by all or any of the methods above described, this one general remark must be made, that the artist must allow time and patience to bring his glass by grinding to the smoothest and finest surface that he possibly can, before he attempts to polish, For this and this only makes his glass polish truly smooth, well, and easily: and the smoother you bring it in grinding, the less labour you will have in polishing; in which consists not only the greatest difficulty, but the greatest danger too of spoiling all you have done before.

OF GIVING GLASSES THE LAST AND FINEST POLISH.

27. *M.*—Having removed the little brass plate from the glass, take, says Mr. Huygens, a very thick slate, or rather a block of blue or grey stone; let it be half an inch thick, and let it be ground true and round at the stone-cutter's; its diameter being

somewhat smaller than the diameter of your glass, leaving a hole quite through, in the centre, of about an inch diameter. Then make some cement, two parts rosin or hard pitch and one part wax; and taking a piece of thick kersey cloth, truly and equally wrought, cut this cloth round, and leave a like hole, one inch diameter, in the middle. Then warming the stone and also warming the glass, and spreading thinly and equally upon them some of this cement, lay on the cloth and thereupon lay on also the glass, having left in the middle a space the breadth of a shilling uncemented and blacked with a candle. Then provide a hollow conical plate of iron or steel (shaped like a high-crowned hat) having the basis of the cone 1 inch diameter, and having round the basis a flat border about 2½ inches diameter, and having the depth or altitude of the cone exactly of the thickness of the slate, cloth and cement, to which the glass is fixed. The vertex of this cone must go down through the slate and cloth, so that being cemented on the slate, the said vertex may approach to the glass within a hair's breadth, and lie perpendicularly over the centre of the lower surface of the glass: and this must be adjusted by the circular glass described in article 17. Within the vertex of this hollow cone, the lower point of the pole is to be applied in polishing, see fig. 6;—but it may be first proper to be observed, that perhaps fish glue and a brass plate, in lieu, and of the dimensions, of the above-said slate, may perhaps be better. Mr. Huygens observes also, that the angle of the cone should be 80 or 90 degrees, and that the hollow vertex of it should be solid enough to receive a small impression from a round steel punch, to put the point of the pole into, which might otherwise have too much liberty, and slip from the vertex. The design of the black spot in the middle of the glass, is to discover by the light of a candle obliquely reflected from your glass, after it has been polished some time, whether it be perfectly clear, and free from the appearence of any bluish colour like that of ashes.

28. Before the work of polishing is begun, it is proper to stretch an even well-wrought piece of linen over the tool, dusting thereupon some very fine tripoly. Then taking the glass in your hand, run it round 40 or 50 times thereupon; and this with chiefly take off the roughness of the glass about the border of it, which otherwise might too much wear away the lower parts of the tool, in which the glass is chiefly to obtain its last polish. If I understand Mr. Huygens right, this cloth is then to be removed, and the glass to be begun to be polished upon the very naked tool itself. But first, there is to be prepared some

very fine tripoly, and some blue vitriol, (sulphate of copper,) otherwise called Cyprian, English and Hungarian vitriol finely powdered: mix four parts of tripoly with one of vitriol: six or eight grains of this mixture (which is about the quantity of two large peas) is sufficient for a glass five inches broad. This compound powder must be wetted with about eight or ten drops of clear vinegar in the middle of the tool; and it must be mixed and softened thoroughly with a very fine small muller. Then with a coarse painting brush take great care to spread it thinly and equably upon the tool, or at least upon a much larger space in the middle of it, than the glass shall run over in the polishing. This coat must be laid on very thin (but not too thin neither) otherwise it will waste away too much in the polishing, and the tool will be apt to be furrowed thereby, and to have its figure impaired; insomuch that sometimes a new daubing thereof must be laid on, which it is not easy to do so equably as at first. This daubing must be perfectly dried by holding over it a hot clean frying pan, or a thin pan of iron, with lighted charcoal therein for that purpose; then leave all till the pool is perfectly cold. Then having some other very fine tripoly very well washed and ground with a muller, and afterwards dried and finely powdered, take some of the same, and strew it thinly and equably on the tool so prepared; then take your coarse glass which lay by you, and smooth all the said tripoly, very equably and finely: then take your glass to be polished, and wipe it thoroughly clean from all cement, grease, or other filth which may stick to it, with a clean cloth dipped in water, a little tinged with tripoly and vitriol; then taking your glass in your hand, apply it on the tool, and move it gently twice or thrice, in a straight line backwards and forwards; then take it off, and observe whether the marks of the tripoly, sticking to the glass, seem to be equably spread over the whole surface thereof; if not, it is a sign that either the tool or the glass is too warm; then you must wait a little, and try again, till you find the glass takes the tripoly every-where alike. Then you may begin boldly to polish, and there will be no great danger of spoiling the figure of the glass; which in the other case would infallibly happen. If the tool be warmer than the glass, it will touch the glass harder in the middle than towards its circumference; because the upper surface of the tool being swelled by heat, will become too flat. On the contrary, if the glass be warmer than the tool, it will bear harder towards its circumference than at the centre; because the inferior surface of the glass is contracted by the coldness of the plate, more than the superior.

29. Mr. Huygens says, that if the work of polishing were to be performed by strength of hand, it would be a work of very great labour, and even could not be performed in glasses of five or six feet focal distance: and he seems to think it absolutely necessary that an extraordinary great force or pressure should be applied upon the glass. For this purpose he has therefore contrived and described two methods for sufficiently increasing the pressure; for the explanation of which, recourse must be had to his directions, [for which, see article 35, &c.;] it may suffice here to say, that they chiefly consist in applying the force of a strong spring to press down the centre of the glass upon the polisher.

30. This operation of polishing, as it is one of the most difficult and nice points of the whole, has been very variously attempted and described by various authors; Sir Isaac Newton, Pere Cherubin, Mr. Huygens, and the common glass-grinders, have taken different methods in this matter. Sir Isaac is the only person who seems not to insist on the necessity of a very violent and strong pressure. In the English 8vo. edition of his Optics, page 95, he has these words: "An object-glass of a fourteen-foot telescope, made by an artificer at London, I once mended considerably, by grinding it on pitch with putty, and leaning very easily on it in the grinding, lest the putty should scratch it. Whether this may not do well enough for polishing these reflecting glasses, I have not yet tried. But he that shall try either this or any other way of polishing which he may think better, may do well to make his glasses ready for polishing by grinding them without that violence, wherewith our London workmen press their glasses in grinding. For by such violent pressure, glasses are apt to bend a little in the grinding, and such bending will certainly spoil their figure."

31. As to his own method of polishing glass, I do not know that he any-where expressly describes it, but his method of polishing reflecting metals he doth, and it was thus in his own words, page 92: "The polish I used was in this manner, I had two round copper plates, each six inches in diameter; the one convex, the other concave, ground very true to one another. On the convex I ground the object-metal, or concave, which was to be polished, till it had taken the figure of the convex, and was ready for a polish. Then I pitched over the convex very thinly, by dropping melted pitch upon it, and warming it to keep the pitch soft, whilst I ground it with the concave copper wetted to make it spread evenly all over the convex. Thus by working it well, I made it as thin as a groat, and after the

convex was cold I ground it again, to give it as true a figure as I could. Then I took putty, which I made very fine by washing it from all its grosser particles, and laying a little of this upon the pitch, I ground it upon the pitch with the concave copper till it had done making a noise; and then upon the pitch I ground the object-metal with a brisk motion for about two or three minutes of time, leaning hard upon it. Then I put fresh putty upon the pitch, and ground it again till it had done making a noise, and afterwards ground the object-metal upon it as before. And this work I repeated till the metal was polished, grinding it the last time with all my strength for a good while together, and frequently breathing upon the pitch to keep it moist, without laying on any more fresh putty. The object-metal was two inches broad, and about one-third part of an inch thick, to keep it from bending. I had two of these metals, and when I had polished them both, I tried which was best, and ground the other again, to see if I could make it better than that which I kept. And thus by many trials I learned the way of polishing, till I made those two reflecting perspectives I spake of above. For this art of polishing will be better learned by repeated practice than by my description. Before I ground the object-metal on the pitch, I always ground the putty on it with the concave copper till it had done making a noise, because if the particles of the putty were not by this means made to stick fast in the pitch, they would, by rolling up and down, grate and fret the object-metal, and fill it full of little holes. It seems not improbable but that glass may also be polished with proper care by the same method."

32. The method of polishing described by Pere Cherubin seems to be chiefly thus: he polishes with tripoly or putty, or first with tripoly, and afterwards with putty. But what he seems most to approve of, is putty alone. He polishes in the same tool he grinds in, and he very verbosely describes various ways of doing it. He prescribes to stretch very tight a very fine thin leather or fine English fustian, or fine holland, or any fine linen, or fine silk, taffety or satin, all of an equable thickness as near as may be, upon the tool; then he daubs thinly on this surface, thus stretched, a streak of putty, sufficiently wetted, to the consistence of thick syrup, about as broad as the glass or a little more, passing through the centre of the tool directly from him; then smoothing the putty by running his bruiser and pressing it backwards and forwards to him and from him, he at length lays on the glass cemented to its handle; and giving it always the same motion, strongly pressing to him

and from him along the streak of putty, and by such pressure forcing the surface of the silk, already somewhat stretched, close to the surface of the tool, to which the figure of the glass was exactly adapted; he says, that he could by that means obtain an excellent fine polish on any of the above-mentioned substances. Before every stroke, he turned the glass a little on its axis, and its handle was on this occasion considerably heavier than usual in grinding, which he commends as very useful in this business; and if new putty was wanting he made no difficulty of laying it on, as often as necessary, always carefully smoothing it thereon, with the bruiser, before the glass was applied.

33. This method I am of opinion might be improved by moving the glass, not by hand, but by the pole and spring, somewhat after the method of Mr. Huygens, especially if the pole were contrived not to move loose in a round brass hole above, but on a strong point pressed down by some spring; the length of the pole being equal to the radius of the tool, and the point where the spring presses the upper end of the pole, being truly perpendicular over the centre of the tool, and exactly in the centre of its sphere.

34. Another method which the same author prescribes for polishing in the tool is thus: he takes a sheet of very fine paper, and examining it very carefully by looking upon it and through it, he takes off with a fine penknife all the little lumps, hard parts, roughnesses, and inequalities, that he can find: then he soaks it in clean water, then he takes and dries it between two clean linen cloths, though not so much as to make it quite dry, but to leave it dampish; then with some very thin starch or paste, he daubs equably all over the surface of his tool as thin as possible, but some every-where; then he lays on his paper very gently and slowly, letting it touch and stick first at one side, and by degrees more and more towards the middle, and by degrees to cover the whole: and he does this slowly, to let all the air go out; then with the palm of his hand he presses the centre and every-where round about it towards the circumference to make the paper stick every-where; and this he does three or four times while it is drying to get out all the air; he lets it dry of itself, then he revises it again with his knife as before; then he has a very coarse bruiser of glass, whose circumference is sharply ground round and at right angles to its surface, which he had coarsely ground before in the same tool; with this, and a very heavy handle, he smooths and polishes, and rubs off all the remaining inequalities of the

paper, and when this is done he lays on a streak of tripoly, and polishes, as in his own method.

35. *H.*—At CC, plate LXXXIII, fig. 7, is represented a square beam of wood, a little longer than the diameter of the tool, and about 1½ inch thick; the two extremities of it, at C and C, are bent downwards, and then are again directed parallel to the whole length, and serve for handles for the workmen to lay hold upon. In the middle of this beam there is fixed an iron spike, so long that when the lower surfaces of the handles CC are placed upon a plane, the point of the spike shall just touch the plane. This point presses upon the apex of the hollow cone, which descends through the hole in the slate, which by the interposition of a cloth was cemented to the glass B lying upon the tool A. To increase this pressure, a sort of a bow DED is shaped out of a deal board, half an inch thick and five feet long, being seven inches broad in the middle, and tapered narrower towards its extremities, so as to end almost in a sharp point. The middle of the bow is fixed to the floor by an iron staple at E driven across it; and is bent into an arch by a rope FIIF; to which two other ropes are tied at I and I; the interval II being equal to the length of the beam CC. One of these ropes, ICCG, goes over the back of the beam CC, passing through a hole in each handle at C and C, and then is lapped round a cylindrical peg at G, that passes through two wooden chaps, to the bottom of which the other rope is tied that comes from the other I. So that by turning the peg G, to lap the rope about it, the bow DD may be bent as much as you please. The tool A is placed upon a strong square board fixed to the table O on one side, and supported on the other side by the post P. Then the workman sits down, and taking hold of the handles CC, he draws the glass to him and from him over the tool A, with a moderate motion. And after every twenty or twenty-four strokes, he turns the glass a little about its axis. This way of polishing took up two or three hours, and was very laborious as well as tedious, because the glass being so much pressed downwards was moved very slowly.

36. Instead of the bow DD, afterwards I invented another spring; by sloping the flat ends of a couple of deal boards $\alpha\beta$, $\alpha\gamma$, fig. 8, and by nailing the flat slopes together very firmly, that the boards might make an acute angle $\beta\alpha\gamma$. One of these boards so joined, was laid upon the floor under the polishing table, the ends $\beta\gamma$ being under the middle of the tool A, fig. 7; so that they lay quite out of the way of the workman, who before was a

little incommoded by the ends of the bow DD. The boards at the end α, fig. 8, were eight or ten inches broad, and from thence went tapering almost to a point at β and γ. The board $\alpha\,\gamma$ lying upon the floor, the end β, of the upper board, was pulled downwards by a rope $\beta\,\epsilon\,\zeta$ that passed under a pulley ϵ, fixed to the floor, and then was lapped round a strong peg ζ that turned stiff in a hole in the floor. Under the end γ the middle of a strong stick $\delta\,\gamma\,\delta$ was fixed at right angles to the board $\alpha\,\gamma$, and cords were tied to each end of this stick at $\delta\,\delta$, which went over the polishing beam CC, as in the former machine. This stick was lifted up but very little from the floor at the time of polishing; and by consequence the ropes δ C, δ C, were long enough to give liberty of motion to the polishing beam CC. Two iron pins $\theta\,\theta$, passing through the ends of the boards at α, were screwed into the floor, but the heads of the pins stood up above the boards, to give them liberty to rise up, when the rope $\beta\,\epsilon\,\zeta$ was stretched.

37. To facilitate the labour of moving the glass backwards and forwards in the tool, I made this addition to the former machine. At M, fig. 7, is represented a strong hand made of wood or iron, having a square cavity cut through the bottom of it, for the polishing beam CC to pass through, not tight, but with some liberty. To one side of this hand M, a long board LL is annexed, some way or other, by means of an iron bolt. The breadth of the lower surface of this board LL is equal to the breadth of the hand M, being two inches and a half; its thickness is half an inch and its length is equal to three semi-diameters of the tool The board LL must be drawn lengthways backward and forward over a block H, fixed firmly to a table O; the thickness of the block being such that the board LL may lie an inch higher than the surface of the tool A. The wooden hooks at Π, and the pins at Σ, keep the motion of the board in the same direction, by hindering it from slipping either sideways or upwards. Over this board, at right angles to it, and over the middle of the block H, there lies a wooden roller, having a strong iron axis which turns in the holes of two iron plates fixed to the ends of the block. The thickness of the roller is about an inch and a half. Through two holes bored through this roller, and made wider at one of them, two strong cords are made to pass with knots at one end of them, to be drawn into the wider parts of the holes, that they may neither slip through nor stand out from the roller. Then each cord is lapped round the cylinder several times; and one end of each is pegged firmly into the board LL, at the end towards M, and

the other ends of them are lapped round a peg at N; which being turned round, will stretch the cords as much as you please. At one end of the axis of this roller there is a handle Q, which being turned round, backwards and forwards alternately, the board LL, with the glass annexed to it, is moved to and fro, so far, that about a third part of its diameter shoots both ways over the margin of the tool. The spike in the middle of the beam CC presses the glass a little obliquely, because the hand M holds the beam CC not tight but somewhat loosely, to the end that the glass may pass over the tool without trembling. Nevertheless this inclination of the spike must be but very small; and may easily be increased or diminished several ways. Two pins or stops must be fixed to the under surface of the board LL, to determine the length of the stroke. The tool A, or rather the stone to which it is cemented, is squeezed fast between the block H and a strong stop on the opposite side of the stone, by the interposition of a wedge. The workman sits upon a round stool, and when one hand is tired with turning the roller, he applies the other; and therefore is not tired so soon as with the other machine, which required both hands, and also a reciprocating motion of his whole body. Sometime after, I caused a longer handle Q *a* to be made, that turned at both ends, for the convenience of using both hands at once.

38. After every twenty or twenty-four strokes, it is necessary to give the glass a small turn about its axis; which is easily done by laying hold of the slate, fixed to it, with one hand, while the other hand goes on with the polishing motion. The tool must also be moved a little after every twenty-five or fifty strokes, by drawing it half a straw's breadth towards that part of it which the glass has left; and by drawing it back again after as many more strokes. At the beginning of the work, the tripoly will be gathered into little lumps in some places of the tool, but will be dispersed again in a little time; and then the area of the tool will become perfectly smooth.

39. If the tripoly does not appear to stick equally to the glass in all parts, and to be diffused over it in slender straight streaks, the frying-pan, with coals in it, must be held over the tool again; till you perceive the area or coat of tripoly is not quite so cold as the other parts of the tool. Then let tripoly be rubbed upon the tool again, and let the glass be pressed over it with your hand, to try whether it sticks equally to the glass in the very place. When it does, you may proceed in the work of polishing. But after I began to make use of vitriol

instead of verdigris, all that I have said about warming the tool may be omitted. Because these coats always touch the glass as they should do, and stick better than before. Also let the tool be rubbed with tripoly over the coat without warming the tool, that the coat may be preserved more entire, and that the glass may touch it better; which must always be repeated after 200 or 400 strokes in polishing. The glass should also be taken from the tool after 200 strokes, by withdrawing the bolt L which connects the hand M to the board LL; and by removing the beam CC. Then rub your finger upon the glass, or a clean rag or a bit of leather, to examine how much it is polished.

40. To save the trouble of counting the strokes, there is a wooden wheel △X, fig. 7, seven or eight inches broad, placed flat against a board, fixed to the side of a wall. It turns easily about an axis, and has twenty-four teeth, like those of a saw, which are pushed round by a bended wire TYX, in this manner. The wire turns about a centre Y, and while one end of it is pulled by the string TV, tied to the end of the board LL, the opposite end YX pushes back a long spring RS fixed to the board at R; which by pressing upon the wire at S causes the part YX to bend a little, and so the point X, in returning to the wheel (the string being relaxed) falls a little lower, into the next tooth, and pushes it forward into the position represented in the figure. There is a springing catch at △ which stays the wheel, after every stroke at X. Lastly, there is a pin fixed in the circumference of the wheel at Z, which by pressing the tail of a hammer, and letting it go again, causes a bell to sound after every revolution of the wheel, and gives notice that the glass must be turned a little about its centre. It is easy to understand, that another piece of wheel-work, having three or four indexes, whose revolutions are in decimal progression, may be fixed to the block H and impelled by the strokes of the board LL; by which means, without any trouble of counting, one may be informed how many strokes go to polish a glass.

41. A glass five or six inches broad, requires about 3000 strokes, upon each surface, to bring it to perfection. And you must carefully examine the middle of the glass opposite to the blacking, whether any place appears darkish or of an ash-colour; or whether any small spots appear by an oblique reflection of the light of a candle, or of a small beam of light let into a dark room. For the other parts of the glass will appear perfectly fine much sooner than the middle.

42. After the glass has been sufficiently polished, let the stone, the cloth, and the cement, be warmed over a pan of charcoal, till the cement grows so soft that the glass may be separated from it by a side motion. Then whatever cement remains upon the glass, must be wiped off with a hot cloth dipped in oil or tallow, and last of all with cleaner cloths. Then if it does not appear perfectly polished (for we are often deceived in this point) the work must be repeated again, by gluing the glass to the slate as before; then it must be wiped very clean, and be made a little rough, as we said before. We may also lay a new fund or coat upon the tool if the old one be spoiled; provided no other glass has been polished in the tool in the mean time. The old fund may be washed off from the tool with a little vinegar. Lastly, take care always to chuse the thickest and the clearest pieces of glass, to avoid a great many difficulties that arise from the unequal pressure in polishing.

ESSAY II.

A Method of Working the Object-glasses of Refracting Telescopes truly spherical.

This essay was written by an optician of the first repute in his day. It was delivered by himself to the Royal Society, sealed up, with an injunction that it was not to be opened till after his decease. This condition being complied with, it was, on being communicated to the public, almost twenty years afterwards, found to be as follows:

43. Prepare two plates or tools of brass, the one convex and the other concave, being both portions of a sphere of the same radius as the focal length of the object-glass you want to have, or rather of a radius somewhat longer than the focal length you want, for a dioptrical reason; let these plates or tools be between two and three times the breadth of the object-glass desired; or, in long focal lengths, twice the breadth will be sufficient. Let these tools be of a sufficient thickness in proportion to their breadth or diameter, and let them be ground with fine emery exactly true to one another, working them

alternately, the one above the other, to preserve the same focal length; or if it is desired longer, you must work the convex above the concave; or if desired shorter, you must grind the concave above the convex.

44. After this, you prepare another brass plate or tool, of the same breadth and thickness as the two former, and of the same radius of concavity; its being truly turned on a lathe will be sufficient for this purpose; which tool is to serve afterwards for the polishing of the two surfaces of your object-glass, and therefore called the *polishing tool.*

45. Prepare a piece of straw-coloured glass of the plate-glass kind, of the proper diameter for the object-glass you desire, which ought always to be broader than the proper aperture for that length. Let this piece of glass be ground flat, in another tool, on both sides, and as nearly parallel as may be, and somewhat polished in order to discover whether there are any veins or flaws in the glass, When you are satisfied of the goodness of the glass, you are then to prepare a handle to fasten your glass to. Great care must be taken in this, for fear of bending your glass by the handle; my method is this: I take a flat piece of brass, or rather of the concavity of the sphere, to which the glass is to be ground; this piece of brass should not be thicker than two-thirds of the thickness of the glass, of a circular form, less in breadth somewhat than the glass itself, and having sides of the same form, at right angles to the flat piece of brass, and these sides ought to be of such a shape as that the fingers may easily apply to it in working, and these sides should be as low as may conveniently be, and no thicker than about two-thirds of the glass. This handle is to be fastened to the glass, by warming the glass and handle gently before a fire, and laying some pitch upon the glass thus warmed, till it becomes soft like melted wax; and then laying your brass handle, a little heated, on the pitch, you press it a little, till you are sure there is nothing between the glass and handle but pitch. You then lay down the glass and handle upon something flat, taking care that the handle is in the middle of the glass, till it is entirely cold. It is very material to know, that the pitch, to be used for fastening the handle to the glass, must be soft pitch, that has never been used, nor melted; for any other pitch will infallibly bend the glass.

46. You then grind your glass in the concave tool with emery, and give it the proper figure and smoothing, for the last polish, in the common manner.

47. In order to give your glass the last polish, which is the most difficult part of the whole work, you are to prepare some pitch for covering the before-mentioned polishing concave tool; which is done in this manner: Take some pitch, and melt it in an iron ladle, and let it boil for a quarter of an hour or thereabouts; by this boiling, the pitch, when cold, will become hard and brittle; or you may shorten this operation, by melting equal quantities of pitch and rosin, and then there is no occasion to let it boil so long. Your pitch being thus prepared, you again melt it, and take it off the fire, and let it stand till the pitch becomes pretty cold, or of a thickish consistence; and having warmed the polishing tool a little, to make the pitch stick to it, you pour out of the ladle upon the polishing tool as much of the pitch as you judge will cover the whole tool, when spread out, to about the thickness of one-eighth of an inch; you then invert this tool with the pitch upon it, and press it upon the convex tool, which must be quite dry, clean, and cold, in order to give it the figure of the convex tool. In case it has not spread out so as to cover the whole surface of the polishing tool, you warm the pitch by holding it before the fire, and pressing it upon the convex tool, as before, till it has entirely covered the surface of the polishing tool; you then plunge it into cold water, till the brass is quite cold.

48. In order to know if your pitch is hard enough, you press the edge of the nail of your thumb upon it, and if it receives an impression, the pitch is not hard enough.

49. You then proceed to prepare this polishing tool, for the last polish of your glass, by grinding this polishing tool upon the convex tool with pretty coarse emery, and a small quantity of water, in the common way that tools are ground one upon another; but this must be done only for a small space of time, and the polishing tool must have no other pressure than its own weight, for fear of some of the emery sticking in the pitch, and you must never allow the emery to grow dry. When you have ground the pitch, so as to be all over of the same colour, you then wash the pitch from all the emery with a brush and clean water: after this you take a bottle of water, and holding the pitch tool in a sloping position, you pour water out of the bottle so as to fall upon every part of its surface.

50. You then place the polishing tool in a horizontal position, and you put upon it some putty, washed from all its gritty particles, but it need not be the finest washing, and you put

a good deal of water upon your polishing tool, mixing the putty and it together, and you polish your glass upon this pitch polisher in the common manner of polishing glasses.

51. After you have polished your glass about ten minutes, you again grind your polisher upon the convex tool with emery, as before, for fear the pitch has, by working, lost any of its proper figure; and the oftener you do this, the truer will be the figure of your glass; and in this manner you proceed till the glass is quite polished.

62. You then take your glass off its handle, by holding it before the fire, till it is so warm that you can slide the handle off the glass; and whilst the glass is warm, you take off as much of the pitch as you can with the sharp edge of a knife; you then lay the glass down to cool, and, when quite cold, you drop some spirts of wine upon it; and this, with a cloth, will wipe off the rest of the pitch.

53. You then examine the centre of the surfaces of your glass; and if it lies to one side of the centre of your glass, mark that place with a spot of ink, and then put on your handle as before, upon the side that is now polished, with its centre over the spot of ink, and grind your glass as before, till the circular remaining part of the glass to be ground is as much distant from the centre of the glass on the other side from the spot, as the spot was from the centre of your glass; you then by heat return your handle to the centre of the glass, and proceed to grind and polish this side of the glass as before.

54. The concave and convex tools should be ground with fine emery, after you have done one side of your glass; for the oftener these are ground together, you will be the more sure of having your figure true.

ESSAY III.

The Method of Casting, Grinding, and Polishing Mirrors for Telescopes.

It is chiefly to the invention of telescopes that we owe all the late discoveries, and most of the present accuracy in astronomy. An invention which certainly, in its first original, was put in practice by an Englishman, Friar Bacon; although its first application to astronomical purposes, may be justly attributed to Galileo. The greatest improvement, which this invention has ever received, is indisputably and singly owing to Sir Isaac Newton; to whose extraordinary sagacity, and very judicious experiments, the world first owes the discovery of the different refrangibility of the rays of light, and the insuperable difficulties arising from thence in perfecting any refracting telescope. This led him to the practice of making telescopes by reflection; which having attempted with his own hands, he perfected some of six inches length about the year 1670. Whosoever, therefore, would thoroughly understand the method of making these telescopes, will find it very proper, in the first place, to peruse, and thoroughly consider, the account which the celebrated author of this invention hath himself given of it in his writings; which are to be met with in the philosophical Transactions, No. 80, 81, 82, 83, 88, 96, 97; and in his Treatise of Light and Colours, beginning at the 89th page of the English 8vo. edition. It will be necessary here, to note an error of the printer in this 89th page; where it is said, "that the apertures of the object-glasses, and the charges and magnifying powers, ought to be as the cubes of the square roots of the lengths of the telescopes;" the word *square* is falsely printed; it should be, as the cubes of the square-square roots of the lengths.

55. As great an improvement as this was to telescopes, I do not find that it was ever effectually prosecuted from that time till about the year 1719 or 20; when a very ingenious gentleman, Mr. Hadley of Essex, attempted it, and succeeded very well in making two instruments of this kind, of about five feet three inches long; one of which he has been pleased to give to the Royal Society. A very particular and curious description of this instrument, and the apparatus for managing thereof, hath been given by Mr. Hadley, with a figure of it also, in the Philosophical Transactions for the months of March and April, 1723, No. 376. It will be necessary for any person that would attempt to make this instrument, to consider that account given by Mr. Hadley; for although he gives therein no account of the manner of casting, grinding, and polishing the specula, yet as to the proportion and composition of the different parts of the instruments, and of the apparatus for moving it, the reader will there find several useful instructions. What is contained in the following papers, is also chiefly owing to the communicative genius of that gentleman; and had he ever given himself the trouble to reduce to writ-

ing what he knows, and hath practised in the above-mentioned particulars, as to the construction of this instrument, the following account had been altogether unnecessary. Upon his encouragement and instructions, the Rev. Mr. James Bradley, Professor of Astronomy in Oxford, attempted the same about three years ago; and having succeeded pretty well, would probably have perfected one of them, had he not been obliged suddenly to remove from the place where he then dwelt, and been since diverted from it by other avocations. Soon after this, Mr. Bradley and I began our endeavours at Kew to perform the same, and our first attempt was to make them about twenty-six inches long. Notwithstanding Mr. Bradley's former trials, and Mr. Hadley's frequent instructions, we were a long while before we could tolerably succeed. The first good one that we finished, was in May, 1724, of the aforesaid length of twenty-six inches. I have since made a pretty good one of about seven inches, and we are now about one of eight feet.

56. The main drift of all our trials hath been, if possible, to reduce the method of making these instruments to some degree of certainty and ease: to the intent that the difficulty in making them, and the danger in miscarrying, might no longer discourage any workman from attempting the same for public sale; which nobody but Mr. Hauksbee, in Crane-court, hath ever ventured upon. He hath made a good one of about 3½ feet, and is now about one of six feet, and another of twelve feet, and deserves very well to be encouraged, being the first person who hath attempted it without the assistance of a fortune which could well bear the disappointment. About the beginning of the last winter, being pretty well satisfied as to most of the circumstances in this performance, and being desirous that these instruments might become cheap and of public sale, we acquainted Mr. Scarlet, near St. Anne's Church, and Mr. Hearne, a mathematical instrument-maker, in Dogwell-court, White-Friars, with the whole process of the operation as we had practised the same; and they have since succeeded in making these instruments. However, as they are not yet become so common, so cheap, and so universally made and used, as one would wish an instrument of this nature to be, we have been encouraged to give this following account, for the general information of all persons who would make the same for their own use or for sale.

57. Having in the first place considered of what length one would propose the instrument to be, and consequently what diameter it will be necessary to give to the large speculum, for

which there are ample instructions by Sir Isaac Newton's table in the Philosophical Transactions aforesaid, allowing about an inch more than the aperture in the table for the false figure of the edges, which very often happens; I say, having determined these things, take a long pole of fir, deal, or any wood, of a little more than double the length of the instrument intended, and strike through each end of it two small steel points, and by one of them hang up the same against a wall perpendicularly; then take two pieces of thin plate brass well hammered, a little thicker than a sixpence; these may be about an inch and a half broad, and let their length be in respect of the diameter of the speculum, as three to two; viz. if the speculum be eight inches diameter, these may be about twelve. Fix each of these strongly with rivets between two thin bits of wainscot, so that a little more than a quarter of an inch in the breadth, may stand out from between the boards. Then fix up their pieces horizontally against the wall under your pole, and therewith, as with a beam compass, strike an arch upon each of them; then file each of them with a smooth file to the arch struck, so as one may be a convex and the other a concave arch of the same circle. These brasses are the guages to keep the speculum, and the tools on which it is ground, always to the same sphere. And that they may be therefore perfectly true to each other, it is necessary to grind them with fine emery one against the other, laying them on a flat table for that purpose, and fixing one of them to the table.

58. When the guages are perfectly true, let a piece of wood be turned about two-tenths of an inch broader than the intended speculum, and somewhat thicker, which it is best to cast in no case less than two-tenths of an inch thick, and for specula of six, eight, or ten, inches broad, this should be at least three or four tenths thick when finished.* This board being turned, take some common pewter, and mix with it about one-tenth of regulus of antimony, and with that wooden pattern cast one of this pewter, which will be considerably harder than common pewter. Let this pewter pattern be truly turned in a lathe, and examined by means of the guages aforesaid, as a pattern for casting the specula themselves; and take care when it is

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* The metal of my reflecting telescope, made by that excellent workman Mr. Hearne, in Dogwell Court, White Friars, by Fleet-street, is six inches broad, and between six and seven tenths thick; besides a brass plate soldered to its back, an inch and a half broad, with four holes in it to fix a short handle to it, mentioned in article 99, having also a socket in the middle, to screw in another handle when finished. Its focal distance is five feet.

turned that it be at least one-twentieth of an inch thicker, and about one-tenth of an inch broader than the speculum intended to be cast therefrom.

59. The manner of making the moulds for casting is now to be explained, and will serve for a direction as well for casting this pewter pattern, as afterwards for casting thereby the speculum itself. The flasks had best be of iron, and must be at least two inches wider every way, than the speculum intended. In each flask there should be the thickness, at least, of one inch of sand. The casting sand which the common founders use from Highgate, will do as well as any; and any sand will do which is naturally mixed with a small proportion of clay, to make it stick. The sand should be as little wet as may be, and well beaten, but not too hard. The ingates should be cut so as to let the metal flow in, in four or five streams over the whole upper part of the mould; otherwise, whatever pores happen in the metal, will not be so equally dispersed as they should be over the whole face of the metal; these pores generally falling near the ingate streams. Let the flasks dry in the sun for some hours, or near a very gentle fire, otherwise they will warp, and give the speculum, when cast, a wrong figure. For besides saving the trouble in grinding, it is best on many accounts to have the speculum cast of a true figure; and it is for this reason, that it is best to cast it from a hard pewter pattern, and not from a wooden one as founders usually cast.

60. The next point that is to be considered is, the composition or ingredients of the metal itself for the specula. As to this, it may be said in general, that any hard white metal that will take a polish, will do more or less well. We have made trials of above 150 different mixtures, and found none of them entirely free from all faults. Three parts of copper, and one part and a quarter of tin, will make a very hard white metal, but it is very liable to be more porous than it should be, especially if the metal be too much heated in melting. Six parts of good shruff brass* and one part of tin, will make a whiter and harder metal; but the fume of the calamine stone in brass, leaves very often streaks of scabrous parts in the surface of the metal; which, if many, utterly spoil it. Take two parts of the former mixed metal of copper and tin, and one part of the latter brass and tin, this also will make a good metal; let the copper and the brass be first melted together, and keep them in fusion for half an hour or more; then clear the pot, and put

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* Plate-brass, cast and milled; the best comes from Hamburg.

in the proper quantity of tin for both; which will instantly melt; stir it well about, and pour it off immediately. This mixture may be melted over and over again, in case of necessity, provided always care be taken that the fire is not suffered to be too violent. A common bellows furnace has been found most convenient for governing the fire, and some metals have succeeded which have been cast by a common brass-founder in their ordinary way of casting; the composition having been first made and melted together for the speculum, and delivered to them only for casting. There hath been tried also another mixture, and another manner for casting, which succeeded better than any of the above-mentioned: it was copper, silver, regulus of antimony, tin, and arsenic; and the metal was cast in very hot moulds of brass; but as this method is very expensive, and will never become common, it need be no further insisted upon in this place.

61. The metal being duly cast, grind the surface of it quite bright upon a common grindstone; keeping it by means of your convex gauge as near to your intended figure as may be. When all the outward surface, and all the sand-holes, and false parts, and inequalities are ground off, then provide a good thick stone; a common small grinding stone will do very well. Let its diameter be to the diameter of the speculum as six to five. With another coarse stone, and sharp sand or coarse emery, rub this stone till it fits the concave gauge; and then with water and coarse emery at first, and afterwards with finer, rub your speculum upon this stone until it forms itself into a true portion of a sphere fitting your convex gauge. A different manner of moving the metal upon the stone, will incline it to form itself somewhat of a smaller or larger sphere. If it be struck round and round, after the manner of glass-grinders, the stone will wear off at the outsides, and the metal will form itself into a portion of a less sphere. If it be struck across and across the middle, it will flat the stone, and become somewhat of a larger sphere. There should be used but very little emery at a time, and often changed; otherwise the metal will always be of a smaller sphere than the stone, and will hardly take a true figure, especially at the outside. For the better grinding the metal, it is necessary that this stone should be placed firm on a strong round board, fixed firmly on a post to the floor, as is usual with glass-grinders, and the same table or pillar will serve for the further grinding and polishing the speculum.

62. When the metal is cast and rough figured (which should be done with taking off as little of the surface of the

metal as is possible, because that crust seems to be generally harder and more solid than the inner parts,) the sides and back of it should be smoothed and finished; lest the doing that afterward, should make the metal cast, and spoil the figure of the aforesaid.

63. A round brass plate must be cast of sufficient breadth and thickness; (for a speculum six inches diameter I used a plate eight or nine inches broad, and half an inch thick.) Let one side be turned to the concavity you design your speculum should have; on the other side let it have such a handle fastened as may make it easily manageable. This handle should be as short as conveniently it can, and fixed to the plate's back rather by some other manner than either by screwing it into a hole in the metal, or by a broad shoulder screwed against the back of it, for fear of bending the plate.

64. Have ready a round marble about one-eighth or one-tenth part broader than the brass plate, and an inch or inch and a quarter thick; let this be cut by a stone-cutter to the same convexity on one side as the concavity of the plate; and then grind it with the plate and emery till all the marks of the chisel are out. This marble is to be covered with pieces of the finest blue hone or whetstone, chusing those that are nearest of a breadth and thickness, but chiefly those that when wetted appear most even and uniform in their colour and grain. They are to be cut into square bits, and these, having each one side ground concave on the convex marble with emery or fine sand, are to be fixed close down on it with some tough and strong cement in the manner of a pavement, leaving a space of a small straw's breadth between each; their grain being likewise placed in an alternate direction, as represented in fig. 12, plate LXXXIII. I choose rather to disperse the squares that come out of the same whetstone to a distance from one another, than to place them together. They must ther be reduced to one common convex surface to fit the brass plate; and if the cement happen to rise any-where between them, so as to come up even with their surface, it must be dug out; and so from time to time, as often as the hones wear down to it. Upon these square pieces of whetstone, the last figure is to be given to the speculum.

65. Besides these, there will be wanted for the last polish, either a very thick round glass plate, (its diameter being about the middle size between that of the brass tool and that of the speculum itself,) or if that cannot be procured of near half an inch in thickness, I imagine a piece of true black marble, of the evenest grain and freest from white veins or threads, may do

in its stead. This glass or marble must be figured on one side to the brass tool likewise, and is to serve for the finishing the polish of the speculum, when covered with sarcenet, as shall be directed.

66. A smaller brass or metal plate, of the same concavity with the larger, will be useful, as well to help to reduce the figure of the hones, whenever it appears to be too convex, as to serve for a bruiser to rub down any gritty matter happening to be amongst your putty, before you put the speculum on the polisher, when you renew the powder. Any of the speculums which prove bad in casting will serve for this purpose.

67. When all is thus far ready, let the marble with the blue hones be fixed in such manner, that it may be often washed during your work, by throwing on it about one-eighth of a pint of water at a time, without inconvenience. Then place the brass tool on the hone pavement, and rub it backwards and forwards with almost a direct motion; yet carrying it by turns a little to the right and left, so as to go a little over the edges of the pavement every way, regularly turning the tool on its own axis, and also changing the direction of the stroke on the hones. This continue, keeping them always very wet, till you have got out all the rings remaining in the plate from the turning, and the blackness from grinding the marble or glass in it: and towards the latter end often washing away the mud which comes from the whetstones.

68. When this is done, lay the brass tool down, and in it grind again, with fine emery, the glass or marble designed for the last polisher, giving it as true a figure as you can; in order to which you may observe the directions already given for grinding glasses; see art 19, &c. But give it no further polish.

69. Chuse a piece of fine sarcenet, as free from rows and great threads as you can. Let it be three or four inches broader than the glass or marble; and turn down the edges of the sarcenet round the sides of the glass, &c. and strain it by lacing it on the back side as tight and smooth as you can, having first cleared it of all wrinkles and folds with a smooth-iron, and drawn out the knots and gouty threads. Then wet it all over as evenly as you can with a pretty strong solution of common pitch in spirit of wine; and when the spirit is dried out repeat the same, and if any bubbles or blisters appear under the sarcenet, endeavour to let them out with the point of a needle. This must be repeated till the silk is not only stuck every-where firmly down to the glass or marble, but is quite filled with the

pitch. A large painter's pencil, made of squirrels' hair, is of use for the spreading this varnish equally on the silk, especially when it begins to be full. It must then be set by for some days, for the spirit to dry well out of it, and the pitch to harden, before any thing more be done to it. If you do not care to wait so long, the pitch may be melted into the silk without dissolving it in spirits. In order to this, strain a second thin silk over the first; but you need not be curious in the choice of it, and having heated all together as hot as you think the silk or glass will safely bear, pour on it a little melted pitch (first strained through a rag) so much as you judge sufficient to fill both silks; it must be kept hot some time till the pitch seems to have spread itself evenly all over. If you find you cannot get it to sink all into the upper silk, but it stands above it any-where, it is a sign there was too much pitch laid on, which should be taken away in those places while it remains liquid, with a hot rag pressed down on it. When all is cold again, strip off the outward silk, and cut away the useless loose edges of the inward. To take off the superfluous pitch where it lies too thick, and reduce the whole to a regular surface, it must be rubbed in the brass tool with a little soap and water, till they are coloured of a pretty deep brown with the pitch: then wash them away, and repeat the same with more soap and water, till the weaving of the silk appears every-where as equally as you can make it. As this work takes up some time, you may expedite it by putting a few drops of spirits of wine to the soap and water, which will help them to dissolve and wear away the pitch something faster, till it comes towards a conclusion; and if there are any places where the pitch lies very thick, you may scrape it away with a sharp knife.

70. This polisher must be carefully kept from all dust and grit, but particularly from emery and filings of hard metals; and therefore should not be used in the place where the others come. After they have served a good while they are more apt to sleek the metals than at first; to prevent which their surfaces may be taken off by rubbing them with soap and water in the tool as before, and then striking them once or twice over with the before-mentioned solution of pitch with a pencil, proceeding as before, only that you must not new put any spirit to your soap and water, nor will you need to change them above once or twice.

71. You may now begin to give the figure to your speculum on the hones, rubbing it and the brass tool on them by turns, till both are all over equally bright; having first fixed on to the

middle of the back of your speculum, a small and low handle with only pitch strained through a rag. For of all cements, that seems the last apt to bend the metals in sticking these handles, &c. on them.

72. The polisher being fixed likewise in a proper manner for your work, rub either the metal itself, or rather the before-mentioned bruiser, being first also figured on the hones, with a little putty washed very fine, and fair water; till it begins to show some polish. Then if you find it takes the polish unequally, that is, more or less about the edges than in the middle, it is a sign the brass tool and metal, &c. are more or less concave than to answer the convexity of the polisher; and must be reduced to the curvature of this, rather than to attempt an alteration in the figure of the polisher; which would be a much more difficult as well as laborious work. If the speculum appears too flat, the larger brass tool must be worked on the hones for some time, keeping its centre near their circumference, with a circular motion; but concluding for four or five minutes with such a motion as was before described.* Then figure the metal anew to the hones, and try it again on the polisher as before. If the metal be too concave, the surface of the hones may be flatted by rubbing the smaller brass plate, or the before-mentioned ill-cast metal, on the middle of them; with a direct but short stroke, so as but just to reach over their circumference with the edge of it. Then the larger brass is to be worked on them in the same manner; and last of all the metal to be polished. When you find the brass tool and hones, &c. answer the curvature of the polisher, you may then examine the truth of the figure of the speculum more strictly, to avoid the loss of time and labour in finishing its polish while the figure is imperfect.

73. Place the speculum in a vertical posture on a table about three and a half or four feet from the floor, see fig. 13. On another table set a candle, whose flame should be about the level of the middle of the speculum, and very near the centre of its concavity. About half an inch before the flame place a flat tin, or thin brass plate, about three inches broad, but four or five high, having several holes about the middle, of different shapes and sizes; some of them as small as the point of the sharpest needle will make them, the biggest about the size of a large mustard seed: darken the room, and move this candle and plate about on the table, till the light from the brightest part of the flame, passing through some of the larger holes to the speculum,

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* See article 67.

is reflected back so as to form the images of these holes, close without one of the side edges of that thin plate. Those largest images in this case will be visible, (although the speculum have no other polish than what the hones give it,) when received on a thick white card held close to that edge of the plate, if the back of the card be either blacked or so shaded that the candle may not shine through it; and the eye be also screened from the candle's direct light. If any difficulty happens in discerning them, the plate may be removed, and the image of the whole flame will be easily seen. Have ready an eye-glass whose focal distance may be something greater than the double of that of the eye-glass you intend for the instrument when finished: you may try several at your discretion. Let this be supported by a small stand moveable on the table, and capable of raising and sinking it, as the height of the flame requires, and of turning it into any direction. By means of this stand, bring the eye-glass into such a position, that the light from some of the holes, after its reflection from the speculum, may be received perpendicularly on its surface; and that its distance from the speculum be such, that the reflected images of the holes may be seen distinctly through it, near the edge of the thin plate, by the light coming immediately from the speculum; guide the candle and thin plate with one hand, and the stand carrying the eye-glass with the other, till you have got them into such situation, that you see distinctly at the same time, through the eye-glass, the edge of the thin plate, and the image of one of the holes close to it. Measure the exact distance of the middle of the speculum from the thin plate directly against the flame, and also from the edge close to which you see the image of the hole. If these measures are the same, set it down as the exact radius of concavity of your speculum, and proper curvature for any that are to be polished on your polisher, though that will allow some latitude: if the measures aforesaid differ, take the mean between them.

74. You will now also judge of the perfection of the spherical figure of your metal by the distinctness with which you see the representations of the holes, with their raggedness, dusts, and small hairs sticking in them: and you will be able to judge of this more exactly, and likewise to discover the particular defects of your speculum, by placing the eye-glass so as to see one of the smallest holes in or near its axis; and then by turns shoving the eye-glass a very little forward towards the speculum and pulling it away from it by turns, letting the candle and plate stand still in the mean time. By this means you will observe

in what manner the light from the metal comes to a point, to form the images, and opens again after it has past it. If the area of the light, just as it comes to or parts from the point, appears not round but oval, squarish, or triangular, &c. it is a sign that the sections of the specular surface, through several diameters of it, have not the same curvature. If the light, just before it comes to a point, has a brighter circle round the circumference, and a greater darkness near the centre, than after it has crossed and is parting again; the surface is more curved towards the circumference, and flatter about the centre, like that of a prolate spheroid round the extremities of its axis: and the ill effects of this figure will be more sensible when it comes to be used in the telescope. But if the light appears more hazy and undefined near the edges, and brighter in the middle before its meeting than afterwards, the metal is then more curved at its centre, and less towards the circumference; and if it be in a proper degree, may probably come near the true parabolic figure. But the skill to judge well of this, must be acquired by observation.

75. In performing the foregoing examination, the image must be reflected back as near the hole itself as the eye's approach to the candle will admit of; that the obliquity of the reflection may not occasion any sensible errors; in order to which the eye should be screened from the candle; and the glaring light which may disturb the observation, may be still more effectually shut out, by placing a plate, with a small hole in it, in that focus of the eye-glass which is next the eye. In fig. 13, A is the speculum, B the candle and plate with the small holes, C the cell with the eye-glass and plate behind it.

76. Instead of the flame of the candle and plate with small holes, I sometimes make use of a piece of glass, thick stuck with globules of quicksilver, strained through a leather and let to fall on it in a dew; placing this glass near a window, and the speculum at a distance on the side of the room, being itself and every thing about it as much in the dark as can be. The light of the window reflected from the globules of mercury, appearing as so many stars, serves instead of the small holes, with this advantage, that the reflection from the metal may be very near at right angles.

77. If the figure of the metal appear not satisfactory, the hones must be worked with the brass tool and water for two or three minutes with the motion, &c. first directed;* then work

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* See article 67.

the metal on them with the like motion, and such length of the stroke as may carry the edge of it about one-sixth or one-quarter of its diameter beyond that of the hone pavement each way; carry it likewise by turns to the right and left to about the same distance. Continue this about five minutes, not pressing the metal down to the hones with any more than its own weight, and observe that the oftener the mud is washed away, the more truly spherical the figure of the speculum will generally be: but the leaving a little more of this mud on the stones has sometimes seemed to give the metal a parabolic figure. I have likewise given it the same by concluding with a kind of spiral motion of the centre of the metal, near the circumference of the hones, in the manner represented in fig. 14, for about half a minute.

78. If after several trials, the metal appears to have always the same kind of defect, and answering to the same particular part of the metal, it is a sign of a different hardness in its several parts, which will make it very difficult to bring that speculum to perfection. In working the tool or metals on the hones, there will often appear little spots in them, much blacker and harder than the rest; these must be dug out as fast as they appear.

79. When the figure is to your mind, you may proceed to finish the polish on the sarcenet with very little putty, and that diluted with a great deal of water. Before you put the putty and water on it, observe, by holding it very obliquely between your eyes and the light, if it have any lists or stripes across it, which appear more glossy than the rest. If it be so, let the motion of the metal in polishing be directly athwart these lists and not along with them, nor ever circular. In other respects you may observe the same directions as were before given for its motion on the hones; not forgetting, after every fifteen or twenty strokes, to turn it on its axis about one-twelfth or one-sixteenth of a revolution. As the polisher grows dry, you will find the metal stick to it more and more stiff: at which time it both polishes faster and with a better gloss: only take care that it grows not so dry as for the metal to take hold of the sarcenet and cut it up; or for the pitch and putty to fix in little knobs here and there on it; which if it happen will presently spoil the figure. As fast therefore as the sarcenet appears to be growing dry at any of its edges, touch the place with the end of a feather dipt in clean water: you may use the same putty at least half an hour. As often as you change it, wash the old clean away, and rub the new about first with your bruiser, to see if there be any gritty or gross particles in it, and rub them

away for fear of scratching the metal; then laying down the edge of the speculum a little way on the edge of the polisher, where it is well covered with water, slide it on to the middle, and then proceed. The less putty you use at a time, the slower the work will advance; but if you use too much, it will spoil a little of the figure round the edges. It will not want any considerable force to press it down; but if it be of five or six inches diameter, or more, it will be very laborious to go through the polish without some kind of machine. One, something like that described by Mr. Huygens, (see article 35,) may do very well; especially if there be added to it some contrivance to hinder the metal's turning irregularly on its axis, and to give the workman a command of it in regard to the lateral motion.

ESSAY IV.

Method of Centring an Object-glass.

80. A circular object-glass is said to be truly centred, when the centre of its circumference is situated in the axis of the glass, fig. 9, plate LXXXII, and to be ill centred, when the centre of its circumference lies beside the axis. Thus let *d* be the centre of the circumference of an object-glass *a b c*; and suppose *e* to be the point where its axis cuts its upper surface. If the points *d* and *e* do not coincide, the glass is ill centred. Let *a f g* be the greatest circle that can be described about the centre *e*, and by grinding away all the margin without this circle, the glass will become truly centred. Now the centre *e*, which lies in the axis of the glass, may be found by several methods, but I prefer this that follows:

81. Let a couple of short cylindrical tubes be turned in wood or brass, and let the convexity of the narrower be so exactly fitted to the concavity of the wider, as just to turn round in it with ease but without waddling; and let the planes of the bases of the tubes be exactly perpendicular to their sides. Place the base of the narrower tube upon a smooth brass plate,

or a wooden board of an equal thickness, and with any sharp pointed tool, describe a true circle upon the board round the outward circumference of the base; and upon the centre of this circle, to be found when the tube is removed, describe a larger circle upon the board. These two circles should be so proportioned, that the one may be somewhat greater and the other somewhat smaller than any of the glasses intended to be centred by them. Then having cleared out all the wood within the inner circle, put the end of the tube into this hole, and there fasten it with glue, so that the base of the tube may lie in the surface of the board: then having fixed the wider tube very firmly in a hole made in a window shutter, and having darkened the room, lay the glass to be centred upon the board fixed to the narrower tube; and having placed the centre of it as near as you can guess over the centre of the hole, fix it to the board with two or three lumps of pitch, or soft cement, placed at its circumference. Then put the narrower tube into the wider as far as it can go, and fix up a smooth screen of white paper to receive the pictures of objects that lie before the window; and when they appear distinct upon the screen, let the inner tube be turned round about its axis; and if the centre of the glass happens to be in this axis, the picture will be perfectly at rest upon the screen; if not, every point of it will describe a circle. With a pencil, mark the highest and the lowest places of any one circle, described by some remarkable point in that part of the picture which appears most distinct; and when this point of the picture is brought to the highest mark, stop the circular motion of the tube, and keeping it in that position, depress the object-glass till the point aforesaid falls exactly in the middle between the two marks. Then turn the tube round again, and the point of the picture will either rest there or will describe a much smaller circle than before, which must be reduced to a quiescent point, by repeating the same operation. Then I say the centre (of refraction) of the glass will lie in the axis of the tube, and by consequence will be equidistant from the circumference of the large circle described upon the board fixed to it. Now to describe a circle upon the glass *f g h*, fig. 10, about its centre of refraction, let a long slender brass plate *a c b* be bent square at each end, leaving a piece in the middle equal in length to the diameter of the large circle *a d b e* that was described upon the board; and let the square ends of the plate be filed away so as to leave a little round pin in the middle of each. Then having laid it over the glass, along any diameter of the large circle *a d b e*, make two holes in the board to receive the pins *a b*; and find the centre of this circle upon the long plate; and with this centre *c* describe as large a circle as you can, upon the glass underneath, with a diamond-pointed compass; and grind away all the margin as far as this circle *f i k*, in a deep tool for grinding eye-glasses; and then the glass will be truly centred. If the pitch or cement be too soft to keep the glass from slipping, while the circle is describing, it may be fixed firmer with wax or harder cement.

82. To show the reason of this practice, fig. 11 represents a section of the object-glass *k l m*, of the board *a b*, and of the tubes *c d* and *h i*, and of the window-shutter *n o*. Imagine the plane of this section, or of the scheme, to pass through *e*, a point in the glass which keeps its place while the rest are turning round it, by the motion of the tube; let it also pass through *l*, the centre of refraction in the glass, and cut an object in the line PQR; then let a pencil of rays flowing from any point Q be collected to the focus *q* upon the screen ST; and the points Q *l q* will be in a straight line described by the axis, or principal ray, of the pencil. Draw Q *e f* cutting the screen in *f*; and while the tube is turning round, the line Q *l q* will describe a conical surface whose axis is the fixed line Q *e f*; and therefore the focus *q* or image of the point Q will describe a circle *q g χ* about *f*, to be found upon the screen by bisecting the interval *q χ* betwixt the highest and lowest points of the circle. Now as *f* is the centre of this circle, so *e* is the centre of another circle described by *l*; therefore by depressing the glass *k l* along the surface of the board *a b*, till the image *q* falls upon the mark *f*, the point *l* will be depressed to *e* the centre of motion, and then it will be in the axis of the tube, and consequently equidistant from the circumference of the circle described upon the board *a b*; and here it is plain that the image *q* will be at rest in the point *f*.

83. It is not necessary to the accuracy of the practice that the point Q should be in the axis of the glass. For in fig. 15, if the glass KLM be turned about its axis QL *q* the image *p* of any collateral point P will remain at rest; because the points PL are at rest, and the axis PL *p* of the oblique pencil in a straight line.

84. The chief advantage of having a glass well centred is this, that the rays coming through any given hole or aperture whose centre coincides with the axis of the glass, will form a distincter image, than if that centre lay beside the axis; because the aberrations of the rays from the geometrical focus of the

pencil, are as the distances of their points of incidence from the centre of refraction in the glass.

85. If the picture be received upon the unpolished side of a piece of plane glass, instead of the paper ST, its motion may be discerned more accurately by viewing it from behind through a convex eye-glass; as in a telescope where cross-hairs are usually strained over a hole put into the place of the rough glass. Therefore, as object-glasses are commonly included in cells that screw upon the end of the tube, one may examine whether they be pretty well centred, by fixing the tube, and by observing, while the cell is unscrewed, whether the hairs keep fixed upon the same lines of an object seed through the telescope.

ESSAY V.

Directions for making the best Composition for the Metals of reflecting Telescopes; together with a Description of the Process for grinding, polishing, and giving the great Speculum the true parabolic Curve.

As the method of casting, grinding, and polishing the specula of reflecting telescopes, by Molyneux and Hadley, (forming the third essay of the present series,) is what the workmen have generally followed, and is consequently well known to them; I shall in the following account avoid a repetition of the general directions there given, and only remark upon such parts of that process which I think are essentially defective, and supply them by a method of my own, which, from long and repeated trials, I have found completely to answer the purpose. After, therefore, referring to the above account for the manner of making the gauges, patterns, the method of casting, as well as a great many other particulars, I will begin with—

THE BEST COMPOSITION FOR THE SPECULA OF REFLECTING TELESCOPES.

86. The perfection of the metal of which the speculum should be made, consists in its hardness, whiteness, and compactness; for upon these properties the reflective powers and durability of the speculum depend. And first of the hardness and whiteness of the metal. There are various compositions recommended in Essay III, all which have, however, their several defects. Three parts copper, and one part and one-fourth of tin will make, it is observed, a very hard white metal; but it is liable to be porous. This, however, is an imperfection which I shall presently show the method of preventing; but the permanent fault of it, and which I have myself experienced, is, that it is not hard enough. The speculum of a reflecting telescope ought to have the utmost possible hardness, compatible with its being operated upon by the tool.

87. It is to be observed, that ever so small a quantity of tin added to melted copper destroys its perfect malleability, and at the same time produces a metal whiter and harder than copper. As the quantity of tin is increased, suppose to a fifth or fourth part, the metal becomes whiter, still harder, and consequently more friable. If the quantity of tin be further increased to a third of the whole composition, it will then have its utmost whiteness; but will be rendered at the same time so exceedingly hard and brittle, that the finest washed emery upon lead or brass will not cut it without breaking up its surface, and the common blue stones used in grinding the speculum will not touch it. Mr. Jackson (sometime since dead) a mathematical instrument-maker, and a most excellent workman, told me, that the tin was increased to the above proportion in his metals; but that they were so exceeding hard, that it cost him an infinite deal of pains, and a journey of two hundred miles, to find out a stone of sufficient hardness to cut it, and whose texture at the same time was fine enough not to injure its surface. I have seen several of his finished metals; they were indeed perfectly hard and white; but the kind of stone with which he ground them he kept a secret.

18. After many experiments with various proportions of tin and copper, by gradually increasing the former, I at last found that fourteen ounces and a half of grain-tin to two pounds of good Swedish copper, made a beautiful, white, and very hard

metal; so hard indeed, that the stones would but barely cut it, and washed emery on brass or tin but just grind the surface without breaking it up; whereas the proportion of tin being increased by the addition of only another half ounce, the former inconvenience immediately took place. This therefore is the *maximum* in point of hardness.

89. This much of the two first considerations, the hardness and whiteness of the metal; the next, and indeed the most essential, property is its compactness, or its being without pores.

90. Thus composition (though complete in the former respects) was, as well as the one just alluded to, (given in Essay III,) subject every now and then to be porous; sometimes, indeed, I succeeded in casting a single metal, or, perhaps two or three, without this imperfection; at other times, and most frequently indeed, they were attended with this defect, without my being at all able to form a probable conjecture at the cause of my success or disappointment. The pores were so very small, that they were not discoverable when the metal had received a good face and figure upon the hones, nor till the last and highest polish had been given; and then it frequently appeared as if dusted over with millions of microscopic pores, which were exceedingly prejudicial in two respects; for first, they became in time a lodgment for a moisture which tarnished the surface; and secondly, on polishing the speculum, the putty necessarily rounded off the edges of the pores, so as to spoil a great part of the metal, by the loss of as much light and sharpness in the image as there were defective points of reflection in the metal.

91. Besides the trouble of a great number of experiments in order to get rid of this mischief, and to ascertain the cause to which it was owing, there was this additional inconvenience attending it, viz. that the fault was not discovered, as was observed before, till a great deal of trouble had been taken in grinding and even polishing the metal, the whole of which was rendered useless by the mortifying discovery of this defect.

92. I was extricated at last from this difficulty, and in some measure by accident. Having one day made a great number of experiments, and having melted down all the good copper I had or could procure; though puzzled and fatigued, yet not caring to give it up, I recollected that I had some metal which was reserved out of curiosity, and was a part of one of the bells of St. Andrew's which had been re-cast. Expecting, however, very little from this gross and uncertain composition,

I was nevertheless determined to see what could be made of it by enriching the composition with a little fresh tin. Accordingly, casting a metal with it, it turned out perfectly free from pores, and in every respect as fine a metal as ever I saw.

93. I could not at first conceive to what this success was owing; but at last I hit upon the real cause of that defect, which had given me so much embarrassment and trouble during a course of near a hundred experiments, and in consequence thereof, fell upon a method which ever after prevented it.

94. I had hitherto always melted the copper first, and when it was sufficiently fused, I used to add the proportional quantity of tin; and as soon as the two were mixed, and the scoria taken off, the metal was poured into the moulds. I began to consider that putty was calcined tin, and strongly suspected, that the excessive heat which the copper necessarily undergoes before fusion, was sufficient to reduce part of the tin to this state of calcination, which therefore might fly off from the composition in the form of putty, at the time the metal was poured into the flasks.

95. Upon this idea, after I had furnished myself with some more Swedish copper and grain-tin (both which I had always before used) I melted the copper, and having added the tin as usual to it, cast the whole into an ingot: this was, as I expected, porous. I then melted it again, and as in this mixed state it did not acquire half the heat which was before necessary to melt the copper alone, so it was not sufficient to calcine the tin; the speculum was then perfectly close, and free from this fault; nor did I ever after, in a single instance, meet with the abovementioned imperfection.

96. All that is necessary, therefore, to be done to procure a a metal which shall be white, as hard as it can be wrought, and perfectly compact, is to melt two pounds of Swedish copper, and when so melted, to add fourteen ounces and a half of grain-tin to it; then, having taken off the scoria, to cast it into an ingot. This metal must be a second time melted, to cast the speculum; but as it will fuse in this compound state with a small heat, and therefore will not calcine the tin into putty, it should be poured off as soon as it is melted, giving it no more heat than is absolutely necessary. It is to be observed, however, that the same metal, by frequent melting, loses something of its hardness and whiteness: when this is the case, it becomes necessary to enrich the metal by the addition of a little tin, perhaps in the proportion of half an ounce to a pound. And indeed when the metal is first made, if instead

of adding the fourteen ounces and a half of tin to the two pounds of melted copper, about one ounce of the tin were to be reserved and added to it in the succeeding melting, before it is cast off into the moulds, the composition would be the more beautiful, and the grain of it much finer: this I know by experience to be the case.

97. The best method for giving the melted metal a good surface is this: the moment before it is poured off, throw into the crucible a spoonful of charcoal-dust; immediately after which the metal must be stirred with a wooden spatula, and poured into the moulds.

98. I wish I may not be considered as tedious in the above detail; but as this business caused me a great deal of trouble, I was willing to give some account of the means by which I was freed from this difficulty ever after. Perhaps, indeed, the whole of this process may be unnecessary, as, many years since, I communicated this composition, and I believe at the same time the method of preventing the pores, to the late Mr. Peter Collison, a member of the Royal Society; and likewise, two or three years since, at the desire of my brother, to Mr. Michell. Although it be possible, therefore, that this method is generally known, yet as I have frequently of late seen specula with this defect, and observed metals of some of Mr. Short's telescopes which are not quite so perfect as could be wished (though they are all exquisitely figured) I was willing by this publication wholly to remove any further embarrassment of this sort, and to furnish workmen with an excellent composition for their metals. And would the Royal Society be pleased to honour the process with a place in their records, I know of no other method so proper to give this, as well as the following information, a general notoriety.

99. The metal being cast, there will be no occasion for the complicated apparatus directed by Dr. Smith, (in Essay III,) for grinding and polishing it. Four tools are all that are necessary, viz. the rough grinder, to work off the rough face of the metal; a brass convex grinder, on which the metal is to receive its [illegible]al figure; a bed of hones, which is to perfect that figure, [illegible] give the metal a fine smooth face; and a concave tool [illegible]ser, with which both the brass grinder and the hones are to be formed. A polisher may be considered as an additional tool; but as the brass grinder is used for this purpose, and its pitchy surface is expeditiously, and without difficulty, formed by the bruiser, the apparatus is therefore not enlarged.

OF ROUGH GRINDING THE SPECULUM.

100. The tool by which the rough surface of the metal is rendered smooth and fit for the hones, is best made of lead stiffened with about a fifth or sixth part of tin. This tool should be at least a third more in diameter than the metal which is to be ground; and for one of any size, not less than an inch thick. It may be cemented upon a block of wood, in order to raise it higher from the bench.

101. This leaden tool being cast, it must be fixed in the lathe, and turned as true as it is possible, by the gauge, to the figure of the intended speculum, making a hole or pit in the middle, as a lodgment for the emery, of about an inch diameter for a metal of four inches: when this is done, deep grooves must be cut across its surface with a graver, in the manner represented in fig. 1, plate LXXXIII. These grooves will serve to lodge the emery, and by their means the tool will cut a great deal faster. There is no occasion to fear any alteration in the convexity of this tool by working the metal upon it, for the emery will bed itself in the lead, and so far arm the surface of it, that it will preserve its figure and cut the metal very fast. Any kind of low handle, fixed on the back of the metal with soft cement, will be sufficient; but it should cover two-thirds of its back to prevent its bending. This way of working will cut the metal faster, and with more truth, than the method described in Essay III; for should the surface and rough parts be attempted to be ground off by a common grindstone by hand, though you did it as near the gauge as possible, yet the metal would be so much out of truth when applied to the succeeding tool, that no time would be saved by it. I used to employ a common labourer for this purpose, who soon acquired such a dexterity at working upon this tool, that in two hours' time he would give a metal of four inches diameter so good a face and figure as even to fit it for the hones. When all the sand holes and irregularities on the face of the metal are ground off, and the whole surface is smooth and regularly figured, the speculum is then ready for the brass-grinder, and must be laid aside for the present.

THE MANNER OF FORMING THE BRASS-GRINDING TOOL.

102. The following is the method I have always pursued. Procure a round stout piece of Hamburgh brass, at most a sixth part larger than the metal to be polished; and let it be well hammered into a degree of convexity (by the assistance of the gauge) suitable to the intended speculum. Having done this, scrape and clean the concave side so thoroughly that it may be well tinned all over; then cast upon it, after it has been pressed a proper depth into the sand, the former composition of tin and lead, in such quantity, that it may (for a speculum of four inches diameter) be at least an inch and a half thick, and with a base considerably broader than the top, in order that it may stand firmly upon the bench in the manner hereafter to be described. This being done, it must be fixed and turned in the lathe with great care, and of such a convexity as exactly to suit the concave gauge, which we suppose already made. It will be necessary to be more careful in forming this than the former tool, and especially that no rings be left from the turning; nor will the succeeding hone tool require so much exactness as any defects in turning, will, by a method hereafter mentioned, be easily remedied ; but any inequality or want of truth in the brass tool will occasion a great deal of trouble before it can be ground out by the emery. This tool must have a hole (somewhat less than that in the metal to be worked upon it) in the middle, quite through to the bottom. When this tool is finished off in the lathe, its diameter should be one-eighth wider in the metal.

HOW TO FORM THE BED OF HONES, OR THE THIRD TOOL.

103. Having chosen the kind of hones, and the best too, of the sort recommended in Essay III, they should be cemented in small pieces, (in a kind of pavement agreeably to directions there given) upon a thick round piece of marble, or metal made of lead and tin like the former composition (which is what I have always used) in such a manner, that the lines between the stones may run straight from one side to the other; so that, placing the teeth of a fine saw in each of these divisions, they may be cleared from one end to the other of the cement which rises between the stones. This bed of hones should be at least

a fourth part larger than the metal which is to be ground upon it. The surface of the metal upon which the hone pavement is to be cemented, may or may not, as you please, be turned of a convexity suitable to the gauge, though I have never taken that trouble. As soon as the hones are cemented down, and the joints cleared by the saw, this tool must be fixed in the lathe, and turned as exactly true to the gauge as possible; which done, it must be laid aside for the present. The next tool to be made is the bruiser.

THE MANNER OF FORMING THE BRUISER, THE FOURTH AND LAST TOOL.*

104. This tool should be likewise made of thick stout brass like the former, perfectly sound, about a quarter of an inch thick, and hammered as near to the gauge as possible. It should be then scraped, cleaned, and tinned on the convex side, as the former tool was on the concave, and the same thickness of lead and tin cast upon it. The general shape of this should differ from the former; for as that increased in diameter at the bottom for the sake of standing firmly, so this should be only as broad at bottom as at top, as it is to be used occasionally in both those positions. When this tool is fixed in the lathe, and turned off concave to the convex gauge with great truth likewise, its diameter ought to be the middle size between the hones and the polisher.

105. Having with the lathe roughly formed the convex brass-grinder, the bed of hones, and the concave bruiser, the convex and concave brass tools, and the metal, must be wrought alternately and reciprocally upon each other with fine emery and water, so as to keep them as nearly to the same figure as possible, in order to which some washed emery must be procured. This is best done by putting it into a phial, which must be half filled with water and well shaken up, so that, as it subsides, the coarsest may fall to the bottom first, and the finest remain at the top: and whenever fresh emery is laid on the tools, the best method (which we should also observe with the putty in polishing) will be, to shake gently the bottle, and pour out a small quantity of the turbid mixture.

OF GRINDING THE SPECULUM, THE BRASS TOOL, AND THE BRUISER TOGETHER.

106. All the tools being ready, upon a firm post in the middle of a room, you are to begin to grind the brass convex tool with the bruiser upon it, working the latter crossways, with strokes sometimes across its diameter, at others a little to the right and left, and always so short that the bruiser may not pass above half an inch within the surface of the brass tool either way, shifting the bruiser round its axis every half dozen strokes or thereabouts. You must likewise, every now and then, shift your own position, by walking round, and working at different sides of the brass tool; at times the strokes should be carried round and round, but not much over the tool: in short, they must be directed in such a way, and the whole grinding conducted in such a manner, and with such equability, that every part of both tools may wear equally. This habit of grinding, as well as the future one of polishing, will be soon acquired. When you have wrought in this manner about a quarter of an hour with the bruiser upon the tool, it will be then necessary to change them, and, placing the bruiser upon its bottom, to work the convex tool upon that in the same manner.

107. When by working in this equable manner, alternately with the bruiser and tool, and occasionally adding fresh emery, you have nearly got out all the vestiges of the turning tool, and brought them both nearly to a figure, it will then be time to give the same form to the metal. This must be done by now and then grinding it upon the brass tool with the same kind of emery, taking care, however, by working the two former tools frequently together, to keep all three exactly in the same curve. The best kind of handle for the metal is made of lead, a little more than double its thickness, and somewhat less in diameter, of about three pounds weight, with a hole in the middle (for reasons to be shown hereafter) a little larger than that in the metal: this handle should be cemented on with pitch. The upper edge of this weight must be rounded off, that the fingers may not be hurt; and a groove, about the bigness of the little finger, be turned round just below it, for the more conveniently holding and taking the metal off the tools.

THE MANNER OF FIGURING THE METAL UPON THE HONES.

108. When the bruiser, brass tool, and metal, are all brought to the same figure, and have all a true good surface, the next part of the process is to give a correct spherical figure and a fine face to the metal, upon the hones. It will be necessary to premise, however, that the hones should be placed in a vessel of water, with which they should be quite covered for at least an hour before they are used, otherwise they will be perpetually altering their figure when the metal comes to be ground upon them. The same precaution is also necessary, if you are called off from the work while you are grinding the metal, for if they be suffered to grow dry, the same inconvenience will arise.

109. In order to give a proper figure to the hones, and exactly suitable to that of the brass tool, bruiser, and metal, when the hones are fixed down to the block, some common flour emery (unwashed) with a good deal of water must be put upon them, and the bruiser being placed upon the hones and rubbed thereon with a few strokes and a light hand, the inequalities of the stone will be quickly worn off; but as a great deal of mud will be suddenly generated, it must be washed off every quarter of a minute with a great deal of water. By a repetition of this, two or three times, the hones (being of a very soft and friable substance) will be cut down to the figure, without wearing or altering the bruiser at all. Though this business may be quickly done, and can be continued but for a few strokes at a time, I need not say that it is necessary that those strokes be carried in the same direction, and with the same care, which was observed in grinding the former tools together.

110. As soon as the hones have received the general figure of the bruiser, and all the turning strokes are worn out from them, the emery must be carefully washed off; in order to which, it will be necessary to clear it from the joints with a brush under a stream of water. The bruiser and metal must be likewise cleared in the same manner, and with equal care, from any lurking particles of emery.

111. The hones being fixed down to the block, you now begin to work the bruiser upon them with very cautious, regular, short strokes, forward and backward, to the right and left, turning the axis of the bruiser in the hand while you move round the hones, by shifting your position, and walking round

the block. Indeed the whole now depends upon a knack in working, which should be conducted nearly in the following manner. Having placed the bruiser on the centre of the hones, slide it in an equable manner forward and backward, with a stroke or two directly across the diameter, a little on one side, and so on the other; then shifting your position an eighth part round the block, and having turned the bruiser in your hand about as much, give it a stroke or two round and round, but not far over the edges of the hones, and then repeat the cross strokes as before: those round strokes (which ought not to be above two or three at most) are given every time you shift your own position and that of the metals, previous to the cross ones, in order to take out any stripes either in the hones or bruiser, which may be supposed to be occasioned by the straight cross strokes. During the time of working, no mud must be suffered to collect upon the hones, so as to destroy the perfect contact between the two tools; and therefore they must every now and then be washed clean by throwing some water upon them. When by working in this manner all the emery strokes are ground off from the bruiser, and it has acquired a good figure and clean surface, you may then begin with the metal upon the hones, in the same cautious manner, washing off the mud as fast as it collects, though that will be much less now than when the bruiser was ground upon them. Every now and then, however, the bruiser must be rubbed gently and lightly upon the hones, which will as it were, by sharpening them and preventing too great smoothness, occasion them to cut the metal much faster.

112. When, after having some time cautiously wrought in the manner before described, the hone-pavement has uniformly taken out all the emery strokes, and given a fine face and true figure to the metal, which will be pretty well known by the great equality there is in the feel while you are working, and by which an experienced workman will form a pretty certain judgment; having proceeded thus far, I say, you may then try your metal, and judge of its figure by this more certain manner.

113. Wash the hone-pavement quite clean; then put the metal upon the centre of it, and give two or three light strokes round and round only, not carrying, however, the edges of the metal much over the hones; this will take out the order of straight strokes: then having again washed the hones, and placed the speculum upon their centre, with gentle pressure, slide it towards you till its edge be brought a little over that of hones, then carry it quite across the diameter as far the other side, and

having given the metal a light stroke or two in this direction, take it off the tool. The metal being wiped quite dry, place it upon a table at a little distance from a window; stand yourself as near the window, at some distance from the metal, and looking obliquely on its surface, turn it round its axis, and you will see at every half turn the grain given by the last cross strokes, flash upon your eye at once over the whole face of the metal. This is as certain a proof of a truly spherical figure as the operose and difficult method described in Essay III; for as there is nothing soft or elastic, either in the metal or in the hones, this glare is a certain proof of a perfect contact in every part of the two surfaces; which there could not be if the spheres were not both perfect, and precisely the same.

114. Indeed there is one accidental circumstance which necessarily affords its aid in this and every business of the like sort; and that is, that a concave and convex surface ground together, though ever so irregular at first, will (if the working be uniform and proper, consisting, especially at last, of cross strokes in every possible direction across the diameter) be formed into portions of true and equal spheres; had it not been for this lucky necessity, it would have been impossible to have produced that correctness which is essential in the speculum of a good reflecting telescope by any mechanic contrivance whatever. For when it is considered, that the errors in reflection are four times as great as in refraction, and that the least defect in figure is magnified by the powers of the instrument, any thing short of perfection in the figure of the speculum would be evidently perceived by a want of distinctness in the performance.

115. I must not, however, quit this article without observing, that I all along suppose, both in forming the tools and at last figuring the metal, (and indeed the same must be observed in the future process of polishing,) that no kind of pressure is used that may endanger the bending or irregularly grinding of them; they should therefore be held with a light hand, and loosely between the fingers, and the motion given should be in a horizontal direction, with no more pressure than their own dead weight.

116. Having now finished the metal on the hones, and rendered it both in point of figure and surface fit for the last and most essential process, viz. that of polishing, I will describe it in the best manner I can; though many little circumstances which will be unavoidably omitted, (and which at the same time are frequently essential to the success of a mechanic process,) can only be supplied by actual experience.

117. The polishing the speculum is the most difficult and essential part of the whole process; for every experienced workman knows, to his vexation, that the most trifling error here will be sufficient to spoil the figure of his metal, and render all his preceding caution useless. I have, however, discovered a method which I shall explain, not only of giving the metal a parabolic figure, but also of recovering it when it happens to be injured; both to be effected in the act of polishing, and the former as certainly as the spherical figure is given upon the hones. Indeed, if we consider rightly, polishing will be perceived to be but a kind of grinding with a finer order of strokes, and with a powder infinitely finer than was before used in what is commonly called the grinding. But before I describe this method, which was the result of many years' experience, I will take the liberty of making some few strictures on that of Essay III, which is followed by the generality of workmen.

118. First, then, the tool itself used by them for polishing the metal is formed with infinite difficulty. The first described polisher is directed to be made by covering the tool with sarcenet, which is to be saturated with a solution of pitch in spirit of wine, by successive applications of it with a brush, till it is covered, and by the evaporation of the spirit of wine filled with this extract of pitch; the surface is then to be worked down and finished with the bruiser. This is all very easy in imagination; but whosoever has used this method (which I have myself unsuccessfully several times) must have found it attended with infinite labour, and at last the business done in a very unsatisfactory manner; for the pitch by this process will be deprived of an essential part of its composition. The spirit of wine dissolves none but the resinous parts of its substance, which is hard and untractable; and if you use soap or spirit of wine to soften or dissolve it, it will equally affect the whole surface, the lower as well as higher parts of it. And suppose that with infinite labour with the bruiser, it is at last reduced to a fine uniform surface, it is nevertheless too hard ever to give a good polish with that lustre which is always seen in Mr. Short's, and indeed all other good metals. Nor will it give a good spherical figure; for a perfect sphere is formed, as I observed before, by that intimate accommodation arising from the wear and yielding of both tool and metal; whereas in this method, there is such a stubbornness in the polisher, that the figure of the metal, good or bad, must depend upon the truth of the former, which is very seldom perfect.

119. If the polisher be made in the second manner proposed, by straining the pitch through an outer covering, which is afterwards to be stripped off, the superficies of pitch and sarcenet are so very thin, that the putty, working into them, forms a surface hard and untractable, so that it is impossible to give the speculum a fine polish. Accordingly, all those metals which are wrought that way, have an order of scratches instead of polish, discovering itself by a greyish visible surface. Besides, supposing this tool perfectly finished, and answering its purpose ever so well, it is impossible it can produce in the speculum any other than a spherical figure; and indeed nothing else is expected from this method, as very evidently appears by the experiment recommended to ascertain the truth of the figure. You are directed to place a small luminous object in the centre of the sphere of which the metal is a segment, and then having adjusted an eye-glass at the distance of its own focal length from the object, and so situated that the image of the object formed by the speculum may be visible to the eye, you are to judge of the perfect figure of the metal by the sharpness and distinctness with which the image appears. Hence it is very evident, that as the object and image are both distant from the metal by exactly its radius, nothing but a truly spherical figure of the speculum can produce a sharp distinct image; and that the image could not be distinct if the figure of the speculum were parabolic. Consequently, if the same speculum used in a telescope were to receive parallel rays, there would necessarily be a considerable aberration produced, and a consequent imperfection in the image. Accordingly, there never was a good telescope made in this manner; for if the number of degrees, or the portion of the sphere of which the great metal is a part, were as considerable as it ought to be, or as great as Mr. Short allowed in his metal, the instrument would bear but a very low charge, unless a great part of the circumference of the metal were cut off by an aperture, and the ill effects of the aberration by that means in some measure prevented.

120. If ever a finished metal turned out without this defect, and has been found perfectly sharp and distinct, it must have been owing to an accidental parabolic tendency, no ways the natural result of the process, and therefore quite unexpected, and most probably unknown to the workman.

121. Without enlarging, therefore, on the difficulty of the above process, and the impossibility of giving the speculum the correctness and the kind of figure essentially necessary to a

good telescope, I will describe (by way of introduction to the succeeding directions) the steps by which I was led to a certain and easy method of giving a proper and correct parabolic figure to the metal, even though it came off imperfect from the hones, and an exquisite polish at the same time.

122. Having made many efforts in the former method, which by no means pleased me, for the reasons above-mentioned; and having observed, from some of Mr. Short's telescopes which fell into my hands, that the high lustre of the polish could never have been produced in the manner above described, but by some softer and more tender substance; and at the same time recollecting, that Sir Isaac Newton had given an account in his Optics of his having finished some metals, and considerably mended the object-glass of a refractor, by working both upon a tool whose surface had been covered with common pitch about the thickness of a groat; reflecting, I say, upon these matters (coarse and uncertain as this method appeared at first sight) I was determined to try whether I could not get rid of my embarrassment, by a mode of operation somewhat similar. Accordingly, shortening Dr. Smith's process, I made a set of tools in the manner before described, except that I was obliged to make some subsequent alteration in the polisher, which I shall presently describe. Having given a good spherical figure to the brass tool and the bruiser and likewise to the metal upon the hones, and made the brass convex tool so hot as just not to hurt the finger, I tied a lump of common pitch (which should be neither too hard nor too soft) in a rag, and holding it in a pair of tongs over a still fire where there was no rising dust, till it was ready to strain through the linen, I caused it to drop upon the several parts of the convex tool, till I supposed it would cover the whole surface about double the thickness of a shilling; then spreading the pitch as equally as I could, I suffered the polisher (by which name I shall for the future call this tool) to grow quite cold. I then warmed the bruiser so hot as almost to burn my fingers, and having fixed it to the bench with its face upwards, I suddenly placed the polisher upon it, and quickly slid it off; by this means rendering the surface of the pitch more equal. The pitch is then to be wiped off from the bruiser with a little tow; and by touching the surface with a tallow candle, and wiping it a second time, it will be then perfectly clean and fit for a second process of the same sort, which must again be performed as quickly as possible; and this is ordinarily sufficient to give a general figure to the surface of the pitch. The bruiser and polisher are then suffered to grow perfectly cold, when the pitch, considering what has been taken off, will be about the thickness of a shilling.

123. It is, however, here necessary to observe, that the pitch should be neither very hard and resinous, nor too soft; if the former, it will be so untractable as not to work kindly; and if too soft, it will in working alter its figure faster than the metal, and too readily fit itself to the irregularity of its figure, if it have any. When both tools were perfectly cold, I gave the polisher a gentle warmth, and then fixed the bruiser to the block with its face upwards; and (having with a large camel-hair brush spread over the face of the polisher a little water and soap, to prevent sticking) with short, straight, and round strokes, I worked it upon the bruiser, every now and then adding a little more water and soap, till the pitch upon the polisher had a fine surface, and the true form of the bruiser; and this I continued to do till they both grew perfectly cold together: in this manner the polisher was perfectly formed in about a quarter of an hour. But here a difficulty arose: when I begun to polish the metal, I found that the edge of the hole in the metal collected the pitch towards the middle of the polisher: and though in this method of working I could give an exquisite polish, as the putty lodged itself in the pitch exceedingly well, yet the figure of the metal was injured in the middle, nor did indeed the work go with that equability which is the inseparable attendant on a good figure. In order to obviate this difficulty, I cast some metals with a continued face, the holes not going quite through, within perhaps the thickness of a sixpence. I finished two or three metals of this sort, and the work promised and went on very well; but when I came to open the holes, which I did with the utmost caution, I found the metals short of perfection; which I attributed to an alteration of the figure from the removal of even that small portion of metal after the speculum had been finished. This I do suppose was in some measure the reason why I spoiled a very distinct and perfect two-foot metal, which bore a charge of two hundred times, only by opening the sharp part of the edge of the hole, because I thought it bounded the field: so essentially necessary is an exquisite correctness of figure in the speculum of a perfect reflector.

124. This experiment not succeeding, instead of casting the metal without a hole, I made one quite through the middle of the polisher, a little less than that in the speculum. This perfectly answered the purpose; no more inconvenience arose from the gathering of the pitch, (for it had now no greater

tendency to collect at the centre than the sides,) and I finished several metals successively, excellent both in point of figure and polish; one of those of two inches diameter, and 7.5 focal length, bore a charge of sixty times and upwards, which when mounted in a telescope, I gave to my brother. This telescope underwent Mr. Short's examination, who was pleased to remark only, that he thought he had made one more distinct.

125. I must observe, that in this method of working the polishing goes on in an agreeable, uniform, and smooth manner; and that the small degree of yielding in the pitch (which is actually not more than the wearing of the metal) produces that mutual accommodation of surfaces so necessary to a true figure. In the beginning of the polish, and indeed for some time during the progress of it (always remembering now and then to remove the metal round its axis) I worked round and round, not far from and always equally distant from the centre, except that every time, previous to the shifting the metal on its axis, I used a cross stroke or two; and when the polish was nearly completed, I mostly used cross strokes, giving a round stroke or two likewise every time I turned the metal on its axis. I observed in this method of working, that the metal always polished fastest in the middle; insomuch, that half or two-thirds of it would be completely polished when the circumference of it was scarcely touched by the tool. Observing this in some of the first metals, and not considering that this way of polishing was in fact a species of grinding, and as perfect as that upon the hones, I went on reluctantly with the work, almost despairing of being able to produce a good figure. However, I always found myself agreeably deceived; for when the polish was extended to the edge, or within the tenth of an inch of it, I almost constantly found the figure good, and the performance of the metal very distinct. But this same circumstance of apparent defect in the metals, was in fact that to which their perfection was owing; for they all, contrary to my expectation turned out parabolic. However, I did not for a great while know any certain way of giving that degree of parabolic tendency which was just necessary, and which will be described hereafter. It was a long time before I got rid of my prejudice against this apparent imperfection in the process, or could reconcile myself to the irregular manner in which the polish proceeded; for I looked upon it as a certain source of error, and notwithstanding I saw it eventually succeed, yet whenever I chanced to find that a metal, when first applied to the polisher, took the polish equally all over, and consequently

the whole business did not take up above ten minutes; under those circumstances, I say, I always used to please myself with the expectation of a correct figure, at least as much so as the metal had received from the hones, where the surface was but just and equally taken off by the putty; but in this I constantly found myself deceived, and the metal turned out good for nothing. In short, at this time, though I speculatively knew that a parabolic figure was necessary to a perfect image, I yet considered it as of little practical consequence.

126. From the foregoing experiments, and a number of succeeding trials, I at length discovered a certain way of giving a correct parabolic figure, and an exquisite polish at the same time. This, which I have strong reasons to believe was Mr. Short's method, I will now describe in as few words as I can.

HOW TO POLISH THE SPECULUM.

127. It is first necessary to observe, that, in order to avoid the detrimental intrusions of any particles of emery, it would not be right to polish in the same room where the metal and tools were ground, nor in the same clothes which were worn in the former process; at least it would be necessary to keep the bench quite wet, to prevent any dust from rising.

128. Having then made the polisher by coating the brass convex tool equally with pitch, which we suppose smoothed and finished with the brass tool in the manner before described, and which is a very easy process, the whole operation is begun and finished in the following manner:

129. The leaden weight or handle upon the back of the metal should be divided into eight parts, by so many deep strokes of a graver upon the upper surface of the lead, marking each stroke with the numbers 1, 2, 3, 4, and so on, that the turns of the metal in the hand may be known to be uniform and regular.

130. To prevent any mischief from coarse particles of putty, I always wash it immediately before using. In order to this, put about half an ounce of putty into an ounce phial, and fill it two-thirds with water; then having shaken the whole, let the putty subside, and stop the bottle with a cork.

131. In a tea-cup with a little water, there should be a full-sized camel-hair brush, and a piece of dry clean soap in a galley-pot: a soft piece of sponge will also be necessary. These, as well as the metal, bruiser, and polisher, should be constantly covered from dust.

132. The polisher being fixed down, and the camel-hair brush being first wetted and rubbed a little over the soap, let every part of the tool be brushed over therewith; then work the bruiser with short, straight, and round strokes, lightly upon the tool, and continue to do so, now and then turning it, till the polisher have a good face, and be fit for the metal. Then having shaken up the putty in the phial, and touched the polisher in five or six places with the cork wetted with that and the water, place the bruiser upon the tool, and give a few strokes upon the putty to rub down any gritty particles; after which, having removed it, work the metal lightly upon the polisher round and round, carrying the edges of the speculum, however, not quite half an inch over the edge of the tool, and now and then with a cross stroke.

133. The first putty, and indeed all the succeeding applications of it, should be wrought with a considerable while; for if time be not given for the putty to bed itself in the pitch, and any quantity of it lie loose upon the polisher, it will accumulate into knobs, which will injure the figure of the metal: and therefore as often as ever such knobs arise, they must be carefully scraped off with the point of a penknife, and the loose stuff taken away with the brush. After the putty is well wrought into the pitch, some more may be added in the same manner, but never much at a time, and always remembering to work upon it first with the bruiser, for fear any gritty particles may find their way upon the polisher. If the bruiser be apt to stick, and do not slide smoothly upon the pitch, the surface of either tool may be occasionally brushed over with the soap and water, but it must be remembered that the wet brush must be but lightly rubbed upon the soap.

134. In the beginning of this process little effect is produced, and the metal does not seem to polish fast, in some measure owing to its taking the polish in the middle, and perhaps because neither that nor the bruiser moves evenly upon the polisher: but a little perseverance will bring the whole into a good temper of working; and, when the pitch is well defended by the coating of the putty, the process will advance apace, and the former acquiring possibly some little warmth, the metal moves more agreeably over it, with a uniform and regular friction. All this while the metal must have no more pressure than that which it derives from its own weight and that of the handle; and the polisher must never be suffered to grow dry, but as often as it has any tendency to do so, the edges of it must be moistened with the hair-pencil; and now and then, even when fresh putty is not laid on, the surface of the polisher should be touched with the brush to keep it moist.

135. When the polish of the metal nearly reaches the edge (for it always, as I said before, begins in the middle) you must alter your method of working; for now the round strokes must be gradually altered for the short and straight ones. Supposing then you are just beginning to alter them; after having put on fresh putty, and gently rubbed it with two or three strokes of the bruiser, you place the metal on the tool, and after a stroke or two round and round, give it a few forward and backward, and from side to side, but with the edges very little over the tool; then having turned the metal one-eighth round in your hand, and having moved yourself as much round the block (which must be remembered throughout the whole process) you go on again with a stroke or two round, to lead you only to the cross strokes, which are now to be principally used, and with more boldness. After this has been done some time, the metal will begin to move stiffly, as the friction now increases, and the speculum polishes very beautifully and fast; and the whole surface of the polishing tool will be equally covered over with a fine metallic bronze. The tool even now must not be suffered to become dry; a single round stroke in each of your stations and turnings of the metal will be sufficient, and the rest must all be cross ones, for we are completing a circular figure. You must now be very diligent, for the polisher drying, and the friction increasing very fast, the business of the spherical figure is nearly at an end. As the metal wears much, its surface must be now and then cleaned, with a piece of shammy leather, from the black stuff which collects upon it; and the polisher likewise from the same matter with a soft piece of wet sponge. You will now be able to judge of the perfect spherical figure of the metal and tool, when there is a perfect correspondence between the surfaces, by the fine equable feel there is in working, which is totally free from all jerks and inequalities. Having proceeded thus far, you may put the last finishing to this figure of the metal by bold cross strokes, only three or four in the directions of each of the eight diameters, turning the metal at the same time: this must be done quickly, for it ought, in this part of the process particularly, to be remembered, that if you permit the tool to grow quite dry, you will never be able, with all your force, to separate that and the metal, without destroying the polisher by heat.

136. The metal has now a beautiful polish and a true spherical figure, but will by no means make a sharp distinct

image in the telescope: for the speculum (if it be tried in the manner hereafter recommended) will not be found to make parallel rays converge without great aberration; indeed the deviation will be so great, as to be very sensibly perceived by a great indistinctness in the image.

HOW TO GIVE THE PARABOLIC FIGURE TO THE METAL.

137. In order then to give the speculum the last and finishing figure, which is done by a few strokes, it must be particularly remarked, that by working the metal round and round, the sphere of the polisher by this means growing less, it wears fastest in the middle: and as a segment of a sphere may become parabolic by opening the extremes gradually from within outwards, so it may be equally well done by increasing the curvature in the middle, in a certain ratio, from without inwards.

138. Supposing then the metal to be now truly spherical, stop the hole in the polisher, by forcing a cork into it underneath, about an inch, so that it do not reach quite to the surface; and having washed off any mud that may be on the surface of the tool with a wet soft piece of sponge, while the surface of it is a little moist, place the centre of the metal upon the middle of the polisher; then having, with the wet brush, lodged as much water round the edge of the metal as the projecting edge will hold, fill the hole of the metal and its handle with water, to prevent the evaporation of the moisture, and the consequent adhesion between the speculum and polisher, and let the whole rest in this state two or three hours: this will produce an intimate contact between the two, and by parting with any degree of warmth they may have acquired by the vicinity of the operator, they will grow perfectly cold together.

139. By this time you may push out the cork from the polisher to discharge the water, and give the metal the parabolic figure in the following manner:—

140. Move the metal gently and slowly at first, a very little round the centre of the polisher, (indeed after this rest, it will move stiffly,) then increasing by degrees the diameter of these strokes, and turning the metal frequently round its axis, give it a larger circular motion, and this without any pressure but its own weight, and holding it loosely between the fingers: this manner of working may safely be continued about two minutes, moving yourself as usual round the block, and carrying the round strokes in their increased and largest state, not

more than will move the edge of the metal half an inch or five-eighths over the tool. The speculum must not all this while be taken off from the polisher; and consequently no fresh putty can be added. It will not be safe to continue this motion longer than the time above mentioned; for if the parabolic tendency be carried the least too far, it will be impossible to recover a true figure of that kind, but by going through the whole process for the spherical one, in the manner before described, by the cross strokes upon the polisher, which takes a great deal of time. However, when there is occasion, it may be done; and I have myself several times recovered the circular figure, when I had inadvertently gone too far with the parabolic; and ultimately finished the metal on the polisher without the use of the hones.

TO TRY THE TRUE FIGURE OF THE METAL.

141. It will now be proper to try the figure of the speculum, and that is always best done by placing it in the telescope it is intended for. In order to this, I used the instrument as a kind of microscope, placing the object, however, at such a distance that the rays may be nearly parallel. At about twenty yards a watch-paper, or some such object, on which there are some very fine hair-strokes of a graver, is fixed up. The lead must be then taken off from the back of the speculum; which is best done by placing the edge of a knife at the junction of the lead and metal, when, by striking the back of it with a slight blow, the pitch immediately separates, and the handle drops off; the remaining pitch may be scraped off with a knife, taking care that none of the dust stick to the polished face of the metal.

142. Having placed the speculum in the cell of the tube, and directed the instrument to the object, make an annular kind of diaphragm with card-paper, so as to cover a circular portion of the middle part of the metal between the hole and the circumference, equal in breadth to about an eighth part of the diameter of the speculum: this paper ring should be fixed in the mouth of the telescope, and remain so during the whole experiment, for the part of the metal covered by it is supposed to be perfect, and therefore unemployed.

143. There must likewise be two other circular pieces of card-paper cut out, of such sizes, that one may cover the centre of the metal by completely filling the hole in the last described annular piece; and the other such a round piece as shall

exactly fit into the tube, and so broad as that the inner edge may just touch the outward circumference of the middle annular piece. It would be convenient to have these two last pieces so fixed to an axis that they may be put in their places, or removed from thence so easily as not to displace or shake the instrument. All these pieces therefore together will completely shut up the mouth of the telescope.

144. Let the round piece which covers the centre of the metal, or that which has no hole in it, be removed; and, by a nice adjustment of the screw, let the image (which is now formed by the centre of the mirror) be made as sharp and distinct as possible. This being done, every thing else remaining at rest, replace the central piece, and remove the outside annular one, by which means the circumference only of the speculum will be exposed, and the image now formed will be from the rays reflected from the outside of the metal. If there be no occasion to move the screw and little metal, and the two images formed by these two portions of the metal be perfectly sharp and equally distinct, the speculum is perfect, and of the true parabolic curve; or at least the errors of the great and little speculum, if there be any, are corrected by each other.

145. If, on the contrary, under the last circumstance, the image from the outside of the metal should not be distinct, and it should become necessary, in order to make it so, that the little speculum be brought nearer, it is plain that the metal is not yet brought to the parabolic figure; but if, on the other hand, in order to procure distinctness, you be obliged to remove the little speculum farther off, then the figure of the great speculum has been carried beyond the parabolic, and has assumed a hyperbolic form. When the latter is the case, the circular figure of the metal must be recovered (after having fixed on the handle with soft pitch) by bold cross strokes upon the polisher, finishing it again in the manner above-described. If the speculum be not brought to the parabolic form, it must cautiously have a few more round strokes upon the polisher; indeed a very few of them, in the manner before described, make in effect a greater difference in the speculum than would be at first imagined. If a metal of a truly spherical figure were to be tried in the above-mentioned manner in the telescope (which I have frequently done) the difference of the foci of the two segments of the metal would be so considerable, as to require two or three turns of the screw to adjust them; so very great is the aberration of a spherical figure of the speculum, and so improper to procure that sharpness and precision so necessary to a good reflecting telescope.

146. This is by no means the case with the object-glasses of refractors; for besides that they are in fact never so distinct as well-finished reflectors, the apertures of them are so exceedingly small, compared to the latter, and the number of degrees employed so very small, that the inconvenience of a spherical figure is not so much perceived. Accordingly, we observe in the generality of reflectors (whose specula, unless by accident, are always spherical) that the only true rays which form the distinct image arise from the middle of the metal: and unless the defect be remedied by a considerable aperture, which destroys much light, the false reflection from the inside of the metal produces a greyish kind of haziness, which is never seen in Mr. Short's, or indeed in any good telescopes.

147. Supposing that the two foci of the different parts of the metal perfectly coincide, and that by the union of them when the apertures are removed, the telescope shews the objects very sharp and distinct, you are not, however, even then to conclude that the instrument is not capable of farther improvement; for you will perceive a sensible difference in the sharpness of the image, under different positions of the great speculum with respect to the little one, by turning round the great metal in its cell, and opposing different parts of it to different parts of the little metal, correcting by this means the error of one by the other. This attempt should be persevered in for some time, turning round the great speculum about one-sixteenth at a time, and carefully observing the most distinct situation each time the eye-piece is screwed on: when, by trying and turning the great metal all round, the distinctest position is discovered, the upper part of the metal should be marked with a black stroke, in order that it may always be lodged in the cell in the same position. This is the method Mr. Short always used; and the caution is of so much consequence, that he thought it necessary to mention it very particularly in his printed directions for the use of the instrument.

148. And farther, Mr. Short frequently corrected the errors of the great by the little metal in another way. If the great speculum did not answer quite well in the telescope, he cured that defect sometimes by trying the effect of several metals successively, by this means correcting the errors of one by the other; for in several of his telescopes which have passed through my hands, when the sizes and powers have been the same, I have found that the great metals, though very distinct in their proper telescopes, yet have, when taken out and changed from one to the other, spoiled both telescopes, rendering them

exceedingly indistinct, which could arise from no other circumstance. For this reason I suppose it was, that he kept, ready finished, a great many large metals of the same focal length, so that, when he wanted to mount a telescope, he might, from a great choice, be able to combine those metals which suited each other best. I am strongly inclined to believe this was the case, not only from the above observation, but because he showed me himself a box of finished metals, in which I am sure there were a dozen and a half of the same focal length.

149. To return: A little use in working will make the whole of the process of grinding and polishing very easy and certain; for though I have endeavoured to be as particular as I can (I am almost afraid too much so) it is yet scarcely possible to supply a want of dexterity, arising from habit only, by the most laboured and minute description. And though the above account may appear irksome to the reader, as it lies cold before the eye, I am very sure, whoever attempts to make the instrument, will not complain of it as tediously particular.

150. I will, however, farther remark, that when the metal begins to move stiffly upon the polisher, and particularly when the figure is almost brought to the parabolic form, it will be necessary to fix the elbows against the sides, in order to give momentum and equability to the motion of the hand by that of the whole body.

151. The same polisher will serve for several metals, if it be somewhat warmed when you begin to use it.

152. There is another circumstance, and a material one too, which must not be omitted; it is this: For the very same reason that the pitch should not be too hard or soft, the work will not proceed well in the heat of summer, or the cold of winter; in the latter, it may be possible to remedy the defect by having the room warmed with a stove; and in the summer, the other inconvenience may perhaps be avoided by using a harder kind of pitch; but I much doubt in either case whether the work will go on so kindly; I have myself always wrought in spring and autumn.

153. The process of polishing, and indeed grinding upon the hones, will not go on so well if it be not continued uninterruptedly from beginning to end; for if the work of either kind be left but for a quarter of an hour, and you then return to it again, it will be sometime before the tool and metal can get into a kindly way of working; and till they do, you are hurting what was done before.

154. I have all along supposed that the metal we have been working was about four inches diameter: if it be either larger or smaller, the sizes of the hones, bruiser, and polisher, must be proportionably different. I never find any ill consequence arising from the different expansion from heat and cold in any of the tools, though they be made of different metals and substances, unless the inconvenience, occasioned by the interruption before hinted at, be thought to result from thence; for the alteration produced in the surface of the speculum, both by grinding and polishing, is so much quicker than any that can be supposed to arise from the former cause, that it is never attended with any practical consequence.

155. Magnifying very minute objects, and particularly reading at a distance, have been generally considered as the surest tests of the goodness of a telescope; and indeed when the page is placed at a great distance, so that the letters subtend but a very small angle at the eye, if then they appear with great precision and sharpness, it is most probable that the instrument is a good one. But we are, nevertheless, sometimes apt to be deceived by this method; nor is it always possible to determine upon the different merits of two instruments of equal power, by this mode of examination; for when the letters are removed to the utmost extent of the powers of the two instruments, the eye is apt to be prejudiced by the imagination. If two or three words can be here and there made out, all the rest are guessed at by the sense; insomuch that an observer, zealous for the honour of his instrument, is very apt to deceive himself in spite of his intentions. The surer test is by figures, where you can procure no aid from this sort of deception. In order to examine my reflecting telescopes, I made upon a piece of copper, and on a black ground, six lines consisting of about twelve pieces of gold figures, and each line of figures differing in magnitude, from the smallest that could be distinctly made, to those of about two-tenths of an inch long; moreover, the figures in the several lines were differently disposed, and the sum of each line also differed. It is evident that by this method all guess is precluded; and that of two instruments of the same powers, that which can make out the least order of figures, which will be known by the sum, is the best telescope. Such a plate I caused to be fixed up for experiments against the top of a steeple, about three hundred yards north of my house; and it will serve to give some idea of the distinctness with which very small figures could be made out at that distance, by saying, that in a clear state of

the air and with the sun behind me, with a telescope of eighteen inches focal length which Count Bruhl did me the honour to accept, and now has in his possession, I have seen the legs of a small fly, and the shadows of them, with great precision and exactness.

156. I cannot conclude without indulging myself in an observation on the amazing sagacity of Sir Isaac Newton in every subject upon which he thought fit to employ his attention. It was he who first proposed, and indeed practised, the polishing with pitch; a substance which at first sight perhaps every one but himself would have thought very improper, from its softness, to produce that correctness of figure so necessary upon these occasions; and yet I do believe, that it is the only substance in nature that is perfectly well calculated for the purpose; for at the same time that it is soft enough to suffer the putty to lodge very freely on its surface, and for that reason to give a most tender and delicate polish; it is likewise totally inelastic, and therefore never, from that principle, suffers any alteration in the figure you give it. If the first makers of the instrument, therefore, had given proper credit to, or had simply followed the hint Sir Isaac gave, it would have saved them infinite trouble, and they would have produced much better instruments; but the pretended refinement, of drawing a tincture from pitch, with spirits of wine, affords you only the resinous, hard, and untractable part of the pitch, divested of all that part of its original substance which is necessary to give it that accommodating pliability in which it excellence consists.

157. It is needless to swell this account with a detail of the process for polishing the little speculum, as it must be conducted in the same manner which has been already described in that of the large one; only observing, that as the little metal has an uninterrupted face, without a hole, so there is no occasion for one in the polisher; and likewise, that as a spherical figure is all that need here be practically attempted, so the difficulty in finishing is infinitely short of that of the other.

158. As it is always necessary to solder to the back of the little speculum a piece of brass, as a fixture for the screw to adjust its axis, I shall just hint a safe and neat method of doing it, which may be very useful to the optical or mathematical instrument-maker upon other occasions. Having cleaned the parts to be soldered very well, cut out a piece of tin-foil the exact size of them; then dip a feather into a pretty strong solution of *sal ammoniac* in water, and rub it over the surfaces to be soldered; after which place the tin-foil between them as

fast as you can (for the air will quickly corrode their surfaces so as to prevent the solder taking) and give the whole a gradual and sufficient heat to melt the tin. If the joints to be soldered have been made very flat, they will not be thicker than a hair: though the surfaces be ever so extensive, the soldering may be conducted in the same manner, only that care must be taken, by general pressure, to keep them close together. In this manner, for instance, a silver graduated plate may be soldered on to the brass limb of a quadrant, so as not to be discernible by any thing but the different colour of the metals. This method was communicated to me by the late Mr. Jackson, who during his life kept it a secret, as he used it in the construction of his quadrants, and it is, I believe, not as yet known to any workman.

159. In the annexed plate, are figured the shape of the leaden tool for rough-grinding; the hones; and the apparatus to be applied to the mouth of the telescope, to ascertain the true figure of the speculum.

160. It was some time after I had written the above account, that I saw Mr. Short's method of polishing object-glasses for refracting telescopes, (forming Essay II. of the present series.) By that paper I find that what I before strongly suspected is really the case, viz. that he knew how well pitch was calculated for purposes of this kind. Only it may be remarked, that as glass is much harder, polishes much slower, and consequently does not wear away and alter its figure so soon as the metal of which the speculum is made; and as at the same time (on account of the very small apertures allowed to telescopes of this sort) nothing more than a spherical figure is proposed; he is therefore obliged to use pitch in a hard, friable, and stubborn state: whereas, considering the delicate substance of the metal speculum, and the figure intended to be given to it, the soft pitch of the common sort, by suffering the putty to bed itself in its substance, produces the most beautiful polish; and by its pliability is better calculated for that mutual accommodation between polisher and metal, which is so necessary to the figure proposed.

EXPLANATION OF THE FIGURES, PLATE LXXXIII.

Fig. 1. The grinder for working off the rough face of the metal; the black strokes represent deep grooves made with a graver.

Fig. 2. The bed of hones, which is to complete the spherical figure of the speculum, and to render its surface fit for the polisher.

Fig. 3, An apparatus for examining the parabolic figure of the speculum.

AA, the mouth of the telescope, or edge of the great tube.

BB, a thin piece of wood fastened into, and flush with the end of the tube; to which is permanently fixed the annular piece of pasteboard CC, intended to cover, and to prevent the action of the corresponding part of the speculum.

D, another piece of pasteboard, fixed by a pin to the piece of wood BB, on which it turns as on a centre; so that the great annular opening HH may be shut up by the ring FF, or the aperture GG by the imperforate piece E, in such manner that, in the first instance, the reflection may be from the centre, and in the latter from the circumference, of the great speculum.

ESSAY VI.

Directions for making the best Composition for the Metals of reflecting Telescopes, and the Method of casting, grinding, polishing, and giving the great Speculum the true parabolic Figure.

161. The methods in general use for casting, grinding, and polishing the metals for reflecting telescopes being well known to workmen, and having been treated of in the most full and satisfactory manner in Essays III and V, I shall not dwell upon these points, but shall add such directions and observations of my own as I have found by experience to answer much better than the methods taught by those writers. Some telescopes constructed by me have been tried by the Rev. Dr. Maskelyne, Astronomer Royal, and found very greatly to excel in brightness,* and to equal in other respects telescopes of the same size, constructed by the best artists in London.

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* "Mr. Edwards's telescopes show a white object perfectly white, and all objects of their natural colours; very different from common reflecting telescopes, which give a dingy copperish appearance to objects. I found by a careful experiment, that they shew objects as bright as a treble object-glass achromatic telescope, both being put under equal circumstances of areas of the aperture of the object-metal and object-glass, and equal magnifying powers; whereas the diameter of the aperture of a common reflecting telescope must be to that of an achromatic telescope as 8 to 5, to produce an equal effect."

NEVIL MASKELYNE.

OF THE BEST COMPOSITION FOR REFLECTING SPECULA.

162. That I may not be tedious upon this point, it may be necessary to acquaint my reader, that I have made experiments upon the following metals and semi-metals, in order to discover a composition for a speculum, which should reflect the greatest quantity of light, and consequently be capable of receiving the finest polish. I combined them in several proportions, and ground and polished them. The metals and semi-metals I tried were silver, platina, iron, copper, brass, lead, and tin; crude antimony, regulus of antimony, martial regulus of antimony, arsenic, bismuth, zinc, and antimony combined with cawkstone.* Having tried many compositions of them, (as enumerated in the concluding section of this essay,) I found that 32 ounces of copper, with 15 or 16 ounces of grain tin (according to the purity of the copper) with the addition of a little brass and arsenic;† viz. one ounce of each to the above proportion of copper and tin, will form a metal capable, when polished in a proper manner, of reflecting much more light than any other metal that has as yet been offered to the public.

163. When I say that the proportion of tin is from 15 or 16 to 32 ounces of copper, I would be understood, that the proportion of tin will not always be accurately the same, as copper will take more or less tin to perfectly saturate it, according to its purity. It might be of use previously to purify the copper as much as possible. A very little experience in these matters will enable any one to know exactly when the copper is completely saturated; as the composition will, if broken, appear of a most beautiful, bright, and glassy nature, very much resembling the fine face of quicksilver. My method to ascertain that point accurately, is to melt 32 ounces of copper, and to add to it, when sufficiently fused, 15 ounces of tin, and to pour the mixture into an ingot: then to a certain known portion of this composition, I add a very small, but known portion of tin, and thus, by a few trials, I can easily obtain the point of complete saturation, and the maximum of perfec-

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* See a most curious experiment upon cawkstone and antimony in the Philosophical Transactions, No. 110.

† If one ounce of silver be added to this composition, the metal will be much better and whiter.

tion. Having then ascertained what portion of tin I added to the above know quantity of the composition, I add the proportional quantity of tin to the whole, when melted a second time. Thus, if I find that I must add a quarter of an ounce of tin to one pound of the composition, so as to obtain the *ne plus ultra* of brilliancy;[*] then I know, that when I shall melt the remainder of the metal a second time, in order to cast the speculum, I must add one ounce of grain tin to four pounds of the composition, made according to the proportion of 32 ounces of copper to 15 ounces of tin. The arsenic must be added in the second melting, when the speculum is intended to be cast, as the heat of the mixture, in the first melting,[†] is so great as to render the most part of the arsenic volatile, and in a great measure prevent its action upon the metals. It is somewhat singular that arsenic, though particularly recommended by Sir Isaac Newton [‡] for this purpose, should be hastily thrown aside by the founders, as well as passed over unnoticed by the writers upon this subject. This imprudent disuse of it I can only attribute to the disagreeable fumes or vapours which arise when it is introduced into the crucible to the melted mixture, which may produce disagreeable effects upon the operator, if proper care be not taken to prevent them from being received into the lungs [§]. All the precaution necessary, is to bruise the arsenic coarsely, and introduce it into the crucible with a pair of tongs, having tied it up in a piece of paper; giving it then a stir with a wooden spatula, retaining your breath, avoid it till you can see no more vapours arise from the crucible, when the metal will be ready to be poured into the flasks to cast the speculum.

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[*] If too much tin should be added; viz. if 17 ounces of tin are put to 32 ounces of copper, the composition is not brilliant when broken, but of a gray, blue, and dull colour. If the quantity of the tin be further increased, the metal will become almost black.

[†] Sir Isaac Newton melted the copper first, then added the arsenic, and lastly the tin; as without doubt he knew that the tin should remain in a fluid state the shortest time possible. It is true that Sir Isaac added the arsenic to the melted copper; but as he well knew that a great part of it would be rendered volatile, he therefore added a very large quantity of it; viz. arsenic 1 to copper 6.

[‡] See Dr. David Gregory's Optics, by Dr. Brown and Dr. Desaguliers, p. 219; or Philosophical Transactions, No. 81.

[§] I have been assured by two ingenious experimental philosophers, that the fumes of arsenic, even when the garlic smell is very strong, are not in the least prejudicial to the lungs.—Nevil Maskelyne.

164. The great use of arsenic, in this composition, is to render the metal much more compact and solid, and indeed much more beautiful, as any one may experience by comparing the composition with arsenic, with the same composition of copper and tin without arsenic. In general I find one ounce of arsenic* sufficient for one pound of metal. A much greater quantity of arsenic may be used without any disadvantage to the beauty or compactness of the metal; but then it is too apt to tarnish if exposed to the air for some time; three-quarters of an ounce, or an ounce of arsenic, to one pound of composition, will not tarnish in the least degree. Indeed the reason why the metals, generally made use of for specula, tarnish when they are much exposed to the air, is because the quantity of copper in their composition is not nearly saturated, and the acid (oxygen) contained in the air, by acting upon it, extracts the copper from the tin, (oxidizes the copper,) and turns the metal into a dirty or dingy-coloured speculum, and which (besides the great loss of light) causes the common reflecting telescopes to show all objects of a dirty red or yellowish colour. This, however, is not the case in the metals made of the above composition; for, as the copper is completely saturated, the air cannot act upon it in the least degree.

165. I must not, however, pass over one caution in the mode or manner of melting the composition, and that is, that the copper must be melted first of all, and rendered as fluid as possible, then the brass and silver must be added, and the whole fluxed with the common black flux, made of two parts of tartar to one of nitre, or by stirring the melted mixture with a wooden spatula of birch, and made as fluid as possible. The tin must now be added, and the whole poured off immediately after it is once stirred together; for if the mixture is continued on the fire some time after the tin is added to it, it will always prove porous afterwards, though it be melted a second time with the smallest heat possible. As I ever found this to be the case, I naturally conjectured that the metal would be most solid and free from pores, when the tin remained the least time possible in a state of calcination. Experience determined the truth of my conjecture, and I now find that the best method possible to make this composition to the greatest advantage is, to melt the copper as fluid as possible; and flux

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* One ounce of arsenic will, however, sufficiently act upon and bind three pounds weight of the metal, so that it shall never tarnish by the air.

it with the black flux; to melt the tin in a separate crucible by itself; to take the two crucibles out of the fire, and pour the melted tin into the fluid copper; and stir it instantly with a wooden spatula, and pour the whole immediately into a large quantity of cold water. The sudden chill from the cold water divides the melted mass into an infinite number of small particles, and by that means cools it instantaneously, and consequently prevents the tin from calcining sensibly; and hence I have always found, that in the second melting, the composition was entirely free from pores, even though no arsenic had been employed. Yet the addition of arsenic ever rendered it much more compact, and indeed specifically heavier,* as well as more brillant and beautiful. On reversing the process, if the tin is put into the bottom of the crucible, and the copper at the top of it, which I have frequently done, the copper will melt with a very little heat; whereas, when the copper is put into the crucible by itself, it requires a pretty strong heat to cause it to melt. When I first made use of this method, I imagined I had discovered a very easy one to melt the copper, and consequently I thought I had greatly improved the common method: and as Mr. Mudge ascribed the pores in the metal to the tin being calcined by the great heat of the fluid copper at its first melting, I naturally expected to find the metal, made by the above process, totally free from pores, especially in the second melting, as the heat was considerably less than if the copper had been melted first by itself. However, I always found it full of pores, much more porous than I had ever seen it before. For some time I could not discover the true cause, having no idea that the pores were owing to the tin remaining so long in the fire in a fluid state, and therefore in a state of perpetual calcination. I attributed the porosity of the metals, which I made of this composition, to a multiude of causes, till thoroughly tried of experiments and conjectures to ascertain the true reason, I was determined to melt the copper first and the tin afterwards, as I had always done before I dropped upon this improved method, as I imagined. The result was, the metal was infinitely more compact, and much less porous. By melting the copper first, and then adding the tin to it, I soon discovered that the longer the tin remained in the fire, the

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* The specific gravity of the composition itself is 8.78; with the addition of one ounce of arsenic to one pound of metal, is 8.80.

more porous the metal turned out; and *vice versa*, the sooner I poured it off, after I had added the tin, the more compact and free from pores it proved. From these observations, I determined to try the effect of adding the tin in a fluid state to the melted copper; and to cool the whole immediately, to prevent, as far as I was able, calcination from taking place. Experience confirmed my conjectures; and I soon found that by pouring the whole melted mass, the instant they were mixed and stirred together, into cold water, the metal always proved in the second melting, solid, and much more compact, beautiful, and white, than I had ever seen it by any other process. One thing I cannot pass over, as it affords a clear proof of the use of arsenic in rendering the metal much more solid and compact, and consequently more free from pores, than if no arsenic had been used in the composition: Whenever I made the composition, by melting the copper and tin together, by putting them into the crucible at the same time, and melting them down together, the metal was always porous, as I observed before; however frequently I melted it afterwards, and though I gave it no more heat than was barely necessary to melt it: yet if I added to this very porous metal, after it was melted, a small quantity of arsenic, viz. an ounce to one pound of the metal, it was really astonishing to see how much better the metal turned out, being considerably harder than before, and incomparably less porous. I mention this circumstance, which any one may easily try, to show the very great advantage of using a small portion of arsenic to render it more compact, and, as Sir Isaac Newton justly observes, more white, than before.

166. The use of the small portion of brass in this composition is to render it more tough, and not so excessively brittle as this composition without the brass would prove. A small portion of silver will render the metal much whiter, though, if too much is added, it is apt to be porous.

Having said so much relative to the composition of the metal, which indeed is a capital article, I pass on to

THE MANNER OF CASTING THE METAL.

167. The sand most proper for casting this, and indeed any other metal, is a fine sand, with no more loam or clay mixed with it naturally, than is absolutely necessary to make it tenacious enough to adhere together when properly moistened

If too much clay is mixed by nature with the sand, it will always blow the metal in different directions, sometimes indeed to the great danger of the operator. On the contrary, if the sand does not contain a sufficient quantity of clay, it will not remain in the flasks, or take a proper impression from the pattern or model. The best sand I could ever meet with for the purpose of casting specula, is the common Highgate sand (near London) generally used by the London founders. It should be as little wet as may be, and well beaten, but not too hard. The flasks should be at least two inches wider than the metal intended to be cast. If the sand is not of a sufficient thickness round the metal, it will constantly become dry when the hot fluid metal is poured into it, and consequently will contract, and, of course the fluid metal will run out of the flasks. A proper thickness of sand will, however, prevent this accident. The metal or pattern should be made of brass or hard pewter, and must be a little larger and thicker than the speculum intended to be cast from it; as the thing cast is always a little less than the pattern, owing to its contracting a small degree in cooling. A wooden pattern will not quit the sand near so well as one made of metal; besides, wood will always warp by the moisture of the sand, and consequently will give a false figure or form to the intended speculum.

168. As the composition I have given for the speculum is the hardest, and consequently the most brittle of any metal yet known, so it is the most difficult to cast. The common manner of casting other specula, will not avail, in the least degree, here; and it was a very considerable time before I found out a certain and infallible way to cast them free from faults or flaws in the face. In general, they cracked in the cooling, from the moisture of the sand. The only method possible to cast them well, (for indeed I have tried many methods,) is to cast them with the face downwards. The ingate or git should be at the back of the metal, and at the very edge of it; its breadth, where it joins the metal, should be at least half the diameter of the metal, and its thickness must be half the thickness of the metal at the edge; the upper part of the git should contain as much metal, at least, or even more, than the speculum itself. I could give my reader sufficient reasons for every part of the process above directed, but I might be thought too tedious: suffice it then that I inform him, that he will find these directions to answer in practice; and, I believe I can say, that no one whatever can cast specula, of this

brilliant and brittle composition, by any other means than what I have now pointed out.

169. When the pattern, with its ingate or git, is taken out of the sand, ten or a dozen small holes should be made through the sand, at the back of the mould, with a small wire or common knitting needle to permit the air to escape, as the metal is poured into the mould. I have found by experience, that several small holes are infinitely better for that purpose, than one large hole.*

170. When the metal is melted a second time, which must be done with as small a degree of heat as possible, add the proportional quantity of crude arsenic in coarse powder, and stir it well with a wooden spatula; when the fumes are gone off, take the metal off the fire, take away the dross, and add half an ounce or an ounce of powdered rosin, or equal parts of powdered rosin and nitre, in order to give the metal a good face; stir it well with a stick, and pour it immediately into the flasks. When the git is filled up with the fluid metal, strike the flasks gently, so as to shake or jog the metal in them in a small degree; this will prevent any flaws in the face from any air-bubbles being lodged there. When the metal has remained in the flasks for a few minutes, so as to become entirely solid, open the flasks while the metal is red-hot, (it cannot crack in this state, though it is exposed to the air, as all metals are malleable when they are red-hot,) and take out the speculum with a pair of tongs, laying hold of it by it the git, but take care to keep the face downwards, to prevent it from sinking. Force out the sand from the hole, in the middle of the mirror, with a piece of wood or iron, and place the speculum in an iron pot, with a large quantity of hot ashes or small coals, so as to bury the speculum in them a sufficient depth. If the sand is not forced out of the hole, in the manner above directed, the metal, by sinking as it cools, will embrace the sand in the middle of the speculum so tight, as to cause it to crack before it becomes entirely cold. And if the metal is not taken out of the sand, and put into a pot with hot ashes or coals to anneal it, I can assert that the moisture from the sand will always break the metal. Let the speculum remain in the

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* If several small holes are made for the air to escape, the back of the metal will be cast much neater than if one hole only is used for this purpose. Besides, when one hole only is used to let the air escape, the metal is very apt to crack in that place, owing to the sinking of the metal in cooling.

ashes till the whole is become quite cold. The git may be easily taken off by marking it round with a common fine half-round file, and giving it then a gentle blow. The metal is then to be rough-ground and figured.

OF ROUGH-GRINDING AND FIGURING THE SPECULUM.

171. In rough-grinding, figuring, and polishing the metal, two tools only are necessary, besides a common grindstone. One chief reason why workmen do not give a good figure to their specula, is, that they use too many tools, which in a great measure destroy each other's effects. As nature always acts in the most simple manner, so if we could always imitate her in this respect, we should arrive at a much greater degree of excellence in most of our mechanical pursuits. Besides, the tools generally made use of by workmen are considerably too large in diameter ever to give a correct and uniform figure. All the tools I make use of, are a rough grinder, composed of lead and tin mixed together, or else of pewter: this rough-grinder serves also for a polisher. This tool, with a bed of stones or hones, are all that are necessary. A bruiser (as directed in Essays III and V) is totally unnecessary, causes considerably more work, and, after all, is really detrimental. The best method I have ever found to rough-grind the speculum, is to grind the surface of it quite bright upon a common grindstone,* made nearly to the figure or focus of the speculum by a gauge. Take it then to a convex tool made of lead and tin, or else of pewter, and grind the metal upon it with fine emery. This emery, however fine it may be, will break up the metal very much; but we can easily cure that process, as I shall show hereafter. This tool or rough grinder, should be made of an elliptical form, and not circular, (for a reason I shall point out hereafter,) and of such dimensions, that the shortest diameter of the ellipse shall be equal in breadth to the diameter of the mirror, and the longest diameter of the elliptical tool should be to the shortest diameter in the proportion

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* The grindstone may easily be brought to the form of the guage, by holding the sharp edge of an iron bar against it, whilst it is turned round, till so much is worn away from its surface, as shall cause it to take the true curvature of the guage.

of 10 to 9 accurately, for a reason to be mentioned hereafter. The manner of working or figuring the metal upon this tool, and indeed upon all the succeeding tools, is taught in Essays III and V, to which I shall refer my reader, as I only mean to give my own improvements.

172. When the metal is brought to a true figure, it must be taken to a convex tool, formed with some stones brought from a place called Edgedon, in Shropshire, situated between Ludlow and Bishop's Castle. These stones or hones are of a fine grain, and will easily cut the metal and bring it to a fine face. Indeed the blue hones,* used in general by the opticians for this purpose, will scarce touch the metal, and it will be a laborious undertaking to bring the metal to a fine face, so as to take out all the breaks-up from the emery, by the common blue hones. By means, however, of the above-mentioned stones, they may easily be ground and truly figured. The bed of stones should be of a circular figure, and but very little larger than the metal intended to be figured upon it; viz. about two-tenths of an inch, but not more, for a speculum of four or five inches in diameter. If the tool is made considerably larger than the metal, it will grind the metal perpetually into a larger sphere, and by no means of a good figure: if the metal and tool are of the same size exactly, the metal will work truly spherical; but it is apt to shorten its focus less and less, unless the metal and tool are worked alternately upwards. It had therefore better be made a little larger (about one twentieth part greater in diameter) than the mirror, when it will not shorten its focus. Too much water should not be used at a time upon the hone pavement, or the figure will be very bad, which may easily be seen by the face of the metal appearing of different degrees of brightness in different parts of it.

173. When the metal is brought to a very fine face and figure by the bed of stones, it is ready to receive a polish; but before I shall give my directions concerning the manner of polishing it, I must mention a circumstance or two I had inadvertently passed over. The metal must not be cast too thick, or it will never take the parabolic figure intended to be given to it. The best proportion I have found for this

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* Should any one, however, make use of the common blue hones, he should use as little water as possible, when the metal is put upon them, as they will cut much better when barely wet, than if much water is used upon their face

purpose is, a metal of 4½ inches diameter and 18 inches focus, should be four-tenths of an inch thick at the edge of it; the back of the mirror should be convex, to strengthen it, and to cause it to spring and adhere to the polisher uniformly. Its convexity should be equal to its concavity on the face, that the metal may be every where of an equal thickness. The handle should be made of lead, of the same convexity and concavity as the metal, its thickness about double that of the metal, and its diameter three-fourths of that of the speculum; it should have a hole in the middle, with a copper or iron screw on it, so as to put it, together with the mirror, to which it is fastened with pitch, on a collar lathe, in order to smooth and finish the edge of the metal, which may be done by holding, at the first, a fine file to it, when in the lathe, and afterwards one of the above-mentioned stones. The motion of the lathe should be slow while the file is used, and the pressure light.

OF POLISHING THE METAL, AND GIVING IT THE TRUE PARABOLIC FIGURE.

174. The rough-grinder of an elliptical form, is now to be covered with common pitch. I generally make my own pitch by boiling tar in a ladle, or crucible, over a very slow fire, till it becomes of the consistence I require; for a great nicety, is required in the degree of the hardness of the pitch. The harder the pitch is, the better figure it will give to the metal, as it does not alter its figure in working, as soft pitch does; besides, the metal will acquire a lustre upon a polisher moderately hard, so as to show objects reflected from it as vivid, and as near their natural colour, as possible; but if the pitch is too soft, some of its finest particles will always adhere to the face of the metal, and form a very fine and thin cuticle or covering upon its surface. This circumstance is rendered very evident by viewing any white object in the metal, (a sheet of white paper for example,) when that fine cuticle or thin surface of the pitch upon the speculum will cause it to show the object of a dingy brown colour, and not of its genuine whiteness. Pitch may be easily made harder, by adding to it a proper quantity of rosin. I often use equal quantities of pitch and rosin, so as to make the mixture just so hard when cold as to receive an impression from a moderate pressure of my nail. A polisher made with pitch and rosin has this advantage: viz. though it is hard, yet it is not so

brittle as when pitch only is used, and made hard by boiling it, and consequently not so liable to break or chip off at the edges, and thereby scratch the metal. Pour the melted pitch and rosin, when pretty cool, from the crucible upon the elliptic tool,* so as to cover it every where, when spread upon it with an iron spatula, about the thickness of a half-crown piece. If the covering is too thin, it will continually alter its figure, by the heat it acquires in working the metal upon it, and thereby give a bad figure also to the speculum. When it is somewhat cool, lay a piece of writing paper upon the surface of the pitch, and gently press the mirror upon the paper; instantly pull the paper from off the pitch, after you have pressed the mirror upon it, else it might adhere to the pitch, and you will find the polisher will be nearly figured to the form of the speculum. If it has not taken an exact figure every where, which would appear by the fine marks of the grain of the paper upon the pitch, gently warm the surface of the pitch, and repeat the operation as before, till you have formed it of the exact figure of the metal.† With a penknife take away now all the superfluous pitch from the edge of the polisher, and with a conical piece of wood form the hole in the middle accurately round; in other words, let the pitchy surface be every where of the exact size and shape as the lead tool which is under it.

175. It may be necessary to mention, that the hole in the middle of the polisher should go quite through the tool, (for a particular reason,) and should be made of the same size, or somewhat less, than the hole in the middle of the speculum. This is a necessary caution, and indeed I have always found that small mirrors, without any hole in the middle, will polish much better, and the figure will be more correct, if the polisher has a hole in the middle of it.

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* The elliptic tool must be made pretty warm, or the pitch will not adhere to it.

† When the polisher is brought to its true figure, gently warm it at the fire, and with the edge of a knife divide it into several squares, by pressing the edge of the knife gently upon the pitch. These squares, by receiving the small portion of the metal that works off it in polishing, will cause the figure of the speculum to be more correct than if no such squares had been made.—The polisher may also be formed, without the writing paper, by dipping the mirror into cold water, and afterwards pressing it upon the surface of the pitch, (when it is somewhat cool,) and by repeating this operation till it has taken the exact figure of the metal.

176. The powder I prefer above all others, to give a most exquisite lustre, is colcothar of vitriol,* and not putty. Putty gives metals a white lustre, or, as workmen call it, a silver hue; but good colcothar of vitriol will polish with a very fine and high black lustre, so as to give the metal finished with it, the complexion of polished steel. To know if the colcothar of vitriol is good, put some of it into your mouth, and if you find it dissolves away, it is good; but if you find it hard and cranch between your teeth, then it is bad, and not well burned. Good colcothar of vitriol is of a deep red, or a deep purple colour, and is soft and oily when rubbed between the fingers: bad colcothar of vitriol is of a light red colour, and feels harsh and gritty. The colcothar of vitriol should be levigated between two surfaces of polished steel, and wrought with a little water; when it is worked dry, you may add a little more water to carry it lower down to what degree you please. When the colcothar of vitriol has been wrought dry three or four times, it will acquire a black colour, and will be low enough or sufficiently fine to give an exquisite lustre. This levigated colcothar of vitriol I put in a small phial, and pour some water upon it, and afterwards I use it for polishing the metals in the same manner that washed putty is always directed to be made use of for that purpose. I always put on a large quantity of washed colcothar of vitriol at once, so as to saturate the pitch, and form a fine coating of the colcothar, and very rarely make use of a second application. If a second or third application of colcothar should be found necessary to bring the metal to a high lustre, or to take out any scratches upon its face, use it very sparingly, or you will destroy the polish you have already attained. When the metal is nearly polished, it will always generate some black mud upon the surface of the mirror, and also upon the tool. Wipe it now away from the face of the metal, with some very soft wash leather; though if too much of this mud be taken away, it will not polish so well. Indeed a little experience in these matters, will better suffice than a volume written upon the subject.

177. In regard to the parabolic figure to be given to the metal, no particular caution is required in the polishing; the

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* Colcothar of vitriol is the ancient name for what chemists now call the red oxide of iron. It may be prepared, by calcining the sulphate of iron (common copperas) until it becomes red.

elliptical tool will always cause the speculum to work into an accurate parabolical figure, supposing the transverse and conjugate diameters bear the true proportion to each other, and the metal is not too thick to prevent it always from adhering firmly and uniformly to the polisher. Should the pitch prove too soft, it will give way, and alter the figure a little. This circumstance will render the figure of the mirror sometimes a small degree short of the parabola, and sometimes a very little beyond it; but by a little perseverance the correct figure is very easily acquired.

178. I could very easily give the reader the reason why an elliptical tool, of a proper proportion, will always give a parabolical figure; and, if the transverse diameter is increased, it will then always give a hyperbolical figure; but as I am writing upon the practical part of making reflecting telescopes, and not the theory, I will not offend his patience. To convince any one of the certainty of my assertions, let him polish a metal 2½ inches diameter, and 9½ inches focus, upon an elliptical tool, whose diameters are 2½ and 3 inches, and I can assert he will always find the metal, when polished, (if it is not too thick) beyond the parabola, or it will always prove hyperbolical. If he poliishes it upon a circular tool in the common way, with cross strokes in every direction possible, using first a few round strokes every time he changes his position, he will find it will always prove spherical, and consequently short of the parabola. A very little experience in these matters will convince any one of the ease and certainty of giving the great speculum a parabolic figure by polishing it in a common manner only, with cross strokes in every possible direction, upon an elliptical tool of the proper dimensions, in which, for common foci and apertures, viz. 2½ to 9½ focus, or 3.8 inches in diameter to 18 inches focus, the diameters should be 10 to 9. The shortest diameter of the ellipse being accurately the same as the diameter of the metal, and the longest diameter of the ellipse to the shortest diameter as 10 to 9.

APPENDIX.

AN ACCOUNT OF SEVERAL COMPOSITIONS OF METALS, ON WHICH TRIALS WERE MADE, TO FIND OUT THE MOST PROPER MIXTURE FOR THE SPECULA OF REFLECTING TELESCOPES.

1. Copper and tin, equal parts—very bad, soft, and of a blue colour.
2. Do. with arsenic ⅛th—but little different from the 1st.
3. Tin 2, copper 1—much worse than the preceding ones.
4. Copper 32, tin 16, arsenic 4, nitre 4—black and brittle.
5. Copper 6, tin 1¾, arsenic 1—very indifferent.
6. Copper 32, tin 14, arsenic 2—a very good metal.
7. Copper 32, tin 13½, arsenic 1—not quite so good as the sixth.
8. Copper 32, tin 13½, arsenic 1½—a good metal.
9. Copper 32, tin 15, arsenic 2—much better than any of the above.
10. Copper 6, tin 2, arsenic 1—compact, but very yellow when polished.
11. Copper 3, tin 1¼—compact, and whiter than the 10th.
12. Copper 32, tin 14½—a pretty good metal, but polishes too yellow.
13. Copper 32, tin 15, arsenic 2, flint-glass in powder 3—very bright, but rotten.
14. Brass 6, tin 1—compact, but too yellow.
15. Two parts of 11th composition, and one part of 14th composition—compact, but much too yellow when polished.
16. Brass 5, tin 1—somewhat whiter than 14th.
17. Brass 4, tin 1—a good metal, but rather yellow.
18. Brass 4, tin 1, with arsenic ⅒th—whiter than 17th.
19. Brass 3, tin 1—will not polish well.
20. Brass 2, tin 1—of a sparry nature.
21. Tin 3, brass 1—too soft, being only a kind of hard pewter.
22. Brass and arsenic, equal parts—a dirty white colour.
23. Brass, copper, and arsenic, equal parts—a dingy white.
24. Brass and Platina, equal parts—very difficult to fuse and mix well together, is then malleable, and of a dingy white colour, like 22d composition.

25. Copper 32, tin 14, crude antimony 4—black and rotten.

26. Copper 32, tin 14, crude antimony 1—bluish and rough-grained.

27. Copper 32, tin 15, arsenic 4, bismuth 2—much too rotten.

28. Copper 32, tin 15, arsenic 3, bismuth 1—much too yellow when polished, and appears also porous.

29. Copper 2, zinc 1—a pale malleable metal.

30. Copper and zinc, equal parts—still malleable and rough-grained.

31. Copper 32, tin 15, arsenic 4, zinc 4—a good metal, but does not take a high lustre.

32. The 31st composition fluxed with corrosive sublimate—a compact and hard metal, but rather yellow when polished.

33. Copper 32, tin 16—a most beautiful brilliant composition, but much too brittle and rotten.

34. Copper 32, tin 17—bluish and rough-grained.

35. Copper 32, tin 18—almost black and rough-grained.

36. Brass 2, zinc 1—nearly a gold colour.

37. Brass and zinc, equal parts—a pale gold colour, and rough-grained.

38. Spelter 4, tin 1—very rotten.

39. Copper and crude antimony, equal parts—of a sparry nature.

40. Copper 32, tin 15, arsenic ¼th of the whole—a very beautiful and brilliant metal, but tarnishes when exposed for some time to the air.

41. Silver and bismuth, equal parts—a yellowish white metal, and not much harder than silver itself.

42. Silver and tin, equal parts—a white metal almost like silver itself, and much too soft for specula.

43. Silver, tin, and bismuth, equal parts—a dingy white colour, but much harder than 41 or 42.

44. Copper 32, tin 15, silver 1—a beautiful compact metal, but polishes rather too yellow.

45. Copper 32, tin 15, silver 2—not so white as 44.

46. Copper 32, tin 16, brass 4, arsenic 2—rather too much tin as the composition was of a bluish complexion and rough-grained.

47. Copper 32, tin 15, brass 1, silver 1, arsenic 1—a most excellent metal, being by much the whitest, hardest, and most reflective, I have ever yet met with.

48. Common bell-metal—polishes very yellow.

49. Common bell-metal 4, regulus of antimony 1—bluish and rough-grained.

50. Common bell-metal 6, regulus of antimony 1—still bluish and rough-grained.

51. Copper 32, tin 14, regulus of antimony $\frac{1}{16}$th; viz. 1 oz. to 1 lb.—too much antimony, it being of a bluish colour and rough-grained.

52. Copper 32, tin 13, regulus of antimony $\frac{1}{18}$th—bluish and rough.

53. Copper 32, tin 13, regulus of antimony $\frac{1}{32}$d; viz. 1 oz. to 2lb.—a very fine metal, in appearance like 33.

54. Copper 32, tin 13, regulus of antimony $\frac{1}{40}$th; viz. 1 oz. to 2½lb.—a beautiful metal, not much unlike 47, but not quite so white.

55. Crude antimony 16, cawk-stone 1 or 2 oz.—a very bright glassy metal, like the common vitrum antimonii, but by no means fit for mirrors.

56. Copper 32, tin 16, vitrum antimonii made from the cawk-stone 1 oz.—a very indifferent composition, as the vitrum antimonii did not differ in its effects from crude antimony.

57. Copper 32, tin 14, lead 2—no art can make this composition mix intimately, as the lead will always separate from the copper and tin.

58. Copper 32, tin 16, regulus of antimony 3—black, and much too rotten.

59. Copper 32, tin 16, iron filings 8—a bluish gray colour and rough-grained, and appeared somewhat like steel when broken through.

60. 59th composition 8 oz. tin 1 oz.—a little whiter than 59th, but still too blue.

61. Equal parts of 59 and 60—still of too blue a colour, and not close-grained.

62. Copper 32, tin 16, arsenic 3, iron filings ¼th of an ounce—a pretty brilliant composition, but much inferior to 47.

63. Platina 1 oz. brass 1 oz. cawk-stone, red hot, ½ oz.—excessively difficult to fuse, and of a dirty light-brown colour, and somewhat malleable.

64. Copper 30, tin 16, iron-filings 4, regulus of antimony 4, and fluxed with corrosive sublimate—an exceedingly hard and compact metal, but of too blue a colour.

65. Copper 2 oz. tin 1 oz. iron-filings 1 dr. regulus of antimony 1 dr.—too blue a colour and rough-grained.

66. Regulus of antimony and tin, equal parts—sparry, and not fit for mirrors.

67. Cast-steel—will not polish upon pitch either with putty or colcothar of vitriol.

68. Steel 1, tin ¼th—very rough-grained and bluish, and not much different from steel itself.

69. Steel 1, tin 1—rough-grained, and of a bluish colour.

70. Steel 1, and 47th composition 20 parts—rough-grained, and not near so good as 47.

71. Steel 1, and 47th composition 30—not much different from 47th composition, but not so beautiful and close-grained.

Many other mixtures were tried by combining the foregoing compositions in more than a hundred variety of proportions ; but none of them were found equal to No. 47, as that mixture forms a metal that is the whitest, hardest, most reflective, and takes the highest lustre, of any thing I have yet seen.

REMARKS ON SEVERAL OF THE ABOVE COMPOSITIONS.

4. The nitre was added to fix the arsenic.

13. Flint-glass was added as a flux. See Shaw's Chemistry, page 255.

The 10th is the composition of Sir Isaac Newton. See Appendix to Gregory's Optics, p. 221. The 11th, 14th, and 15th, are the compositions of Mr. Molyneux, see Essay III ; and the 12th is the composition of Mr. Mudge, see Essay V.

19 and 21. These compositions are mentioned by Neri and Kunchall, in Neri's art of Glass-making. Surely they never tried those compositions themselves, but took them upon the report of other authors ; as the 19th will not take a good lustre, and the 21st is very soft like hard pewter, therefore highly improper for specula, which should be as hard as possible.

33. Unless the copper is very pure, this composition will be of a dark blue colour, as 15 ounces of grain tin will generally saturate two pounds weight of copper.

47. This metal, when broken, should appear of a bright, glassy, and quicksilver complexion. If it appears hard, and of a dead white, more tin must be added (the copper will sometimes take 16 ounces of tin, if it is very pure.) If it appears bluish and rough, more copper or brass must be added,

49. The common bell-metal is not a mixture of pure copper and tin, but tin mixed with copper ore, a little purified, before it is brought into pure copper.

55. See this most wonderful stone, (cawk-stone,) and its strange effect upon antimony, described in the Philos. Trans. No. 110.

62. In all compositions with iron in them, the mixture will not run sufficiently fluid.

64. The regulus of antimony was added here, to dissolve or cause to melt the iron-filings.

68. The steel was melted by a furnace of a particular construction, built on purpose, as it would not melt in a crucible and a common air-furnace.

ADDITION TO THE DIRECTIONS CONCERNING THE COMPOSITION OF THE METALS OF REFLECTING TELESCOPES.

180. After writing the Essay commencing at page 176, the author, from his anxiety to be completely explicit, added the following remarks.

In making the composition of the metal, it is better to proceed thus, than according to the method I have laid down in my paper, as I have since experienced in some metals I have made. Make the brilliant composition first of copper and tin. Melt the proportional quantity of silver and brass in a small crucible by itself. When you put the brilliant composition the second time into the crcuible, add also the lump of brass and silver melted together before in a separate crucible; and when the whole is now fluid, add the proportional quantity of arsenic, and then pour it off into the flasks, after the scoria is taken off, and a little powdered rosin is thrown into it. In other words, it is better not to add the brass to the melted copper in the first melting, as the heat of the copper calcines the *lapis calaminaris* in the brass, which renders the metal not so good as if the brass and silver were melted together (as silver melts with a less heat than brass) and then added to the metal in the second melting. As copper requires a much greater heat to melt it than brass, it gives too great a heat to the brass when it is added to it, which by calcining the *lapis calaminaris* in the brass, will sometimes cause the metal to be in a small degree porous. By pursuing the above method, it will never be porous in the least degree. We are not to imagine it porous because it breaks up with the emery. It will always break up with the finest emery; but these breaks-up are taken out by the bed of hones or stones. If the common blue hones are used, but little water must be used at a time, or they will never cut the metal.

OF THE FUEL USED IN CASTING THE METAL.

181. I have used all kinds of fuel in casting the metal; viz. coal-coke, and wood-charcoal; but the best by far, and which I almost always used, is coke. It is common coal charred, and gives a fine and constant heat: it is to be had at all malsters, as they dry their malt with it. This is the material they always use to cast with at Birmingham and Wolverhampton. Common coal smokes so much that you cannot see into the crucible, and is a very nasty material. The coke casts no smoke at all. I have sometimes, but very seldom, used wood charcoal; but it is very dear, besides it does not do near so well as the coke, as the draught of an air-furnace is so great, it burns it out immediately, so that you might almost as soon endeavour to melt the metal with paper thrown into the furnace.

OF THE EYE-GLASSES OF REFLECTING TELESCOPES.

182. The kind of glass most proper for the eye-glasses of reflecting telescopes, is crown-glass, such as is used for the convex glasses in the compound object-glass of achromatic telescopes; and those pieces are the best, which, when laid upon a sheet of white paper, show it of a bluish green colour, and not of a yellowish green. Crown-glass is much preferable to flint glass, or indeed any other sort of glass we are acquainted with, for this purpose; as it entirely destroys, by its colour, all dingy or yellowish appearance of objects in reflecting telescopes, (which may arise from the metals not being sufficiently white, or from a bad polish,) and shows them of their natural colour. The dingy appearance of objects in the reflecting telescope is highly disagreeable, but this will be entirely removed if the metals are made of the 47th composition, and the eye-glasses are formed of crown-glass. Even flint-glass, when used for the eye-glasses to

reflecting telescopes, will always show objects too yellow, as neither the flint-glass nor the metals are sufficiently white. But the combination of the colour of the crown-glass, and of the light reflected from the metals, will always show objects of their true natural colour, and totally free from all dingy or yellowish tinge. I must also add, that crown-glass is much more free from veins than flint-glass, and therefore much preferable. I have also been informed, by a gentleman of Stourbridge, in Worcestershire, who is a glass-maker, that crown-glass is the most pure glass made in this kingdom, and also transmits more light than even flint-glass, as objects may be seen through a much thicker piece of crown than flint glass. This circumstance may perhaps be owing to the quantity of lead which enters the composition of flint-glass, which, by rendering it more dense than any other kind of glass, makes it reflect more, and consequently transmit fewer rays of light. Be this as it will, I can affirm from my own experience, that crown-glass is much preferable to flint-glass for the eye-glasses of all reflecting telescopes.

TO DETERMINE THE SIZE AND PLACE OF THE EYE-HOLE IN A SINGLE OR COMPOUND EYE-PIECE OF A REFLECTING TELESCOPE.

183. It is absolutely necessary for perfect vision, that the eye should be applied to a small hole of a certain dimension, placed exactly in the focus of the single eye-glass, if the eye-piece consists of one glass* only, or else in the compound focus of the glasses, if it is constructed with two, as is most commonly practised. If the small eye-hole is not exactly in the proper place, and also of the true size, the telescope will prove faulty, as it will always either take in foreign light, and by that means the object will appear very indistinct, or else it will cut of many of the rays which should come to the eye, and then the object will not appear so vivid as it ought to do. To rectify therefore its size and place, let the following rules be observed :

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* Some astronomers prefer an eye-piece of one double convex-glass —, for the higher powers of their telescopes, as it will transmit more light than can pass through two glasses. In Mr. Herschel's telescopes of the Newtonian form, the eye-pieces for the greatest powers consist only of one small double convex-glass.

Let the distance of the eye-hole from the eye-glass, if it is a single one, be put, as near as can be attained by measure, equal to the focal distance of the eye-glass; but if it is a compound eye-glass, the distance of the eye-hole from the glass nearest the eye may be found thus: multiply the difference between the focal distances of the glass next to the mirror, and the distance of the two eye-glasses, by the focal distance of the glass nearest to the eye, and divide this product by the sum of the focal distance of the two glasses, lessened by their distance, and you will have the compound focal distance required. Example.—If the focal distance of the glass nearest to the mirror is three inches, the focal distance of the glass nearest the eye is one inch, and their distance from each other is two inches, then the compound focal distance from the eye glass will be $\frac{\overline{3-2}+1}{3+1-2}=\frac{1}{2}$ an inch.

184. The diameter of the eye-hole may also be determined by dividing the diameter of the great speculum by the magnifying power of the telescope. Thus if the aperture of the telescope is 4 inches, and power 150, the diameter of the eye-hole will be 0,027 of an inch nearly, or $\frac{4}{150}=0{,}02666$, &c.

185. Having now found the place and size of the eye-hole by calculation nearly, the true place and size must be determined accurately by experiment, since our measures of the foci, distances, &c. of the glasses, cannot be found with sufficient accuracy.

With a small convex-glass of an inch or an inch and a half focal distance, view the picture of the large mirror in the eye-hole; hold the convex-glass as steady as you can in one hand, and move your eye upwards or downwards, towards the right hand or towards the left; then if the picture of the large metal in the eye-hole has a motion in the same direction with the eye, the focus of the eye-glass, whether single or compound, is between the eye-hole and the eye-glass; but if the picture of the great speculum in the eye-hole appears to move contrary to the motion of the eye, then the true focus is between the eye and the eye-hole. In the former case the eye-hole must be brought nearer to the eye-glass, in the latter case it must be removed farther from it, till you perceive the picture of the great mirror become stationary, or without any motion, in whatever direction the eye is moved; for then, and then only, the eye-hole is most accurately in the focus of the single or compound eye-glass.

186. The diameter of the eye-hole may also be determined exactly by viewing, with the small convex-glass held in the hand, as in the preceding operation, the exact size of the picture of the great metal in the place of the eye-hole determined accurately by the foregoing direction. If the area of the eye-hole appears a small degree larger than the area of the emergent pencil of rays, or the picture of the great speculum, then it is sufficiently large to transmit all the rays of light which comes from the great metal. But if the area of the eye-hole is found to be less than the area of the picture of the great speculum, the eye-hole must be enlarged till its diameter shall be found equal to, or rather a little larger than the diameter of the emergent pencil of rays.

TO TRY THE FIGURE OF THE GREAT SPECULUM.

187. Mr. Mudge (see Essay V.) has given a method to try the figure of the great speculum (for the small mirror is always spherical) by circular apertures of pasteboard, applied to the mouth, or the object-end of the telescope; but this end may be much more easily obtained, without the trouble of using diaphragms of pasteboard; barely by looking through the telescope, and by viewing, at a proper distance, (50 or 100 yards for instance,) a circle of half an inch or an inch in diameter, with a pretty broad black margin to it. Adjust the telescope so as to show the circle as distinct as possible; turn then the screw which moves the small mirror, either to the right or left hand, and you will see a regular dark haze round the circle, becoming broader and broader as you continue turning the screw; then if the haze is more distinct, and the edge of it better defined, when you turn the screw from the place of distinct vision towards the right hand, than when it is turned from distinct vision towards the left hand, the figure of the great metal is spherical; if the black haze is most distinct when the screw is turned towards the left hand, it is hyperbolical, or beyond the parabola; but if the haze and the edges of it, are equally distinct on both sides the true focus, or point of distinct vision, which the eye will judge most accurately, then, in such case, the great speculum has the true parabolic curve required. These and the following directions concerning the method to centre the mirrors, are suited to a Gregorian reflector, but for a Cassegrain telescope they must be reversed.

TO CENTRE THE MIRRORS.

188. It is of the utmost consequence to the perfection of reflecting telescopes, that the mirrors be truly parallel to each other, and also that the centres of them, together with the centres of the eye-glasses, be all in one direct line, viz. in the axis of the tube. Indeed, unless these particulars are attended to, the instrument will prove defective and faulty, even though the mirrors have the most exquisite figure possible to be given them. That truly excellent artist, the late ingenious Mr. James Short, always took the greatest care to adjust and centre the metals of his telescopes; and, to prevent them from being deranged by any accident, he always marked the upper part of the great mirror by a black line, and fastened the screws on the back of the small metal with common soft solder. Mr. Mudge (as already detailed in Essay V,) very justly advises us to turn the great mirror in its cell, and examine in what situation it is most distinct; but he has given us no directions how we are to place the metals parallel to each other, at the same time that their centres are exactly in the axis of the tube. To supply these omissions, I shall now point out such methods as I have always found excellent for those purposes.

I. TO ADJUST THE ARM WHICH CARRIES THE SMALL SPECULUM.

189. Extend two fine threads or wires across the apertures of the tube, at right angles, so as to intersect each other exactly in the axis of the telescope: before the arm is finally fastened to the slider, place it in the tube, and through the eye-piece (without glasses) the intersection of the cross-wires must be seen exactly in the centre of the hole of the arm. When this exactness is obtained, let the arm be firmly riveted and soldered to the slider.

II. TO PLACE THE SMALL MIRROR PARALLEL TO THE LARGE SPECULUM.

190. Divide the circumference of the mouth-piece of the tube of the telescope into four equal parts. Provide a circle of

pasteboard about one-half or two thirds of the diameter of the mouth of the tube. Procure also a narrow strip of wood, whose length is exactly equal to the inside diameter of the mouth of the tube; divide it into two equal parts, and to this middle point fasten the centre of the pasteboard circle by a small pin. Apply now this small apparatus to the two opposite marks made on the mouth of the tube; by this means the centre of the pasteboard circle will coincide with the centre of the tube. Care also must be taken that the pasteboard circle be in the same plane with the mouth of the telescope, or, which is the same thing, at right angles to its axis: which is easily effected by applying the edge of a ruler across the mouth of the telescope, and by making any of the diameters of the pasteboard circle touch the edge of the ruler. Take now the eye-glasses from the eye-tube, and screw that tube without its glasses, in its proper place; direct then the mouth of the telescope towards a window or the sky, apply your eye to the small hole in the eye-tube, and observe whether the ring of light in the small mirror is exactly of the same breadth in every part of it, which will always be the case when the small metal is parallel to the great speculum; in all other positions of the small speculum, the ring of light in it (which is only the reflected image of that part of the great mirror which is not hid by the pasteboard circle) will appear of different breadths in different parts of its circumference; adjust now the small mirror by the three screws at its back, till the ring of light appears, in every part, exactly of the same uniform breadth; and thus, by a few trials, the face of the small metal may easily be placed parallel to the face of the great speculum.

III. TO PLACE THE CENTRE OF THE SMALL MIRROR IN THE AXIS OF THE TUBE.

191. Put the circular pasteboard on the mouth of the tube, as before; then apply the eye to the eye-hole, (the eye-glasses being removed,) and observe whether the outer edge of the ring of light in the small mirror, when adjusted by the preceding rule, is equi-distant in every part of its circumference from the edge of the small metal; in such case, the centre of the small mirror is coincident with the axis of the telescope; but if the outer edge of the ring of light in the small speculum is nearer to the edge of it in some parts of its circumference than, in others; or in any other words, if the dark part surrounding the ring of light in the small speculum has not the same breadth in every part of its circumference, then the centre of the small metal is not coincident with the axis of the tube, but must be raised higher or depressed lower, must be put towards the right hand, or towards the left, as shall appear necessary. The easiest method to perform this, is to make the screw, which goes through the hole in the upright stem of brass which carries the small metal, with a broad shoulder to it, and to make the hole in the centre of the brass stem pretty large, (but not so large as the shoulder of the screw,) by which means the small mirror may be raised or depressed, may be placed a little to the right hand, or towards the left, as is found to be most proper, and may be retained in any of those positions by the three small screws that bear against the back of the small speculum:—This and the preceding adjustment must be repeated by trials, till the ring of light in the small mirror is of one uniform breadth in every part of its circumference, and at the same time, the outer edge of the ring of light is equi-distant from the edge of the small metal; for then, and then only, the face of the small mirror is parallel to the face of the great speculum, and at the same time, its centre is coincident with the axis of the tube; or the centres of the eye-glasses, and the centres of the great and small specula, are in one right line.

192. When the small mirror has been adjusted, by the preceding direction, those two adjustments may be examined and rectified to the utmost degree of precision by the following method:

Put up a circle of half an inch or an inch in diameter, with a broad black margin to its circumference, at the distance of fifty or a hundred yards from the telescope. Turn the screw, which carries the brass stem and the small mirror, nearer to or farther from the great speculum, and you will observe, if the metals are centred very well, the margin of the circle will appear to become less and less, so as to form continually a less circle, till at last, as you continue turning the screw, it will terminate in a black spot in the middle of the true circle (which will still continue visible with a large broad and black haze round it, equally broad in every part of it. If the black spot appears on the margin of the true circle, and consequently the black haze is not equally broad round the true circle, then the mirrors are not exquisitely centred, but the small metal must be adjusted by the three small screws at the back of it, by screwing up, in a very small degree, the small screw which is diametrically opposite the black spot, or on the other side the centre of the circle on whose margin* the spot appears. When the metals are found to be exquisitely centred, fasten the three small screws at the back of the small speculum, with common soft solder, to prevent them from drawing, or giving way. Put up now a watch paper, or any other printed paper, with letters or figures upon it of different dimensions, some of which should be very small, at the distance of at least sixty times the focal length of the great speculum from the telescope. Turn the large mirror in its cell, about the eighth part of a revolution each time, and observe in which of those positions the minute figures or letters upon the paper are most distinct; mark then, with a black stroke, the upper part of the back of the great speculum, and a corresponding part upon the inside of the brass tube, adjoining to the black stroke on the back of the mirror; by which means, if the great speculum is taken out of its cell at any time, it may be easily replaced exactly in the same position. The mirrors may also be examined by means of any of the fixed stars, particularly by those of the first magnitude; for if the mirrors are truly centred and adjusted to their best position, a fixed star, when made indistinct by the adjusting screw on the side of the tube, should always appear, in reflecting telescopes, as a truly round circle of fire with a black spot exactly in its centre; and when the telescope is adjusted to distinct vision, the star should appear, if the telescope is excellent, and the state of the air favourable, exactly round, and totally free from all irradiations, or false rays and glare. Indeed I can assert from experience, that no object is so proper to determine the excellence of telescopes as the fixed stars, as the least irregularity in the figure of the metals in reflecting telescopes, or of the object-glass in achromatics, is rendered by them exceedingly conspicuous by a false glare, and by their not appearing perfectly round. The ingenious Mr. William Herschel, of Bath, F R S. a

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* When the metals are centred exceedingly near, but not accurately true the true margin of the circle will appear too broad in some one part of its circumference; that is, the black line, forming the circumference of the true circle, will not appear equally broad in every part of it. In such a case, screw up the small screw at the back of the small speculum, which is opposite the part of the circumference of the circle which appears too black, or too broad.

gentleman well known in the astronomical world, has discovered nearly 300 double and treble stars,* many of which are exceedingly minute ones; and which, at the same time that they will afford us an opportunity to prove the goodness of our telescopes, show the excellence of his own,† and illustrate the observation of the royal Psalmist, that, "The heavens declare the glory of God, and the firmament showeth his handy-work."

193. As the following table of the apertures, powers, and prices of reflecting telescopes, constructed in the Gregorian form, by the late ingenious Mr. James Short, is very scarce, it may not be unacceptable to my reader, if I here insert it:

Numb.	Focal length in inches	Diam. of aperture in inches.	Magnifying Powers.	Prices. Guineas.
1	3	1,1	1 Power of .... 18 times.	3
2	4½	1,3	1 . . do. .... 25 ,,	4
3	7	1,9	1 . . do. .... 40 ,,	6
4	9½	2,5	2 . . do. .... 40, and 60 ,,	8
5	12	3,0	2 . . do. .... 55, and 85 ,,	10
6	12	3,0	4 . . do. . . 35, 55, 85, and 110 ,,	14
7	18	3,8	4 . . do.. 55, 95, 130, and 200 ,,	20
8	24	4,5	4 . . do.. 90, 150, 230, and 300 ,,	35
9	36	6,3	4 . . do.. 100, 200, 300, and 400 ,,	75
10	48	7,6	4 . . do.. 120, 260, 380, and 500 ,,	100
11	72	12,2	4 . . do.. 200, 400, 600, and 800 ,,	300
12	144	18,0	4 . . do.. 300, 600, 900, and 1200 ,,	800

194. Mr. Short in the above table, always greatly overrated the highest power of his telescopes. By experiment, they were found to magnify much less than expressed in his paper. Mr. Short finished two or three telescopes of the Gregorian form, of 18 inches focus, with 4,5 inches aperture, and power

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* See Philosophical Transactions, vol. 72.

† The diameter of the great mirror of Mr. Herschel's longest reflecting telescope [which is of the Newtonian construction] is 12 inches, its focal distance is 20 feet, and its magnifying powers, for the first stars, are from 300 to 6000 times.

170. He also made one telescope, of the Cassegrain form, of 24 inches focus, with six inches aperture, and power 355. But it was very indistinct with that power. The greatest magnifier it bore, with sufficient distinctness, was 231 times. He also made six telescopes of the same focus, of the Gregorian form, which bore the usual magnifying powers very well.

A TABLE OF THE APERTURES, POWERS, &C. OF TELESCOPES OF THE NEWTONIAN CONSTRUCTION, IN WHICH THE FIGURE OF THE GREAT METAL IS SUPPOSED TO BE TRULY SPHERICAL.

Focal dist. of concave metal.	Aperture of concave metal.	Sir Isaac Newton's numbers.	Focal dist. of single eye-glass.	Magnifying power.
Feet.	*Inch. Dec.*		*Inch. Dec.*	
½	0,86	100	0,167	36
1	1,44	168	0,199	60
2	2,45	283	0,236	102
3	3,31	383	0,261	138
4	4,10	476	0,281	171
5	4,85	562	0,297	202
6	5,57	645	0,311	232
7	6,24	....	0,323	260
8	6,89	800	0,334	287
9	7,54	....	0,314	314
10	8,16	946	0,353	310
11	8,76	....	0,362	365
12	9,36	1084	0,367	390
13	9,94	....	0,377	414
14	10,49	....	0,384	437
15	11,04	....	0,391	460
16	11,59	1345	0,397	483
17	12,14	....	0,403	506
18	12,67	....	0,409	528
19	13,20	....	0,414	550
20	13,71	1591	0,120	571
21	14,23	....	0,425	593
22	14,73	....	0,430	614
23	15,21	....	0,435	635
24	15,73	1824	0,439	656

195. As telescopes of Sir Isaac Newton's construction are now found (particularly by the late exquisite observations of Mr. Herschel, of Bath) to perform most excellently in the minutiæ of astronomy, especially if small apertures and long foci are made use of, I have added the foregoing table, chiefly taken from Dr. Smith's Optics, and have continued it on from 17 to 24 feet local distance of the great mirror. I have also annexed it to Sir Isaac Newton's numbers, by means of which the apertures of reflecting telescopes, of any construction, may be easily computed. See Appendix to Gregory's Optics, page 229, or Philosophical Transactions, No 81.

196. It may be necessary to mention, that the preceding table was constructed by using the dimensions of the middle aperture, and power of Mr. Hadley's excellent Newtonian telescope as a standard; viz. focal distance of great mirror 62½ inches, aperture of concave metal 5 inches, and power 208 times. Mr. Herschel chiefly makes use of a Newtonian reflector, the focal distance of whose great mirror is 7 feet, its aperture 6,25 inches, and powers 227 and 460 times, though sometimes he uses a power of 6450 for the fixed stars.

197. If the metals of a Newtonian telescope are worked as exquisitely as those in Mr. Herschel's seven-feet reflector, the highest power that such a telescope should bear, with perfect distinctness, will be given by multiplying the diameter of the great speculum, by 74; and the focal distance of the single eye-glass may be found by dividing the focal distance of the great mirror by the magnifying power; thus, $6{,}25 \times 74 = 462$, the magnifying power; and $\frac{7 \times 12}{462} = 0{,}182$ of an inch, the focal distance of the single eye-glass required.

TO GRIND AND POLISH THE SMALL SPECULUM OF A NEWTONIAN TELESCOPE TRULY FLAT.

198. It may perhaps be necessary to inform those that would wish to find telescopes of the Newtonian form, that the small elliptical plane mirror may be ground truly flat, by making use of two or more tools considerably larger than the speculum intended to be finished upon them, after it is brought as near the figure as can be done upon a small tool of lead with fine emery.

199. The tools or beds of hones should be no less than six inches in diameter. The figure of the tools is not allowed to be completed, till the speculum can be first highly finished upon one of them, and afterwards be applied to another without receiving any change. The last half dozen of strokes should be in the direction of the longer axis of the ellipsis. When this

is perfected, it must be polished upon the pitch polisher of a circular form, whose diameter is about one-tenth part greater than the transverse axis of the speculum. For this method of figuring the small speculum truly flat, I am obliged to that excellent astronomer, Mr. Herschel of Bath.

TO FIND BY EXPERIMENT, THE MAGNIFYING POWER OF ANY TELESCOPE.

200. Many methods have been contrived to determine experimentally the magnifying power of any telescope. That excellent artist Mr. Ramsden, showed me, some time ago, a small instrument, of his own invention, to measure the diameter of the emergent pencil of rays, at the eye-hole, to the utmost degree of precision. By dividing the diameter of the great mirror in a reflecting telescope, or the diameter of the object-glass in a refractor, by the diameter of the emergent pencil of rays, determined by that instrument, the magnifying power will then be given. But as that instrument, constructed chiefly upon the principle of Mr. Dolland's object-glass micrometer, is somewhat expensive,* and therefore may not be found in the hands of every one who is possessed of a telescope; I shall lay down a plain and easy method, by which I could always discover the powers of my telescopes very readily, and with sufficient accuracy.

201. At the distance of one or two hundred yards from the telescope, put up a small circle of paper of any determined diameter, an inch, for instance; upon a card, or any piece of strong paper, through which the light cannot be easily transmitted, draw two black parallel lines, whose distance from each other is exactly equal to the diameter of the small circle. Adjust the telescope to distinct vision, and through it view the aforesaid small circle with one eye, and with the other eye, open also, view at the same time the two parallel lines. Let the parallel lines be then moved nearer to or further from your eye, till you see them appear exactly to cover the small

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* Mr. Ramsden informed me that the price of one of his small instruments, to determine the power of any telescope, would be about three guineas. Whether any other Optician makes these instruments, as invented by Mr. Ramsden, I cannot tell, having never seen any other than what Mr. Ramsden showed to me.

circle viewed in the telescope. Measure now the distance of the small circle, and also of the parallel lines, from your eye. Divide then the distance of the former by that of the latter, and you will have the magnifying power of the telescope required.

202. Two other methods to determine, by experiment, the power of any telescope, are given in Dr. Smith's Optics, in the notes upon Art. 109 and 485.

ESSAY VII.

An account of the Cause and Cure of the Tremors peculiarly affecting reflecting Telescopes more than refracting ones; contained in the Extracts of two Letters to the Astronomer Royal.

EXTRACT.

Ludlou, February 26, 1782.

203. I have the pleasure to inform you that I have made one discovery of no small moment to reflecting telescopes, and which cannot fail of bringing them again into your good opinion, and of restoring them again, as preferable to achromatics for astronomical purposes. I am sure, whatever discoveries are to be made in the heavens, we must be obliged to reflectors for them, as we can give them what aperture we please. In short, Sir, I have discovered the true cause of the tremors in reflectors, and can, and have, cured them in my own telescope. This is not imaginary. I do not deceive myself, as I have already shown the difference to a gentleman of this place. I can make them show objects to tremble or remain steady, as I please. I now see the great difference, and the advantage of curing these tremors.

EXTRACT II.

Ludlow, November 16, 1782.

204. In regard to the cause of tremors in reflecting telescopes, I have not made a great many experiments upon them; though what I have made seem to show me the true cause of them ; viz. 1st, to the springs at the back of the great speculum, which are every moment varying their elasticity, and therefore do not press the metal equally at all parts of it ; nor indeed does the pressure continue the same at the same place for a few seconds. This is one cause. 2d, Another cause, I think, is the eye-hole of reflecting telescopes ; since, as the emergent pencil of rays comes through so small a hole, the least motion of the eyo side-ways, or upwards, or downwards, will cause the objects to dance or tremble.* This latter part of the error may be easily cured in a Newtonian reflector, by taking away the small eye-hole entirely, which will be no detriment in the night time, as no light from the sky can fall immediately on the eye-glass. In the Gregorian construction, the eye-hole cannot be so easily removed, even in the night, except it is very dark, as the circumambient sky-light will fall immediately on the eye-glasses. If you will take away the springs at the back of the metal, and put the metal to stand (for a trial only,) on two small bits of card placed as in fig. 3, plate LXXXIII, where *a* is the top of the metal, *b* the bottom, *c* and *d* the two pieces of card ; if you take care to wedge it in its cell just so tight with the bits of card as to prevent the metal from falling down or backwards, I think you will not find any tremors then appear in the telescope, if you will try it against an achromatic at the same time. The above method is only to show that the springs at the back are the chief cause

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* In a subsequent letter, Mr. Edwards very properly attributes the detriment arising from the eye-hole to the inflexion of light ; the effects of which seem to have been first observed by Grimaldo, but which were afterwards examined farther by very nice experiments by Sir Isaac Newton, and shown by him to arise, not from the ordinary refraction of the air, (as had been supposed by some,) but rather, (as attributed in his Queries,) to a real repulsion subsisting between the rays of light and bodies which they approach near to. In fact, the bad effect of the eye-hole in producing indistinctness at least, if not tremors, is very sensible, although the eye be kept as steady and free from any transverse motion as possible. N. M.

of those tremors; at least they have always appeared so to my eyes. I remember once, when the objects had great tremors, I took off the springs, and fastened the metal gently in with two bits of card, and I could not then perceive the least tremors. I replaced the springs; the tremors returned as bad as ever. I then took them away as before, and could see no tremors. A gentleman of Ludlow, present with me, saw the same, and declared that the springs were the immediate cause of the tremors; though, if the eye was moved much at right angles to the axis of the pencil of rays, we could still perceive some tremors owing to the eye-hole. I much dislike the constant practice of putting the metals to bear their whole weight on their lower point as at *b*, as the weight of the metal resting on that point bends the metal in a small degree, and hurts the figure. This may appear strange; but indeed I can at any time totally spoil the figure of a metal by wedging it in only with the thickness of a bit of common writing paper. Dr. Smyth says, one-thousandth of an inch will spoil its figure. I am sure also, that that quantity, if not less, will injure it. If the metal was made to rest at two points, viz. *c*, *d*, each of which is 45° from *b*, and 90 from each other, I think the figure would not be injured at all. I do not see that the thickness of the metal is of any service to prevent this small degree of bending, for I never yet saw a large metal whose figure I could not spoil with an exceeding small pressure at its back. Nor do I approve of three screws at the back, to bear against the metal, as I altered my own small telescope to that plan, and I never could make the screws bear equally alike, but they would bear harder against one place than another, and so spoil the figure. I think they had best be fastened by three small screws passing through the tube, perpendicular to the axis, and of such a thickness as for their sides to touch the back of the mirror barely without any shake. By removing the brass piece (viz. the brass into which the eye-piece is screwed) you may see the screws bear side-ways against the mirror in three places, and may file away the sides of the screws so as to make them just touch the mirror, but not much more.

ESSAY VIII.

Remarks on the Tremors peculiarly affecting Reflecting Telescopes more than refracting ones.

205. In the continual course of my observations at the Royal Observatory, I have almost constantly found the two reflecting telescopes, a Gregorian of two feet, and a Newtonian of six feet, both made by the late Mr. Short, to show the celestial objects indistinct and affected with tremors, when at the same time the forty-six inch treble object-glass achromatic showed them much freer or entirely free from them; and for the most part more distinct and better than even the six-feet reflector did; though one should suppose the latter, from its length and aperture, ought to be a much more powerful telescope than the former. The same difference between the effect of reflectors and refractors I found also in viewing land-objects; having often seen them perfectly steady for hours together through the achromatic telescope, and at the same time in continual tremors through the reflectors. Remarkable as this difference is between the effects of reflecting and refracting telescopes, I do not know that it has been hitherto noticed by astronomers; I was led to it from constantly comparing the achromatic and one of the reflectors together, immediately after observations of Jupiter's satellites, or occultations of stars by the moon, or any other observations had been made at the same time by myself with one of the telescopes and by my assistant with the other. But I found the detriment which the tremors produce in the effect of reflecting telescopes to be so great, that unless they could be removed, I had long considered reflecting telescopes as instruments that ought to be banished from astronomical uses, as being much inferior in their effects to achromatic telescopes of much smaller apertures. I wished, however, that the cause of this strange phenomenon in reflecting telescopes, might if possible be discovered, and thence a means might be found of removing an error so fatal to their improvement, and consequently to that of astronomy Mr. Edwards having been long employed in the improvement of reflecting telescopes, I some years ago proposed to him this subject of the tremors of reflecting telescopes, as a problem for his consideration,

to try if he could resolve it; which he has at length happily done, to the great improvement of reflecting telescopes, and benefit of astronomy; as is explained in the foregoing account of it, extracted from his letters addressed to myself. I have only to add, that upon removing the springs from the back of the great speculum of my six-feet reflector, and steadying the metal by screws instead, I found the tremors of the object immediately removed, and the object to appear incomparably better than it did before. I also found that by removing the eye-hole, which is not at all necessary either for celestial or terrestrial objects, in a Newtonian reflector, that the appearance of the object was still very sensibly improved, though not near so much as it was before by taking away the springs. In short, by these two easy alterations, the six-feet reflector was so much improved, as to show the object (a printed paper) sensibly better and more distinct than the forty-six inch telescope, which before had greatly the advantage of the reflector.

206. Some time previous to my trying the advantage arising from removing the springs, I had hit upon an extraordinary experiment, which greatly improved the performance of the six-feet reflector, even as much as the removal of the springs did afterwards. As a like management may improve many other telescopes, I shall here relate it. I removed the great speculum from the position it ought to hold perpendicular to the axis of the tube when the telescope is said to be rightly adjusted, to one a little inclined to the same; and found a certain inclination, of about 2½° (as I found by the alteration of the appearance of objects in the finder, one of Dolland's best night-glasses with a field of 6°) which caused the telescope to show the object (a printed paper) incomparably better than before; insomuch that I could read many of the words, which before I could make nothing at all of. It is plain, therefore, that this telescope shows best with a certain oblique pencil of rays. Probably it will be found that this circumstance is by no means peculiar to this telescope.*

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* When the great speculum is thus inclined, the little speculum must be placed out of the centre of the tube towards one side, in order to receive the rays of the oblique pencil which come down the axis of the tube; and then none of the light will be stopped by the sides of the tube, nor more light intercepted by the little speculum than in the common position of it.

207. Consulting No. 376, in vol. 32, of the Philosophical Transactions, I see that Mr. Hadley, to whom the world is so much indebted for executing both sorts of reflecting telescopes, and introducing them into common use, as well as for the quadrant that goes by his name, supported the great speculum of his telescope at the back, not by springs, but by three screws directly answering to three bearing on the forepart. Mr. Hadley, however, unfortunately directs the applying of a plate with a little hole in the middle before the eye-glass towards the eye, to let no light pass to the eye from the inside of the tube, but what comes from the oval plane speculum.

208. What a pity it is that Mr. Short, an able artist, who first found out the means of enlarging the apertures of these instruments considerably, by giving his great specula a parabolic figure, should by an unfortunate mistake of applying springs to support his great specula, reduce the excellence of his telescopes to a degree probably below that of Mr. Hadley's, who brought these telescopes into common use in the year 1723. I have but too much reason to believe, that all Mr. Short's telescopes were constructed in this improper manner. This may serve as a fresh instance of the soundness of the Royal Society's motto, *nullius in verba.*

209. Mr. Herschel's telescopes, which show very minute double stars, that other telescopes, hitherto reputed good ones will not reach, (of which I am myself a witness,) and are probably superior to any telescopes made before, are unencumbered with springs and small eye-holes. He tells me that he found springs could not be applied to great specula that were above five inches diameter without great inconvenience; because if they were not made very stiff they would yield to the weight of the speculum in high altitudes, and so alter the adjustment; and if they were made very stiff they spoiled the figure of the speculum.

ESSAY IX.

Miscellaneous Observations connected with the Grinding and Polishing of Lenses and Specula.

The essays of the series concluded by the present, are not to be regarded as belonging exclusively to the art of forming lenses and specula. They have, to a certain extent, a general application, and every mechanic, aiming at improvements, ought to be familiar with them. They show very clearly, the difficulty of obtaining surfaces, of any description, accurately true; and as accurately plain and spherical surfaces are more frequently required than any other in all delicate and valuable machinery, they may be considered replete with instruction for suggesting general expedients to obtain such surfaces, and to ascertain when they are true. We trust that in the course of the few remarks we have now to offer, the correctness of these considerations will be very apparent.

When figures appear at the commencement of the following paragraphs, they refer to paragraphs or articles of that number in the preceding essays.

3. The tools upon which lenses are ground, are generally directed to be made of brass, but when their size exceeds four or five inches in diameter, cast iron will answer extremely well, and may be made considerably thinner with equal strength. If the iron tool be equally thick, one side will do for a concave lens, and the other for a convex lens, nearly of the same sphere; for the difference in the diameter of the spheres of which the surfaces are respectively segments, will only be that of two concentric circles differing by the thickness of the tool. A cast-iron dish, or tool, ten inches in diameter, will be sufficiently strong if three-tenths of an inch thick. No material will be cheaper than iron in the first cost of the tool, if a good foundry be at hand; and no metal which can be used, wears away so slowly in rough-grinding, or is so little liable to change its figure by accident or pressure. The iron tool should be cast from a hard pewter or type-metal pattern; its form is so simple as to present no difficulty in the casting: and if properly cast, it may be taken as it comes from the founder, and formed to a good figure by grinding in it till

all its surface is of one colour, a piece of thick rough glass with coarse sand or emery. The founder will require a small hole in the centre of the pattern, for the insertion of a wire to lift it out of the sand after it is moulded. This hole, to prevent its being made with any violence that would injure the figure of the pattern, should be bored in the lathe before the turning of the pattern is commenced, and it would be best to screw the hole, and to furnish the founder with a short piece of wire screwed at the end to fit it. By this wire, the pattern, after the moulding is completed, can be drawn off the sand without any lateral motion, and without the force usually employed in such cases to wedge a smooth wire in the hole sufficiently tight to bear the weight of the pattern. The same remark will apply to forming the patterns for specula, and moulding with them. The hole made by the wire in the sand is easily filled up when the parts of the mould are separated.

The piece of glass employed to work the cast-iron to a correct figure, may afterwards be used as a bruiser, and will answer better than one of lead or pewter, because emery sinks into soft metals, and does not therefore get fully and regularly crushed down. The bruiser also serves to press down and figure the pitch employed in polishing.

5. Brass and copper are mentioned for gauges; but brass is the most proper metal. It is more easily filled than copper; when hammered, it is more firm and elastic, and not so easily deranged in its figure. The brass should he made to lie quite flat upon a plane surface before it is made into a gauge; or the difficulty of using it accurately will be increased and rendered less certain. Small gauges may be most expeditiously formed in the lathe—cementing the brass upon a chuck.

22 to 25. When the quality of glass to be ground away, to give a lens the requisite convexity or concavity, is considerable, taking up for example three to four hours or more in grinding, it will be found most economical, and the swifest mode of operation, not to use emery, but siliceous sand, washing away the sand with plenty of water, and adding a fresh quantity, as soon as its sharpness goes off. Emery used in the same way, would be expensive, and to grind with it as long as it contained any sharp particles, would take up too much time. The siliceous sand may be that of the sea-shore, or the sandstone employed for grindstones reduced to powder and passed through a sieve of 35 to 40 wires in the inch, or 1225 to 1600 apertures in the square inch. The figuring of a convex glass upon a common

grindstone, or of a concave glass upon a small convex grindstone running in a lathe, may also be practised, regulating the work with the gauge of the intended sphere; but this plan is not on the whole very convenient, and the glass is frequently cracked and broken by the violence of the operation.

26. As soon as the surface of glass is in any degree glazed after rough-grinding, the action of any powder not rough enough to take off that glaze or polish, is very remarkably diminished. The surface of the glass seems to be hardened. Hence the remark, that "the artist must allow time and patience to bring his glass by grinding to the smoothest and finest surface that he possibly can, before he attempts to polish," is of great consequence, and indeed indispensable to success.

27 to 42. All methods yet known for polishing lenses, are inferior to that founded upon Sir Isaac Newton's directions, to use pitch and putty with a slight pressure—polishing as directed in Essay II. which will produce lenses of the highest excellence. Cloth, silk, leather, and all similar substances, when spread over the tool, for polishing upon, have defects from which pitch is free. The direction for spreading the polishing powder, in art. 28, are good, and the machines described in art. 35 to 40, may be applied to purposes of less nicety, or even for lenses, when the glass is exceedingly thick, and not apt to be bent under the force applied. In the best optical instruments, however, the thinnest glass that, with strength enough to retain its figure, will admit the proper curvature, is employed; because thicker glass would increase the loss of light without any counterbalancing advantage.

45. The use of *new* pitch as the cement with which glasses may be most safely fastened to handles, is particularly worthy of note; and it is certainly advisable to transfer the hint to the art of grinding specula.

46. The manner of working best adapted to produce a good figure in rough-grinding and smoothing, is slightly adverted to in art. 23; but the equable and varied strokes required may be fully understood from art. 106; these particulars being common both to grinding lenses and metallic specula.

47. The artist is left to his choice, either to boil pitch till it is brittle, or to use equal parts of pitch and rosin. The mixture is not only sooner prepared, but, as observed in art. 174, has with its hardness the advantage of greater cohesion.

The following table of the foci of the object-glasses of Dolland's excellent achromatic telescopes, where two glasses only are employed, may be acceptable to those who have the construction of such telescopes in view:—

Diameters of the Spheres to which the Lenses are ground.				Comp'd focus.	Diameters of the Spheres to which the Lenses are ground.				Comp'd focus.
Convex of crown glass.		Concave of flint glass.		Inch	Convex of crown glass.		Concave of flint glass.		Inch
1st. side inches.	*2d. side inches.*	*1st. side inches.*	*2d. side inches.*		*1st. side inches.*	*2d. side inches.*	*1st. side inches.*	*2d. side inches.*	
3.2	5.3	5.3	8.8	5	35.2	58 3	58 3	96 8	55
6.4	10.6	10.6	17.6	10	38.4	63.6	53.6	105.6	60
9.6	15.9	15.9	26.4	15	41.6	68.9	68.9	111.4	65
12.8	21.2	22.2	35.2	20	44.8	74.2	74.2	123.2	70
16.0	26.5	26.5	44 0	25	48.0	79.5	76.5	132.0	75
19.2	31.8	31.8	52.8	30	51.2	84.8	84.8	140.8	80
22.4	37.1	37.1	61.6	35	54.4	90.1	90.1	149.6	85
25.6	42.4	42.4	70.4	40	57.6	95.4	95 4	158.4	90
28.8	47.7	47.7	79.2	45	60.8	100.7	100 7	167.2	95
32.0	53.0	53.0	88.0	50	64.0	106.0	106.0	176.0	100

The variety of foci, to which the different surfaces of achromatic object-glasses are ground, constitutes an inconvenience, but not the chief difficulty which will be felt in forming such glasses, by those who do not propose the manufacture of them as a business; and who are therefore anxious that the lenses which they do grind may answer the immediate purpose desired, without accumulating any stock: the probability is, that however accurately the lenses may be ground to the curves set down, a single set of them will not combine so as to produce a truly achromatic or colourless effect. The reason is, that there is a great difficulty in obtaining crown and flint glass which, when ground into lenses, shall prove exactly adapted to each other in refracting power. The best method is, to finish a considerable number of lenses to the proper foci, from different specimens of each sort of glass, and to prove by experiment those which perform the best in conjunction.

The crown glass employed, is the finest quality of the sort in ordinary use for windows. Flint-glass is that in use for table glasses.

The following directions for preparing very fine flint-glass are given by Cazalet of Bourdeaux:—Put into a platina crucible, capable of containing twelve ounces of flint-glass, 100 parts of pure minium, previously strained through a silk sieve, 50 parts of purified nitre, one part of very pure and very white lime, and 60 parts of very white sand, calcined and pounded in an iron mortar, afterwards washed by ebullition with sulphuric acid, and still farther purified with muriatic acid. This mixture, exposed in a bottle glass-house furnace, becomes very liquid. At the end of thirty-six hours it is poured into pure water, in order to be reduced to a fine powder. It must then be washed and purified in the same manner as the sand, re-melted as before, again thrown into water, pulverized, and putrified with the acids, then again melted, and at the end of forty-eight hours taken out of the crucible, and run upon a plate of copper previously made very hot; in this situation it is left to cool by insensible degrees. By this method, a very white glass is said to be obtained, free from fibres, spots, &c. and possessing all the qualities requisite for object-glasses.

If pure materials be used, and if the crucible, while it remains in the fire, be always covered with its cover of the same metal, the oxides of manganese and arsenic are not necessary.

As glass is composed of materials differing in specific gravity, these materials, arranging themselves in some measure according to their specific gravity, are unequally dispersed through the glass. Lenses may therefore prove imperfect, although free from specks or flaws. Hence Dr. Benzenberg, in an essay on the improvement of object glasses for telescopes, strongly recommends that the glass be suffered to cool in the pots, without stirring, and that mass be then divided in a horizontal direction, so that the variation may be regular over the whole surface, and then, by a proper form of the glasses, (upon the achromatic principle the errors of refraction may be corrected.

As many who may decline the task of manufacturing an achromatic refracting telescope, may yet wish to attempt the common refracting telescope, we add the following information relative to their apertures and eye-glasses, from Huygens. This eminent philosopher, finding his standard telescope of 30 feet (the common refractor was the only one known in his time) to bear an aperture whose diameter was 3 inches, and an eye-glass whose focal distance was $3\frac{3}{10}$ inches, gave the following rule for the apertures and eye-glasses of other telescopes:

Multiply the number of feet in the focal distance of any proposed object-glass by 3000, and the square-root of the product will give the breadth of its aperture in hundreth parts of an inch, and the same breadth of the aperture, increased by a tenth part of itself, gives the focal distance of the eye-glass in hundreth parts of an inch.

All lenses which are to be accurately figured and finished, must be executed by hand. Machines have been invented to grind at once large quantities of spectacle-glasses, and other, lenses for common purposes, which are sold at a very cheap rate, but which would be far from making good telescopes, or fit for instruments of high magnifying power, where philosophical inferences were to be drawn from the observations made with them. One construction for these machines is this: a globe works in a concave cup very nearly a hemisphere, which it exactly fits; the globe turns round with its axis horizontal; the hemisphere upon the end of an upright spindle, consequently its motion is in a direction at right angles to that of the globe. Glasses to be ground concave are cemented upon the concave hemisphere; to be convex, they must be cemented to the globe: a spherical surface results from the compound motion of the machine. A more detailed account of one of the best glass-grinding machines, we shall perhaps be able to present to the reader before the close of this work. At present it suffices to observe, that the lenses ground in them are not the best; and that even if they were equal to the lenses done wholly by hand, it would be the most expensive mode, for those who only require a few lenses, and these of very different foci, to construct a machine for the purpose. Machines are wholly inapplicable to the grinding of metallic specula.

When a plano-convex glass is required, it might be thought sufficient to select a piece of good plate-glass, and for the plane side to adopt one of its original surfaces without any alteration. But that the surfaces of plate-glass are not accurate planes, will be obvious from a review of the manner in which glasses of that description are ground and polished, and which it may not be uninteresting to give in connection with this subject: S. Bernard published in the Journal Polytechnique, a description of the manner of polishing and silvering plates for looking-glasses, cast at St. Gobin, but the subsequent operations conducted at the manufactory in the Fauxbourgh St. Antoine, at Paris. The plates are conveyed from the place where they are cast, in frames admitting them to stand upon end; these frames are suspended, by very elastic springs, on carriages, which are also hung upon springs; and between the plates are put, at certain distances, slips of elastic cloth, to prevent their striking against each other. The operation of rough-grinding is performed much after the manner of marble-masons' work in polishing marble; one piece of glass being rubbed backwards and forwards upon another, in all directions, with sand and water, and additional weights being laid upon the moving piece, as the work advances. During this operation the plates are bedded in plaster of Paris. The truth of the surface is proved by rulers and levels. After sand has produced a good surface, emery of four or five degrees of fineness is successively employed. After the use of the finest emery, the plate is placed upon a reddened piece of woollen cloth, in order that, in the course of polishing, the degree of brilliancy attained may be perceived. Red oxide of iron (called in England *colcothar,* and by the French *rouge d' Angleterre*) is employed to polish with. This polishing powder is applied by means of a kind of brush, the bottom of which consists of a sort of felt or velvet; and to assist the workman, it is pressed upon the plate by the action of a spring three or four feet long. When the glass is supposed to be finished, it is placed upon a carpet of a dark green colour, which shows whether all the parts have the same brilliancy. Those parts which have not been sufficiently polished appear whiter, and being marked, they are gone over again.

In this account there is no indication of means to produce a perfect plane; rulers and levels can discover nothing but considerable inequalities and cross-windings of the surface. The plane will certainly be imperfect unless the production of it be the necessary result of the operation.

In the plate-glass manufactory at St. Helens, near Liverpool, which is the only one of eminence in England, the process is not essentially different to the above, but the motion and power required to grind and polish are derived from machinery. The polish, in particular, is given by a felt-rubber, the surface of which is small in comparison with that to be polished, and which passes rapidly over every part of the glass. It would be difficult, perhaps impossible, to polish otherwise the large surfaces required in plate-glass, with sufficient rapidity and certainty; and as the result answers the purpose of commerce, there is no temptation to improvement. When two surfaces are ground together, in proportion as their surfaces adapt themselves to each other, the force with which they adhere together increases: this adhesion is occasioned by the pressure of the atmosphere; it accumulates in a rapid ratio with the surface, and would constitute the difficulty to be encountered in polishing large plates of glass by a process more correct in its principle than those hitherto adopted.

This account of the manufacture of plate-glass, renders it easy to explain appearances that might excite considerable surprise. Looking-glasses reputed plane, have exhibited in some measure the phenomena of concave and convex mirrors, especially that of the concave mirror in throwing a faint image to a distance before them. It is evident that the plate may contain risings or indentations, by the greater or less action of a small polisher upon particular parts of its surface, and therefore will exhibit the appearances in question.

It will now be evident, that a plano-convex lens, though made of the best plate-glass, must have its plane side ground again, if required perfectly true: and the grinding and polishing of a plane surface is attended with a greater risk of error than any other. The remark in art. 114, applies only in the case mentioned: two *plane* surfaces, though quite true, would if ground together, infallibly destroy each other's correctness; and if irregular, no perseverance of grinding would make them plane. In the method given in art. 198-9, if the correspondence of surfaces mentioned does not occur, there is no resource but a repetition of the process; the length of time required to finish the speculum cannot be estimated beforehand, as success must be the result of accident. To this subject, therefore, we must now advert:

There is but one general method known in the arts to produce a true plane; it consists in grinding and polishing, by working interchangeably upon each other, *three* surfaces of the same size; the three surfaces thus employed, correct the errors of each other, and are all of them perfected at once: a greater or a less number of surfaces has never been found to succeed. To grind a piece of glass, therefore, truly flat, let two pieces of iron or brass, for the tools, be filed as nearly plane as they can be; the glass itself will be the third surface; let the surfaces of glass and the iron or brass tools be ground for an equal length of time upon each other, chiefly by cross strokes, equally given in every direction, but intermixed with circular or elliptical strokes, and never suffering the diameter of one surface to pass more than a third over that of the other. When the glass is fit to receive the last polish, one of the metallic surfaces must be used upon the pitch, as much, or nearly as much as the glass, and thus all the three surfaces will be kept true to the very last.

To grind a plane metallic speculum, upon this principle, first let the speculum be ground upon a piece of sandstone, made flat by grinding it alternately upon two other flat pieces of the same sort of stone: then prepare two surfaces of pewter by casting them upon a flat stone or plate of metal previously heated; grind the speculum alternately upon these surfaces with fine emery; then prepare and use two flat beds of hones in the same manner; lastly, in polishing, one of the pewter surfaces being covered with pitch, the other, first perfectly cleared from emery, must be frequently employed, especially near the conclusion of the process, to keep the speculum and pitched surface true. For an account of the art of flat filing, and other remarks on grinding flat surfaces, see the Panorama of Science and Art, vol. 1. p. 22—32.

An able and ingenious engineer, Matthew Murray, of Leeds, proposes the grinding of flat surfaces by machinery, as follows: two grindstones must be fitted up to run with their flat surfaces horizontal; the under surface of one of them must lie over the upper surface of the other, and the circumference of the one extend to the centre of the other, as nearly as the axes will permit. If these stones be sufficiently thick to prevent their binding; if one of them be constructed to sink, or the other to rise, as the stones wear away, and the whole machine is steady, the surfaces thus working together will form each other into planes; and will communicate their flatness to any material ground upon them. Iron is reduced too slowly by grinding, for the working of any large surface of it to be attempted in that way; therefore filing and turning is resorted to; but to all the softer metals, this machine might doubtless be applied with great effect, and produce much more correct surfaces in works of metal than we are accustomed to meet with. Plate-glass it would certainly work truer to the extent of the dimensions experience might prove manageable upon it, than the methods yet practised. Its application to plane metallic specula is obstructed by the extremely limited demand there is for such specula, and possibly it would not be easy to overcome the difficulty that might occur in adapting the pitch polisher to the motion in question, for a purpose requiring a more exquisite delicacy of figure and polish than any other production of art whatever. Our allusion to this machine will doubtless gratify the curious.

Putty (the yellow oxide of tin) gives a white lustre to the substances polished with it: and colcothar (the red oxide of iron) gives a black lustre: putty is therefore the most proper for glass, and colcothar for metals. Le Sage observes, on another account, that putty is far preferable to colcothar for polishing glass; but its much higher price occasions its disuse in large works. He says that the sulphate of iron which the colcothar is liable to retain, when dissolved in water, is decomposed, and the yellow ochre which results from it penetrates the glass, forms a crust on it, and renders it greasy, dull, and yellowish, a tint which it communicates to the images of objects. Whether this be really the case with good glass, may deserve further examination. In France, where the observation was made, glass is frequently so imperfectly manufactured that in a short period it loses its transparency, by spontaneous decomposition. Hence one of the most eminent chemists of that country, undertook a course of experiments to discover a simple test for good glass, and he found nothing to answer better, that to put a small quantity of the glass to be proved, along with some sulphate of iron, into a crucible, and to heat the crucible till the sulphate was converted into the red oxide of iron. If the clearness of the glass suffer no diminution by this process, it may be depended upon.

We may mention, while engaged with this subject, a circumstance of which we have been assured, that glass, fixed in iron frames, in a few years becomes dull, and transmits much less light than before. This remark may certainly indicate the propriety of never fixing an optical glass in an iron frame. To ordinary observation, glass appears to be one of the most unchangeable substances; but the chemist, regarding it merely as a mixture of silex and potass, readily admits that it may be decomposed under a greater number of circumstances than have yet been accurately examined.

60, 102. The description of brass called Hamburg brass is probably the same as that which is now generally called Dutch brass; where it cannot be met with, there is little doubt that English sheet brass, selected of a fine yellow colour, and very tough, may be relied on as excellent for any purpose to which that mixed metal can be applied, and it may be used for the purpose mentioned in art. 162.

171. Instead of reducing the edge of a grindstone to the

curvature of a speculum, it would be much more easy and certain to cement a circular piece of sandstone, of soft and open grain, upon the chuck of a lathe, and turn it to the gauge with a tool of a single point; then while it revolves in the lathe, to smooth it with a thin piece of the same sort of stone, the breadth of its radius, and made by a gauge to the sphere with a chisel or old rasp. In this way the speculum may be figured much more regularly, and sooner, than upon a grindstone.

When a speculum gets dirty by any means, the only fluid with which it can be safely cleaned is alcohol, which should remain on it for an hour or two, and after being poured off, the speculum should be cautiously dried with very soft wash leather. Even a slight tarnish may by this means be lessened; but if, afterwards, the performance is not good, the speculum must be polished anew.

The effect of galvanism in tarnishing a speculum does not appear to have been yet attended to; but it will always take place, in a greater or less degree, where two different metals, as the speculum in the cell of the brass tube, lie for a considerable time in contact, especially in a damp atmosphere, when the metals become covered with moisture. This may suggest the propriety of taking specula out of their tubes when not likely to be soon wanted for use, and keeping them in a box or drawer made of wood, baked and varnished, to render it a non-conductor of electricity.

From the mean result of a number of experiments, made by Captain Henry Kater, it appears that the light of a Cassegrainian telescope to that of a Gregorian, of equal power and aperture, is at the least as 20½ to 10; a circumstance which is of great importance, and will render the Cassegrainian telescope by much the most desirable in all cases where the inversion of objects is of no consequence.

In forming the several parts of a complex machine or instrument, it is very important to consider diligently what principle will best ensure their correctness; but as mechanical execution, from imperceptible sources of error, is always falling short of the exactness contemplated as the result of carrying the principle into effect, it is also of importance to have the readiest and best means of ascertaining and checking such deviations from the perfection desired, before these parts are combined, and the difficulty increased of perceiving the real cause of the defect. To prove the figure of a lens or a speculum, for example, the process of measurement, or the use of a gauge, can afford no aid; but the properties which nothing but their correctness can ensure may be found out by due investigation, and if they have these properties, the proofs of their excellence may attain the certainty of geometrical demonstration. The more we can extend and simplify such effectual means of proving correctness of workmanship, the more will the arts improve, and the less will be the expense of their productions. These observations, applied to the separate parts of the machine, apply equally to the combining of them, in which the object should be to follow the plan admitting the most distinct proof of the truth of their adjustments. The essays of the present series illustrate these remarks, in a manner that may give utility to the following summary, which comprises only a small part of what might have been derived from them:

1. The method of examining the figure of a speculum, in art. 74—76, is worth notice, though superseded by the more agreeable and concise method of art. 113, which applies to metals as left by the hones; one mode of proving the figure of a finished metal is given in art. 141, &c. but the simplest and most complete at page 198.

2. If a hole be made in a finished speculum, or even any attempt to widen a hole, the figure of the speculum is destroyed, art. 123.

3. A speculum with a hole in its centre, cannot be polished and brought to a good figure, unless there be a corresponding hole in the polisher, art. 123—4.

4. If the work on the hones be well done, the speculum will not have a good figure, unless the polish commences in the middle, which is an evidence that the mode of working tends, as it ought, to the parabola, art. 125.

5. If a convex surface be ground upon a concave, the spheres will flatten; but if the concave be uppermost, the spheres will deepen, art. 43.

6. If tin and copper be melted together in the same vessel, part of the tin oxidizes; and the oxide, being diffused through the alloy, prevents a good speculum being obtained;—the best mode of preventing this effect upon tin, is given in art. 165, and upon brass, in p. 194.

7. An elliptical tool necessary to complete the figure of a specula to a parabola, art. 171, 178.

8. A tool considerably larger than the metal lessens the sphere and spoils the figure: metal and tool of the same size

exactly, work truly spherical; but the focus varies, agreeably to remark 5 above, unless worked alternately upwards.

9. So much water may be used upon the hone-pavement as to spoil the figure, art 172.

10. The metal may be made so thick as never to take a parabolic figure, 173.

11. The directions p. 199—202, for centring the mirrors of a telescope; for adjusting the arm which carries the small speculum; for obtaining the parallelism of the two specula; and for placing the small one in the axis of the tube, exemplify the success with which the separate parts of a mechanical combination may be proved by their properties.

Of all philosophers now living, the celebrated Dr. Herschel has had perhaps the greatest experience, and has been the most successful in the use and construction of reflecting telescopes. A valuable account of his telescope of 40-feet, and of the machinery for managing it, are given by himself in the Philos. Trans. of the Royal Society, but he does not enter upon the details of grinding and polishing the speculum, a subject upon which his observations would have been extremely valuable, and we may hope that he will take some occasion of presenting them to the public. We close this essay with the following remarks, abstracted from his contributions to the Philos. Trans.

In his paper of observations on the transit of Mercury, Nov. 9, 1802, he has made some highly curious observations on circumstances which affect telescopes:

On a frosty morning, one of his telescopes did not act properly, though at other times it had. One morning, a 20-feet speculum went off, and broke into two pieces, with a crack. Hoar frost does not seem to injure mirrors. Dry air does; damp does not.

The northern lights do not seem to interfere with telescopes, except that objects appear tremulous. In windy weather, stars resemble planets, and the telescopic view is bad, though the stars appear well. Even when the weather appears fine, the best instrument will sometimes not act.

The vicinity of a building renders objects indistinct. A telescope, the moment it is brought out, will often not act well, though, after an hour's exposure, it will succeed.

A confined place will prevent the proper action of a telescope. We cannot expect to make a delicate observation, with a high magnifying power, when looking through a door, window, or slit in the roof of an observatory: even a confined place in the open air will be detrimental.

Heat will alter the focal length of a mirror: one of 10 feet, had its focus increased $\frac{8}{100}$ of an inch by the sun's rays. At another time, a hot iron, placed at the back of a seven-feet reflector, at the distance of three-quarters of an inch, had its focus shortened 5.33 inches in 1½ minute. At three inches distance of the hot iron, the focus was shortened 2.83 inches. A thermometer, in contact with the mirror, was hardly observed to have risen during these alterations.

The following general principle was deduced from numerous experiments: "That in order to see well with telescopes, it is required that the temperature of the atmosphere and mirror should be uniform, and the air fraught with moisture."

A 40-feet telescope should only be used for examining objects that other instruments will not reach. To look through one larger than is required is a loss of time, which, in a fine night, an astronomer has not to spare; but it ought to be known, that the opportunities of using the 40-feet reflector are rendered very scarce by two material circumstances. The first is, the changeable temperature of the atmosphere, by which the mirror is often covered with the condensation of vapour upon its surface, which renders it useless for many hours; and in cold weather by freezing upon it for the whole night, and even for weeks together; for the ice cannot be safely taken off till a general thaw removes it. The next is, that, with all imaginable care, the polish of a mirror exposed like that in the 40-feet telescope, though well covered up, will only preserve its required lustre and delicacy about two years.

The 20-feet telescope, on account of the moderate weight of the mirror, and the proportionably long wooden tube, has the great advantage that, with proper precaution, it may be used in any temperature. Sometimes, however, a sudden change from cold to heat towards morning, has put a stop to the observations of the night. The mirror will also preserve an excellent polish for several years; and having a second one ready to supply the place of that which is in use, the instrument may always be ready for observation.

Method of ornamenting all kinds of Glass in imitation of Engraving or Etching.

By this invention, for which a patent was taken out, it is proposed to execute on glass, borders, ciphers, coats of arms, and the most elaborate designs, in a style of elegance hitherto unknown, and which cannot possibly be equalled by the modes of etching and engraving upon the same material, as hitherto practised. This improvement is effected by coating, and afterwards etching, engraving, and chasing on the glass so coated: and in its explanation it may be proper to advert to the ordinary processes.

The method heretofore used for engraving and designing upon glass, consists in the use of a machine with wheels of different substances, which have been employed with a sharp stone in powder, as emery or sand, to grind off some parts of the surface of the glass; and then, by means of more or less grinding and polishing different parts on the rough surface, the intended design is produced. And the usual method of grinding window-glass, for the purpose of making blind windows, has been by means of a machine moving on the surface of the glass in contact with sand or sharp stone, or the like substances applied by the hand, thereby grinding off the polished surface, leaving the glass sufficiently opake to prevent any objects being clearly distinguished through it, and yet affording sufficient light for common purposes. Now the present invention and object of the patentee, instead of grinding or taking off any part of the surface of the glass as aforesaid, is to lay on an additional surface or coating of glass, prepared for that purpose, which, when subjected to a proper degree of heat, will incorporate with the surface of the glass operated upon, so as to produce an effect similar to that which has heretofore been obtained by means of grinding; and when it is required that the glass should be ornamented with a border, cipher, or design, then, previous to the application of heat, with an etching, engraving, or chasing tool, or other pointed instrument, such parts of the surface or coating so laid on must be worked out as will produce an effect similar, but greatly superior, to the effect produced by the usual mode of grinding and polishing with wheels.

To prepare the glass for coating, take one or more of the smallest pots in the furnace, called by the glass-makers pile-end pots, or any other pot or crucible, according to the quantity wanted; fill it with materials made up in the same manner as for making the best flint-glass, broken glass, or what the glass-makers term cullitt, being the principal ingredient; and the proportions which the Patentee has used with the greatest advantage are the following:

Mixture No. 1.

Cullit, or broken glass	160 parts.
Pearl ashes	10 do.
Red lead	40 do.
Arsenic	10 do.

Mixture No. 2.

Cullitt, or broken glass . . .	120 parts.
Red lead	160 do.
Sand, or siliceous earth . . .	60 do.
Borax	60 do.

Mixture No. 3.

Red lead	70 parts.
Sand, or siliceous earth . . .	22½ do.
Calcined borax	40 do.

When the above mixtures have been subjected to a degree of heat in the furnace sufficient to fuse and completely vitrify the substances employed, the Patentee then takes of each mixture, in equal parts, the quantity which is to be ground and levigated into an impalpable powder, and to be mixed with a menstruum proper to give it the cohesion required in working with it.

Litharge may be substituted for red lead in the above mixtures; and different proportions of the above ingredients, or others of a like quality, will produce nearly a similar effect; but the most beautiful specimens were produced by the combinations above specified. The patentee does not claim any exclusive right to the making of this glass, but to the application of it to the surface of other glass, and for operating upon it in a manner entirely new, and for producing an effect superior and different to any thing hitherto produced.

The glass may be levigated in any of the usual modes, taking care that no injurious substance is introduced, and that the utmost degree of fineness is obtained which the powder is capable of; and for this purpose the patentee prefers a small mill with a pan, the bottom and sides of which are strong glass, with a grinder or levigator, cast also of solid glass, to work therein. When thus prepared by complete levigation, the glass is ready for mixing with the following menstruum:

Take one part of double-refined loaf sugar, dissolved in two parts of pure water, to which, at the time of mixing up the powder, add about one third part of common writing ink, the component parts of which are universally known; or instead of ink, use a watery solution of calcined sulphate of iron (green copperas); the effect produced by the addition of either of these latter substances is intended to be similar to that which is produced by the addition of oxide of manganese, used in small quantity by the glass-makers in making their best flint-glass, because without such addition the specimens had a cloudy or milky appearance, somewhat similar to what is termed by the workmen in the glass-house *shappy metal,* and which quality and appearance the addition of the above-mentioned oxide tends to prevent. The oxide of manganese, or possibly other oxides, may produce the same effect here, but the ink, or the sulphate of iron, are sufficiently cheap to warrant their general use, and they fully answer the purpose required.

Take of the compound menstruum above described, a sufficient quantity to render the ground mixture or levigated glass of a proper consistence for laying on with a very thin and even surface, and which necessary quantity and consistency, as well as the necessary thickness of the coating to be laid on, the operator will soon and easily ascertain; and as in the course of working or laying on the mixture some of the watery parts will evaporate, he must add, as occasion requires, the necessary quantity of the solution of sugar.

The advantages of the simple mixture of sugar and water, over essential oils, gums, resins, and other substances which have been tried, are very important; when any of the oils, gums, or resins was used, the coating became so firm upon the surface that the workman could not proceed without difficulty, and the delicate parts of the designs could not be etched out with the nicety and precision required; but the menstruum of sugar and water renders the coating sufficiently fixed to prevent the surface from being rubbed off whilst the work is under hand: and when the workman wishes to operate upon any particular part of the surface, he has only to breathe upon that part, by which means the menstruum imbibes sufficient moisture to render it soft and pliable to the tool, while those parts not breathed upon remain as fixed as before. Other substances may probably be found which will produce the same effect, but the one pointed out possesses all the advantages required.

When the levigated mixture is prepared by mixing it with the menstruum, it may be applied to the surface of the glass to be operated upon by means of brushes of squirrel's or camel's hair, by which it may be laid on with a very thin and even surface; and the most convenient form of the brush is to have the point spread out, and so disposed as to form a crescent or segment of a circle. The size of the brushes must of course be proportioned to the nature of the work to be performed.

After the coating has been applied evenly over the surface of the glass, and if no part of the surface covered is intended to be polished or worked out, the glass is then exposed to a heat sufficient to produce a semi-vitrification of the coated surface, and to incorporate it sufficiently with the substance or body of glass so coated; but great care must be taken not to extend the degree of heat farther than is necessary for these purposes, because in that case a complete vitrification of the coating would ensue, whereby the desired effect of having a surface in imitation of the rough surface produced by grinding would not be obtained; and although, when such an accident does occur, the article may be recoated and again submitted to the fire, the loss of labour would be considerable, and may, by a proper attention to the necessary degree of heat, be easily avoided: and if, after this coating has been applied, any border, cipher, coat of arms, or other ornamental design, is wanted to be executed upon the article, then previous to the heat being applied, with an etching, engraving, or chasing tool, or any other pointed instrument of sufficiently hard material, such parts of the coated surface must be worked out as will produce the desired effect. The glass operated upon must then be subjected to heat, which, as before-mentioned, must not be such as to produce more than its semi-vitrification.

This invention is not only applicable to all kinds of useful and ornamental articles of glass-ware, whereon the common methods of engraving have been practised, but may be applied to window-glass and plate-glass of every description, in place of grinding, for the purpose of making blind windows: and it is peculiarly adapted to produce beautiful specimens of art for the windows of altar-pieces libraries, museums, coach-windows, ornamental buildings of all descriptions, and all other purposes wherein plate-glass and window-glass have been commonly used.

The work executed upon this plan has also the advantage of wearing much cleaner than that of ground glass; the surface of which being somewhat fractured by the action of the wheel and cutting material, inevitably gathers dirt on every part left rough or unpolished.

An expeditious Method of determining Altitudes, of every denomination, with a new portable Mountain Barometer; and a description of the Instrument.

The mensuration of heights by the barometer has been, by the labours of M. de Luc, Sir George Shuckburgh, General Roy, and several other scientific men, brought to such perfection, and affords so much easier a mode of ascertaining the elevations of the different parts of the surface of the earth, to a considerable precision, than any other known process, that it might have been supposed that, in the course of thirty years, which have elasped since this branch of science has been perfected, a very great number of observations would have been made, and heights of almost the whole surface of our own country ascertained by the numerous travellers who continually traverse it. The contrary is, however, the case; and the small number of observations of this kind may be attributed to several causes.

The instruments are of considerable expense, and, from their complicated construction, easily liable to be out of order in the course of a long journey.

The observations themselves, though each not taking up any very long time, yet, when multiplied on every hill and valley, as they ought to be, for the purpose of obtaining a just idea of the face of the country surveyed, in the aggregate consume much of the traveller's time: and the constant unpacking and re-packing the instrument, becomes a greater labour than our natural indolence easily submits to.

It has, moreover, been generally supposed, that two instruments and two observers making simultaneous observations at the upper and lower stations of the height to be measured, are indispensably necessary. This, of course, would put it out of the power of a solitary traveller to make any observations at all.

Whether from these, or other causes, the fact is, that whoever reads the numerous tours, surveys, and reports of the different parts of our island, published within these last twenty years, and many of them professedly with a view to science, either of agriculture, mineralogy, or geology, will be perpetually disappointed, by meeting with mere guesses at the elevations of the tracts of country described; though a knowledge of those elevations is almost indispensable to the geologist, mineralogist, and military surveyor; highly useful to the scientific agriculturist; and very interesting to every one, who, from mere motives of enlarged and enlightened curiosity, reads books of travels, or employs his own leisure in traversing the countries described by other voyagers.

I cannot therefore but hope, that by simplifying the barometer, and thereby rendering the instrument much less expensive, and its use at the same time more easy, and showing that very considerable accuracy may be obtained by a single observer, this most useful branch of science may be cultivated, to so great an extent, that, in the course of a few years, we may have almost as perfect an idea of the relative heights of the different parts of England, as we now have of their horizontal distance.

A barometer, nearly similar to that which I am now about to describe, was constructed, several years since, by Dr. Hugh Hamilton, and is by him described at large in the fifth volume of the Transactions of the Irish Academy. I saw the instrument, in his hands, nearly seventeen years ago, and was much pleased with its performance. I do not know, however, that any more were then made. I have lately constructed the barometer, whose description I shall now give, which is still more simple than Dr. Hamilton's, and much cheaper, and which, in many trials I have made of it, appears to unite solidity, lightness, and ease of observation, to as great a degree as can be wished.

The barometer tube is about 33½ inches in length; its bore is a tenth of an inch in diameter, and its external diameter is three-tenths of an inch. This sized bore is fully sufficient to allow the free motion of the mercury.* This cistern is of box-wood, turned truly cylindrical, and is one inch in its external diameter, and an inch in depth; a short stem projects from its top (the instrument being in a position for making an observation) for the purpose of giving a firmer hold to the tube: this stem is perforated with a hole sufficiently large to admit the tube, which is glued to it in the usual mode. The tube projects into the cistern exactly to half its depth. The bottom of the cistern is closed by a strong lid of box, which screws on the cistern, and pressing against a leather glued to the inside of the lid, renders the whole perfectly impervious to the mercury in every position. The tube being filled and boiled in the common way, and the instrument held inverted in a perpendicular position, mercury is poured into the cistern till it is filled within two-tenths of an inch at the top. The lid is then firmly screwed on, and secured from being opened (by idle curiosity) by a small screw passing through its side. The essential part of the instrument is now finished. The end of the tube in the cistern, can never be uncovered by the mercury in any possible position, and of course no air can ever enter into it; and, as the areas of the cistern and tube are as the squares of the diameters, the diameter of the bore of the tube being ·1, its external diameter ·3, and the diameter of the cistern 1·0, the area of the cistern is 100—9 91, and there being two-tenths of an inch left empty in the cistern, the mercury must fall 182-tenths, or 18 inches and two-tenths, before the cistern is quite full: a space adequate to the measure of greater heights than any known mountain on the earth, much more to that of any height in this country. It will not easily be believed, by those who have not seen it, that the air will act on a cistern thus completely closed, and of which the wood, in its thinnest part, is above a quarter of an inch in thickness; but the fact is, that even when the pores of the boxwood are closed by thick varnish, (except in that part which touches the mahogany tube,) in order to prevent

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* Several of the barometers were constructed with the lower part of the tube only a twentieth of an inch in bore, somewhat on the principle of the marine barometers. This alteration was made, because, in some few instances, when very carelessly used, air had got into the tube, but upon minute investigation, the simple tube was found to be preferable.

the wood from being affected by damp, the mercury, on turning up the barometer, takes its level almost instantaneously, certainly in less than half a minute, and that, when the instrument is suspended by the side of the best mountain barometer, of Ramsden's construction, with an open cistern, no difference whatever can be perceived in their sensibility to the variations of the atmosphere. It is obvious that the variations of altitude in this instrument, its dimensions being as above stated, will be one ninety-first part less than in a barometer furnished with an apparatus for bringing the surface of the mercury in the cistern to a fixed level; this defect might be remedied by dividing the scale accordingly; but it is much more convenient to divide the scale to real inches, and make the necessary allowance in the result.

The tube and cistern being thus prepared, are mounted in a mahogany tube or frame of the size of a common walking-stick. The stem of the cistern goes into the mahogany tube, and is there secured by a piece of brass tube, which fits to the cistern and mahogany frame to which it is screwed; or the stem may be on the outside, cut into a screw, and so be screwed into the mahogany tube. The tube is secured in the mahogany case by passing through perforated corks in the usual way.

For the observation of the height of the mercury, two opposite slits are cut in the mahogany tube, reaching from about 32 to 20 inches for the long scales; and 32 to 25 inches for the short ones: which are sufficiently long for any purpose in this country. The front slit has its sides bevelled, and is, exteriorly, about three-fourths of an inch wide; on one side is fixed a brass scale, divided as usual to inches, tenths, and twentieths. On this scale a nonius slides, moveable by a small knob, which reads off, as in other barometers, to the 500th of an inch. To this nonius a small portion of brass tube is attached, which embraces the barometer tube, and its lower edge is, in observation, made a tangent to the convex surface of the mercury, as in other well-constructed barometers; and the very narrow slit behind gives abundant light for observation.

On the bevelled side of the front slit, opposite the scale, a thermometer is placed for taking the heat of the instrument; and there is room for the scale of correction, placed on Ramsden's attached thermometers, as well as Fahrenheit's scale. This thermometer is so contrived as to take out of its place, and answers the purpose of the attached and detached thermometer.

A thin brass tube, with slits in it, turns half round, on two pins, in the usual manner, and covers the apertures above described in the mahogany tube when the barometer is not in use.

The mahogany tube is made rather tapering, and with a ferrule at the end opposite the cistern. This ferrule unscrews, and shows a steel ring, by which the barometer may be suspended when convenient.

Along the mahogany tube is a scale of feet, carefully divided to inches; the feet being accurately laid down by small dots, on the heads of brass pins, sunk into the wood. A scale of this kind is always convenient, and may be often of great use.

To those travellers whose pursuits may lead them to the measures of the higher class of mountains, I would venture to recommend a barometer constructed with a tube of two feet long only; so that the whole instrument should not much exceed 25 inches in length. This barometer would not of course be useful until the mercury fell below 24 inches, which would be at a height of about 6000 feet in the atmosphere; but its great portability into regions where, from both the difficulties of the path, and the rarity of the air breathed, every ounce of encumbrance becomes a serious evil; and moreover, the great security to the instrument itself, arising from its shortness, would, I am persuaded, render it well worth while to carry such instruments where great altitudes are to be measured; and it is to be remembered that the instrument loses no part of its accuracy, when it once comes into action, by being thus shortened.

Having thus described the instrument, a few practical remarks on the manner of using it may not be superfluous.

When I am about to make an observation, about five minutes before I arrive at the place I take out the thermometer, holding it by the upper end at nearly arm's length from any body, and, if the sun shines, in the shade of my person. It very soon takes the temperature of the air, and is not sensibly affected by the heat of the hand. The heat being observed and written down, the barometer is turned up; the brass tube half-turned; and the instrument held between the finger and thumb of the left hand about the slit, so as to let it hang freely in a perpendicular position. Few persons, if any, have sufficient steadiness of hand to prevent little vibrations in the mercury in this position; the hand, therefore, should be either rested against any fixed body, or, if no such occurs, by kneeling on one knee. The cistern should be let down so as to touch the ground, the left hand holding the barometer in a vertical position, which a little practice will render very easy. The index must then by moved by the knob till its under surface, as before stated, is tangent to the mercury. A few light taps should be given to the tube, to ascertain that the mercury has fallen as low as it can. The height being then read off and registered, together with that of the attached thermometer, the brass tube is turned back, so as to cover the slits; the instrument gently inverted, and the whole is finished. All this may be done in two minutes.

It may not be improper here to add, that I have found by experience, that it is not necessary to quit the chaise in order to make observations with this barometer; it is only requisite for the horses to stand still. The thermometer, if held at arm's length out of the chaise window, will give the temperature exactly, before the order is given to stop the carriage; and the delay to the traveller will not much exceed a minute, as the observation may be read off and written down while the carriage is again going on.

The most convenient mode for deducing the heights from the barometrical observations is, certainly, by the common logarithmic tables; and it is unnecessary here to detail the method, which may be found in numerous books. It is, however, necessary for this method to carry the tables of logarithms, which is sometimes inconvenient. The engraved table formed by Mr. Ramsden is on a single narrow sheet, and extremely portable, besides being very easy in its use; but it may be lost or mislaid when wanted. Several ingenious formulæ have been devised, which may either be engraven on the instrument itself, or committed to memory. Of the former, Sir George Shuckburgh has given a very concise one, in his second paper on the measurement of heights by the barometer, in the 68th volume of the Philosophical Transactions; and Professor Leslie has invented a very elegant one of the latter sort; but these, though very simple in form, require a considerable number of figures in the operation, and are, on that account, inconvenient. For the purpose, therefore, of computing on the spot, and very near to the truth, any observations made on a journey, and that, almost without the necessity of writing at all, I have caused the following short table to be engraven on the scale of the barometer. It expresses the value of the difference of the tenth of an inch in the height of the mercury at the temperature of freezing, in English feet.

Sir H. C. Englefield's mountain barometer.

Inches.	Feet.	Inches.	Feet.	Inches.	Feet.	Inches.	Feet.
20·05	130	22·25	117	25·05	104	28·35	92
·20	129	·45	116	·30	103	·65	91
·35	128	·65	115	·55	102	·95	90
·50	127	·85	114	·80	101	29·27	89
·66	126	23·05	113	26·05	100	·61	88
·82	125	·25	112	·30	99	·95	87
21·00	124	·45	111	·57	98	30·30	86
·18	123	·65	110	·85	97	·65	85
·35	122	·87	109	27·15	96	31·00	84
·53	121	24·10	108	·45	95	·37	83
·70	120	·32	107	·75	94	·75	82
·87	119	·55	106	28·05	93	32·10	81
22·05	118	·80	105				

The method of using this table is as follows:—1st, Add the two observed heights of the barometer, and halve the sum to obtain the mean height. 2nd, Subtract the lesser height from the greater, the remainder is of course the difference of heights in tenths, &c. of an inch. 3rd, Enter the table with the mean height, and take out the feet answering to it, making a proportion, if the mean height does not exactly answer to a foot. (This proportion may be made by head.) Multiply the number thus obtained by the tenths, &c. of an inch of difference of height. The result will be nearly the number of feet, answering to the difference of height between the two barometers at the temperature of freezing. When the lower barometer stands between 29 and 30 inches, and the elevation does not exceed 1500 feet, this rule will give the height within one foot of the result from the logarithmic method. When the elevation is about 3000 feet, the error will be nearly three feet, and at heights greater than 3000 feet, the error increases in a higher ratio. It is always in defect. In this country, however, such elevations do not exist; and in those parts where a knowledge of the comparative heights of different hills is the most generally useful, they seldom exceed 1000 feet; at all events, such observations as relate to great elevations may be always recomputed by more rigorous methods at leisure.

The correction of the heights thus obtained, for the temperature of the air above freezing, is by Sir George Shuckburgh supposed to be as the height of the thermometer, and to be 2·44-thousandths of the approximate height for each degree of Fahrenheit, additive when the tempering is above freezing, and subtractive when below freezing.—General Roy's observations and experiments lead to a supposition that the correction is not exactly as the height of the thermometer, and that at about the temperature of 50 degrees it amounts to 2·5-thousandths, and is less, both much above and much below that temperature. For the purpose of immediate computation, I take the correction at 2·5, which, though certainly rather too great, will in general be productive of very small error, and affords a rule which is easily remembered and quickly applied. It is this:—

For every four degrees that the mean temperature of the two detached thermometers exceeds 32 degrees, add one-hundredth of the approximate height, as before obtained, to it; for every 40 degrees one-tenth, and so for any greater or less number of degrees.

I have not hitherto mentioned the correction, which in fact ought to be the first in order, viz. that for the difference of temperature of the two barometers themselves: but this correction is in general so small, as to be safely neglected. Should it, however, be thought necessary to apply it in this approximate method of computing heights, the rule deduced from Sir George Shuckburgh's method is as follows, and it wants no table, though he has given one for it.

When the barometer stands at twenty inches, the expansion of the mercury for one degree of Fahrenheit, is two-thousandths of an inch; when it stands at 30 inches it is three-thousandths; and for the intermediate inches it increases exactly as the height of the mercury; that is, at 21 inches it is ·0021, at 22 inches ·0022, and so on; so that the height in inches is the number of ten-thousandths of expansion for one degree of Fahrenheit. This is very easily remembered. The expansion for any number of degrees is in proportion to the degrees themselves; that is, for two degrees it is twice as much, for ten degrees ten times as much, and so on. Take, therefore, the difference of height of the *attached thermometers* at the two stations, and multiply the expansion for one degree at the coldest barometer, (which will almost always be the one at the highest station,) by the number of degrees of difference between the heat of the two barometers, and add the quantity to the observed height of the coldest barometer, and it is corrected for the expansion of the mercury by the heat of the instrument.

An example will make the whole clear:—

	Inches.	Therm. attached
Observation at bottom	29·400	.... 50°
———— at top	25·190	 46
		Difference 4

Expansion for 1° at twenty-five inches	·0025
Multiply by difference	4
	·0100

One hundredth of an inch is therefore to be added to the observed height of the upper barometer 25·190, so the corrected height is 25·200. It is, however, to be observed, that the application of this correction is of doubtful accuracy in practice; as it is by no means certain that the attached thermometer, be it placed where it may in mounting, will give the real heat of the column of mercury in the barometer, and therefore I had at first said that it might on the whole, in general practice, be neglected. If much accuracy is wished, and time permits, the surest way is to leave the barometer in the shade so long as for the whole instrument to acquire the temperature of the air, and then to make this correction according to the rule given above, from the difference of the two *detached thermometers*; and this barometer, from the lightness of its mounting, will have the advantage of taking the temperature of the air sooner than those formerly made with solid wooden cases.

It may not be improper to give an example of the method already detailed:—

Observation at bottom	29·400	Therm. in air	45°
———— at top	25·200	Therm. in air	41
	2)54·660		2)86
Mean	27·300	Mean heat .	43
		Standard . .	32
Difference	42 tenths		
Value of a tenth by the table .	95·5 feet	Difference	11
	1910		
	3820		
Approximate height	4011·0 feet		
Do. by Sir G. Shuckburgh . .	4016·0		
Error . . .	—5 feet		

Correction for Temperature.

For 8° = 2-hundredths	80 feet
For 3° = 3 four-hundredths	30
Correction +	110
Do. by Sir G. Shuckburgh	107·4
Error +	2·6

Approximate height by me	4011	By Sir G. S.	4016
Correction for temperature	110		107·4
Result	4121		4123·4

EXAMPLE SECOND.

Observation at bottom	30·017	Therm. in air	60°
———— at top	29·534	Therm. in air	57°
	2)59·551		2)117
Mean	29·275	Mean	58·5
Difference	4·83	Standard	32
Value of a tenth by the table	87·5	Difference	26·5
	350·0		
	70·00		
	2·625		
Approximate height	422·625		
Do. by Sir G. Shuckburgh	422·9		
Error	00·3		

Correction for Temperature.

For 24° = 6 hundredths	25·3
2 = 2 four-hundredths	2·0
½ = 1 eight-hundredth	0·5
Correction +	27·8
Do. by Sir G. Shuckburgh	27·2
Error +	0·6

Approximate height by me	422·6	By Sir G. S.	422·9
Correction for temperature	+ 27·8		27.2
	450·4		450·1

These two examples show how near the truth the method here recommended will come, even in considerable heights.

It has been already observed, that in observations made with the barometer I have described, a small correction is necessary on account of the rise of the mercury in the cistern, as the barometer falls. Altitudes being in all cases measured by the differences of the heights of the mercury at the two stations, and these differences being evidently always too small in this barometer, the correction is obviously always additive. As in constructing different barometers, the interior and exterior diameters of the tube will not always be exactly similar, though the cisterns may be turned always alike; this error, and of course the correction for it, should be in each instrument deduced from a comparison with a barometer of known accuracy at different heights. It will probably vary in different instruments from a ninetieth to a seventieth. Indeed, if it were always taken at an eightieth, in instruments constructed as above directed, the possible error could only amount to about one foot on a thousand; a quantity of very little importance.

It now remains to say a few words on the necessity of two barometers for the mensuration of heights, and the probable error to be incurred by using a single one. There is no doubt, that when very great accuracy is required, two barometers ought to be used; but even with every precaution, altitudes cannot be taken by barometers sufficiently near for the purpose of carrying water, either by pipes or canals: and for the purpose of the geologist, military surveyor, or agriculturist, it is of very little importance whether a mountain is 1000 or 1010 feet high, though it is of the highest utility that he should know whether it is 800 or 1000. I have, during the course of many years, been in the habit of taking observations of altitudes by a single barometer, and have had many opportunities of repeating my observations on the same hills when the barometer has been at different heights, and either falling or rising during the time of observation; and more than once I have observed heights which had been trigonometrically taken by the best instruments; and can safely say, that the difference between these observations has seldom amounted to so much as two feet on a hundr d. The mode I use is this:—At setting out, I take the height of the mercury, and note the time of observation; I likewise note the time of the second observation, and on returning to the first station, observe again, and note the time. If the barometer has altered in the interval, a simple proportion corrects either of the three observations, and reduces the height to what would have been observed had the mercury been stationary. It is true that this method supposes the motion of the mercury to have been uniform during the interval of observation; but except in very variable weather, which does not often occur, particularly in summer, when the greater number of these observations will naturally be made, this supposition is liable to but small error. It is also true, that a traveller has often no opportunity of making a second observation at the spot he sets out from. Even in this case, a near approximation may often be made by observing, for example, at a stream on each side of the hill to be measured. If also he observes the barometer repeatedly in the morning before he sets out, and sees its tendency, and does the same at every halt, during the day, he will have data whereon to found a nearly accurate correction. But if all this should be out of his power, even under the most unfavourable circumstances, barometrical observations will give a much more accurate idea of the outline of a country than any we now possess; and it should be ever remembered that observations, though defective, if carefully made, and faithfully recorded, are valuable, and if repeated by different travellers, the errors will, in most cases, compensate each other, and from the whole very accurate conclusions may be drawn.

I have entered into a greater detail than would be necessary for a greater part of your readers, in the hope of being intelligible to those who are less acquainted with the subject, and who may wish to employ any instrument-maker for the construction of barometers similar to that which I have described.

In justice to a very ingenious young artist, permit me to add, that I have employed in making those which I have, Mr. Thomas Jones, of No. 124, Mount-street, Berkeley-square, (pupil of the late Mr. Ramsden,) and who makes them complete at the price of three guineas and a half, with a short scale, reading from 25 to 31 inches; and four guineas for those with a long scale, reading from 20 to 31 inches.

N. B. On comparing several barometers made by Mr. Thomas Jones, since this description was first written, I find that in some of them the mercury does not take its true height on turning up the instrument, quite so quick as in the two which he constructed for me. This difference is owing to the greater closeness of fibre in some pieces of box-wood than in others, but it does not affect the accuracy of the instrument. In order to give a quicker action to these barometers, I advised Mr. Jones to bore a small hole or two in these cisterns, and insert a pin of open-grained wood into them. This answered perfectly well; but a curious circumstance occurred; when deal or willow-wood pins were inserted, the mercury, when shaken for some time, passed through the pores of these woods in the form of a fine black powder, and it was necessary to substitute ashen pins to confine it in the cistern. It may not be superfluous to say, that the weight of this barometer is less than a pound and a half. The weight of Ramsden's last improved barometer is 4½ pounds, and that of his earliest about 6¾ pounds. I subjoin a few observations, by which the accuracy of this barometer may be fairly estimated.

On Richmond Hill.

1806.		Barometer.	Thermometer.	Results.
Jan. 1,	Hill top . . .	29·540	44°	
	Thames' side .	29·686		Feet.
		·146		133
Jan. 2,	Hill top . . .	29·708	38	
	Thames' side .	29·860		
		·152		134
Jan. 31,	Hill top . . .	29·301	36	
	Thames' side	29·453	37	
		·152		137
Feb. 23,	Hill top . . .	29·758	51	
	Thames' side .	29·912		
		·154		139
Feb. 24,	Hill top . . .	30·180	53	
	Thames' side .	30·334	54	
		·154		140

On the Signal Hill at Brighthelmston.

In 1796, with a barometer of Ramsden's.

	Feet.
Signal-house above high water mark	410
In 1806, with my barometer	403
	416
	418

Devil's Dyke, near Brighthelmston.

In 1788, with a barometer of Ramsden's	697
In 1806, with my barometer	695

Lord Abercorn's Lodge, at Stanmore, above the Stream in Edgeware Town.

Jan. 3,	306
Jan. 7,	306

The observations from which this height was deduced, were made in the chaise, both on Jan. 3rd and 7th.

GENERAL DESCRIPTION OF THE MOUNTAIN BAROMETER.

In plate LXXXIV, fig. 1, *a a a a* represents the cistern, made of boxwood.

c c c, The cover, made of brass, which screws on, and is prevented from being unscrewed (by idle curiosity) by four mall screws *t*.

e e, The stem of the cistern, into which the glass tube *n n*, is firmly glued.

RR, the mahogany tube, in which is inserted the stem of he cistern, where it is secured by the screws *t t*, passing into it.

Description of a portable Easel.

The object of this contrivance is, to render the easel more portable, for the convenience of artists when travelling in the country. This easel, when folded up, forms a square staff, shown flat-ways in fig. 2, plate LXXXIV, and edge-ways in fig. 3; the rails of which it is composed are kept together by brass hoops or caps *a a*, fixed on each end; when set up for use, it appears as represented in fig. 4, forming a very secure and steady support for the tablet or picture, represented by the dotted lines. It consists of three deal rods, or bars, A, B, C, the two former being the whole length of it, but the latter only two-thirds; the bars A and B are united by a centre-pin, which also passes through one leaf of a brass hinge *p*: the other leaf being screwed to the short bar C, to permit it to be opened out from the others, to any distance, at pleasure. On the joint of this hinge, and the centre-pin, connecting the other two bars, the easel can be opened out, as in fig. 4, to stand in the most convenient position, for the support of the picture, and to suit the ground if uneven. The front legs, AB, are pierced with a number of holes, for the reception of pins *b b*, by which two short ledges or rails D, are held, so as to form a shift for the reception of the tablet; these rails, one of which is shown separately at D, when the easel is packed up for carriage, are placed at the end of the short leg C, behind the others; the two smaller ends of them being received into a gap, made in the hinge, as is shown at D, fig. 3: the brass hoop *a* containing them altogether. In order to make the surface of the cross, against which the picture rests, flat or plane, two pieces of wood, *d d*, fig. 3. of the same thickness as the bars of the cross, are applied upon the limb B: they fit into two spaces *e e*, made in the limb A, when the instrument is shut up; and holes are also made in the bar D, for the two pegs which support the shelf to pass through, and thereby to retain the bars AB in any required extent of their opening; and the prop C may be also kept from moving by wire-hooks extending to it from those bars.

The whole instrument may be rendered more steady in the fields, &c. by forming the lower ends of the three bars into points, shod with iron, the better to enter into the earth; and which may be rounded off a little at their ends, so as not to injure the carpet or floor of a room. The dimensions of this easel may be made such that it may be used as a walking staff, and it will prove a useful assistant in the agreeable art of drawing scenery after nature.

Directions for using the common Micrometer.

Micrometers, as first contrived, being only adapted to the measuring small angles, as the diameters of the sun and moon, or other planets, and taking the distance of such objects as appeared within the aperture of the telescope at the same time, were not of so general use as those which are contrived not only to answer the ends that the first inventors aimed at, but likewise to take the difference of right ascension and declination of such objects as are farther asunder than the telescope will take in at once, but which pass through the aperture of it at different times. Cassini first made use of threads intersecting one another at half right angles for determining the difference of right ascensions and declinations of objects near the same parallel; and this apparatus being simple and easily procured, is of very great use to such as are not provided with a micrometer made according to the late improvements. But where such an one is at hand, that method, however curious, need not be made use of, the micrometer serving for the same purpose with great exactness. It was for this reason indeed that the late alteration in the form of the micrometer was made, they being before not so convenient for making such sort of observations, both hairs being usually moveable, and no provision being made for setting the hairs parallel to the diurnal motion of the objects to be observed; both which inconveniences are avoided in the present micrometers.

The micrometer, as now contrived, is not only of use in measuring small angles or distances between such objects as appear within the aperture of the telescope at the same time, but likewise in taking the difference of right ascension and declination between stars and planets, &c. which in their apparent diurnal motion follow one another through the telescope, if kept in the same situation. In making the first kind of observations, turn the short tube which carries the eye glass and micrometer, &c. till the cross thread (or that which cuts the parallel threads at right angles) lies parallel to a line passing through the objects whose distance is to be measured, and then by raising or depressing the telescope by help of the stand, bring the objects to appear upon or near the cross thread, and one of them just to touch the fixt parallel thread:

then turn the index of the micrometer till the moveable thread touches the other object, and the number of revolutions and parts of a revolution shown by the index, turned into minutes and seconds, by the table made as hereafter directed, will be the apparent angular distance of those objects. It is here supposed, that the threads exactly close, so as to touch each other when the index stands at the beginning of the divisions: for if they do not, there must be an allowance made in every observation; to avoid which, it is always best to adjust the threads to the beginning of the divisions when they are first put on; for which purpose, the holes in the little plate which carries the moveable thread, are made oblong to give room to move it as occasion requires, before it is pinched hard by the small screws which fasten it to the moveable arm, through which the long screw passes. The other parallel thread, which I call the fixed one, must be first adjusted by setting its edge exactly over the two marks made on each side the short diameter of the aperture in the broad plates, and the cross thread must be likewise set to agree with the strokes made on each side the longest diameter, and then the intersection of the cross thread and the fixed parallel one, will be the centre of the motion given to the outer plate of the micrometer (to which the great screw, index, and threads are fastened) by the worm, by turning of which the fixed parallel thread may easily be made to lie parallel to the apparent motion of any object, in order to take the difference of declination and right ascension from any other that follows through the aperture of the telescope.

This contrivance is of very great use to make a star, &c. move true along the fixt parallel thread, which is absolutely necessary in order to take the true difference of right ascension and declination between it and any other that follows. Without this contrivance, it is very difficult to make a star move exactly upon the thread, and it can only be done by repeated trials, which may sometimes take up a great deal of time.

If therefore a star is made to move on the parallel thread just at the cross, and (the telescope continuing fixed in the same position) it is afterwards, near its going out of the aperture, found not to be upon the thread, that must then be brought to the star by the help of the worm, and then the thread will be parallel to the diurnal motion of the star in that part of the heavens, and consequently the cross thread will represent a meridian, and the others parallels of declinations, and the difference of time between the passage of the star at the cross wire, (which was made to move along the thread,) and the transit of any other star, &c. over the cross thread which represents a meridian, turned into degrees and minutes, will give the difference of right ascension. And, if the moveable parallel thread be brought, by turning the index, to touch the other star about the time of its passage over the cross thread, then the number of revolutions and parts shown by the index (turned into minutes and seconds of a degree by the table,) will be the difference of declination between the two stars. If the star is made to pass along the fixed thread, so as to seem perfectly bisected, there must be an allowance made for the semi-diameter of the thread or wire, because I suppose the index to be adjusted as before to the inner edges of the wires; but it may, if it is found convenient, be adjusted to the middle of the threads, or else correction may be made in the observed distance.

In taking any angle, it is convenient that each of the parallel threads be about the same distance from the middle of the aperture of the eye-glass; and for this reason the whole micrometer is contrived to slide to and fro, as the case requires. The same motion is also of use in taking the difference of right ascension and declination, by sliding the fixt parallel thread (on which the preceding star is brought to move) towards one side of the eye-glass; for by that means a greater angle may be taken in between the parallel threads, if need be; and it must always be remembered, that the moveable parallel thread should be set either north or south of the other, according as the following star is expected to be really south or north of the preceding.

In making an observation, either the inner or the outer edges, or the middle of the wires, may be brought to touch the objects; but then it must be remembered to allow something for the thickness of the wire, in case the observation be not made from that part to which the index is adjusted. In observing the diameters of the sun, moon, or planets, it may perhaps be most convenient to make use of the outer edges of the threads, because they will appear most distinct when quite within the limb of the planet, &c.; but if there should be any sensible inflection of the rays of light in passing by the wires, this would be best avoided by using the inner edge of one wire and the outer edge of the other. And in taking the distance or difference of declination between two stars, &c. the middle of the threads may perhaps be most convenient: but however the observation is made, due correction must be allowed for the thickness of the wire, if requisite.

The difference of declination of two stars, &c. may be observed with great exactness, because the motion of the stars is parallel to the threads; but in taking any other distance, the motion of the stars being oblique to them is a great impediment, because if one star be brought to one thread, before the eye can be directed so as to judge how the other thread agrees to the other star, the former must be somewhat removed from its thread; so that in this sort of observation, the best way of judging when the threads are at the proper distance, is by frequently moving the eye backwards and forwards from one to the other: this method must chiefly be made use of when the distance of the objects is pretty large, and the motion or rolling of the eye great.

The micrometer is so contrived that it may be applied to telescopes of different lengths; but then there must be a table for each telescope, by which the revolutions of the screw may be turned into minutes and seconds of a degree. In order to this, it is necessary that the threads of the micrometer should be placed exactly in the common focus of the object-glass and eye-glass, that is, where the images of objects seen through the telescope are distinctly formed. The readiest way of doing this is, first to slide the micrometer into the grooves fixt to the short brass tube, which carries the whole apparatus of the eye-glass, &c. and then to draw the eye-glass out by means of its sliding work, till the threads of the micrometer are in its focus, which is known by their appearing most distinct, &c.; then thrust the short tube before-mentioned into its proper place, as far as the shoulders of the brass-work will admit, and place the object-glass in its cell, and looking through the telescope at some very distinct object, slide the wooden tube in or out, till you make the object appear most distinct, or till it has the least motion upon the threads when the eye is moved to and fro; for then the threads of the micrometer will be in the common focus of both glasses, and that will be the proper distance that the object-glass ought always to be at from the threads; and there should be made some mark or ketch in the wooden tube, in order to set it always at the same distance.

The proper distance of the threads from the object-glass being thus settled, the table for turning the revolutions, &c.

of the screw into angles, or minutes and seconds of a degree, may be made several ways; but as good and easy a method as any is, carefully to measure how many inches and parts of an inch the object-glass is distant from the threads, and with the same scale to find also how many inches and parts of an inch, a hundred, &c. revolutions and threads of the screw of the micrometer are equal to: then making the first distance radius, the last will be the sine or tangent of an angle answering to 100 revolutions. And having the angle answering to 100 revolutions, the angle for any other number will be easily known and set down in the table, as also the parts of a revolution; for in small angles, such as can be observed with the micrometer, their sines, tangents or chords are nearly in the same proportion with the angles themselves. The distance before mentioned (to be used as radius) ought strictly to be taken from the threads to a point within the object-glass, about one-third of its thickness from that surface which is towards the wires, if the glass be, as usual, equally convex on both sides; but if the focus of the object-glass is pretty long, and its thickness not great, the error that can arise by measuring from any part of the object glass will become insensible as to the alteration in the angle.

The table for the micrometer may likewise be made by setting up two marks at a distance on the ground, and observing with the micrometer the revolutions, &c. which they subtend when seen through the telescope, and then computing the angles those objects subtend at the object-glass, by measuring their distance from each other and from the object-glass. The like may also be done by opening the threads to any number of revolutions, and then making a star move exactly upon the perpendicular thread, and noting the time it is passing from one parallel thread to the other; for that time, turned into minutes and seconds of a degree, by allowing for the star's declination and going of the clock, &c. will be the angle answering to the number of revolutions; from which the whole table may be made. This method perhaps might be most advantageously practised in stars near the pole, where the apparent motion being slow, a second in time will answer to a much smaller angle than towards the equator; but I believe, upon trial, the first method will be found most easy and practicable, especially if the scale made use of be well divided.

An improved Method of dividing Astronomical Circles and other Instruments.

The art of dividing astronomical circles and other instruments for taking angles, has ever been thought highly important to the improvement of astronomy and geography, and has consequently, at different periods, formed a subject of much attention and inquiry. The method of dividing which, until very lately, was in general use, was that practised so successfully by the late Mr. Bird; but the laborious and delicate operation by the scale and beam compasses, has recently been superseded by the invention of Mr. Troughton, of the excellency of which the mural circle at the Royal Observatory at Greenwich affords a noble proof. But this method, though decidedly superior to Mr. Bird's, seems yet to leave somewhat more to be done with respect to simplicity and facility of execution; and it is with the hope of having in some measure attained these desirable objects, that I am induced to lay before the Royal Society, a mode of dividing, which, I am led to believe, will not be found inferior in accuracy to any that has hitherto been proposed.

In the essential principle on which this method is founded, I find that I have been anticipated by the Duc de Chaulnes; but some parts of the apparatus which he has described are so complicated, and others so incapable of the necessary adjustments, that his method of dividing never has been, nor ever can be introduced to practice, and indeed was intended by its author merely to form a model, which was to be employed as part of a dividing engine.

The method which I am about to describe requires no other apparatus than two pieces easily made, which I shall call *adjustable dots*; three microscopes, (two furnished with micrometers,) and a cutting point with its frame.

The general principle of this method consists in viewing the two micrometer microscopes, as the points of a pair of beam compasses, and the moveable dots as divisions, capable of the nicest adjustment previously to their being transferred to the limb of the instrument. Its principle advantages are its simplicity, and the exclusion of all errors, excepting such as may arise from careless execution, the imperfection of vision, or the instability of the apparatus employed.

The *adjustable dots* are represented in plate LXXXV, figs. 1, 2, and 3. *a a a a*, fig. 1, is a flat piece of brass, intended to rest on the face of the arc to be divided, and to be clamped to it by means of the screw C, fig. 3, where the adjustable dot is represented in perspective. The piece *c c*, slides smoothly in a dove-tail groove, formed by the pieces *b b*, and is moveable by the screw *d*; *e f*, slides in like manner in a dove-tail groove beneath, and at right angles to the piece *c c*, and is moveable by the screw *g*. That part of the clamp which bears against the edge of the arc, should be curved in such a manner as to have only its two extremes in contact with the edge, by which means the motion of the sliding piece *c c*, will always be in the proper direction. A very thin and narrow tongue of silver or gold, on which is a well-defined circular dot, is soldered to the lower surface of *e f*, beneath, and projecting from *e*: the lower surfaces of this tongue, of the piece *e f*, and of *a a a a*, are all in the same plane. It is evident from this construction, that the tongue with the circular dot is moveable on the surface of the limb of the instrument, both to and from its centre, and in a direction at right angles to the radius. The screws *d* and *g*, are to be turned by a key with a handle of wood or ivory, in order to avoid any change of temperature which might arise from the near approach of the hand; the sliding pieces should move easily, and yet be perfectly free from shake.

There is another mode of constructing the adjustable pieces, which I conceive may be found far preferable to that I have just described, though in the use of them greater care and nicety will be required. It is to draw two fine lines at right angles to each other on the silver tongue of the piece *e f*, fig. 1, which lines may be used instead of the dot, by causing them to bisect the angles formed by the cross wires of the microscopes, and thus ensuring, as far as vision is concerned, as great a degree of accuracy in dividing as can afterwards be attained in reading off.

The line in the direction of the piece *e f*, must be drawn when the adjustable piece is fixed on a circle, and when the piece *c c* is placed about half way between the limits of its adjustment; in which position this line will be directed towards the centre of the instrument, and, unless the circle to be divided is very small, the difference from this direction, within the limits of its adjustments, will scarcely become sensible. This will be better understood when the manner of using the adjustable dots has been described. The silver tongue, with its cross lines, is represented at A, fig. 1.

The three microscopes are similar to those used in reading off divisions of astronomical instruments of modern construction, and therefore need not be very particularly described Two of these microscopes are furnished with micrometers in the usual manner, each having a set of cross wires as represented at fig. 6, moveable in the direction *a b*, by means of the micrometer screw.

The two micrometer microscopes have adjustable supports, one of which is seen at fig. 4, in which *a a* are two pieces of brass forming a dove-tail groove for the sliding piece A, which carries the microscope, and which is moveable by the screw represented in the plate. In the circular opening formed in the sliding piece A, a piece of brass tube is soldered, in which the microscope slides rather stiffly, in order to be adjusted to distinct vision. The supports are made very strong, and are furnished beneath with clamps, by which, or by any other equivalent contrivance, they may be firmly fixed to an arc, hereafter to be described. One of the microscopes, with its support, is represented at fig. 5, from which its construction will be readily understood; the micrometer head is omitted in the engraving, as it would only occasion confusion. The object-glass of each microscope is fixed in a tube having a fine screw cut on its outside, by means of which, after the microscope has been adjusted as nearly as possible to distinct vision, any remaining parallax may be removed, when the object-glass is to be secured by the nut *a*, in the usual manner.

Fig. 7, represents the support for the third microscope, and also the cutting point, the frame of which is attached to this support. ABCDE, is a thick plate of brass, having a tube soldered in the opening C, to receive the microscope. The projecting square pieces BD, receive the conical points of the screws FF, of the cutting frame, the general construction of which will be readily understood from the engraving. The cutting point, which is elliptical, as recommended by Mr. Troughton, passes obliquely at an angle of about fifty degrees through the flat piece of brass G. The pieces *a a* project half an inch or more beyond the piece G, and to their under surfaces a thin slip of silver or gold is soldered, or otherwise securely fastened, on which a well-defined circular dot is made, as represented in the plate. The sides HI, HI, of the cutting frame, must be of a sufficient length for the ends I I, to reach nearly to the surface of the instrument to be divided, when the frame hangs perpendicularly from BD; by this construction of the cutting frame, it is evident that the circular dot may be adjusted so that its image may pass through the point of intersection of the wires of the microscope, when carried through its field of view, and that the cutting point may be seen through the same microscope when employed in tracing the divisions on the limb of the instrument. A profile of the cutting point and frame is given at fig. 8.

As every thing depends on the rectilineal motion of the cutting point when tracing a division, too much care cannot be employed in its use, and it is greatly to be wished some better mode of giving it motion could be adopted in place of the inflexible projecting handles at present employed, as a lateral deviation of only $\frac{1}{10000}$ of an inch, in a circle of two feet diameter, would occasion an error in the division amounting to about a whole second. Perhaps an universal joint applied to the upper surface of the piece G, and connected with a handle, might be used with advantage. The length of that part of the cutting point which projects beneath the piece G, may also prove a source of error; but this may be easily obviated by making the piece G much thicker, and passing the screw through it, as represented in the profile.

An arc of cast iron or brass must be provided, of about 120 degrees in length, and of a radius rather greater than that of the instrument to be divided. Its breadth may be about two inches, and its thickness should be fully sufficient to ensure its not bending. This arc, which is designed to carry the three microscopes, is to be fastened at its extremities by clamps, screws, or otherwise, to the frame-work of the instrument to be divided, in such a manner as that the microscopes may project over its limb, and be at a proper distance above it for distinct vision, and that the surface of the arc may be parallel to the face of the instrument. The manner of fastening this arc must be left to the ingenuity of the artist. In some instances it may perhaps be found convenient to construct a temporary frame for the reception of the instrument during the operation of dividing, but in whatever manner the arc is applied, it is absolutely necessary that it should be so secured as to be perfectly immoveable.

I shall now proceed to detail the manner in which this apparatus is to be employed in dividing a circle, which I shall suppose to be two feet in diameter. The first operation necessary is to describe, on the face of the instrument, the circles which are to limit the divisions. This may readily be done by causing a fixed point to press on the surface of the circle, whilst it is made to revolve on its axis. The support carrying the third microscope and cutting frame, which microscope I shall in future distinguish by calling it the *fixed microscope*, is then to be firmly screwed to the arc, as near to its right extremity as conveniently may be, and so that the intersection of the cross wires of the microscope may be a little without the exterior circle described on the face of the instrument, and yet that both the circles that limit the divisions may pass through the field of view. The support of the fixed microscope must also be so placed, as that the cutting point may move in the direction of the diameter of the circle to be divided. The moveable microscopes are to be attached to the arc by their clamps, and to be always so adjusted that the intersections of their wires may appear half way between the circles intended to limit the divisions. The microscope which is placed next to the fixed microscope, I shall distinguish by the letter A, and the other by the letter B. The micrometer head of A must be placed to the right, and that of B to the left, of their respective microscopes.

It will, perhaps, be found most convenient to commence by dividing the circle into five equal parts of seventy-two degrees each. For this purpose, having fixed the circle by means of the clamp attached to its tangent screw, (with which every instrument is provided,) draw a fine line with the cutting point from the exterior circle described on the face of the instrument to the edge of its limb; this line I shall call the line of reference. Adjust the fixed microscope to distinct vision, by sliding it in its support, and cause the line of reference accurately to bisect the vertical angles formed by the cross wires of the microscope, by moving the circle, and by turning the microscope in the tube of its support. Move the eye to the right and left, and observe whether the line of reference appears to change its position. If it is perfectly stationary in every situation of the eye, the adjustment of the microscope is correct; if not, the remaining parallax must be destroyed by moving the object-glass, which must afterwards be secured by means of its nut.

The next step is to adjust the cutting frame. To this end, place the projecting pieces *a a*, of the cutting frame, fig. 7.

on the face of the limb of the instrument, when the dot will be at a proper distance from the microscope for distinct vision. Slide it through the field of view, and examine whether its centre passes accurately through the intersection of the cross wires· and if not, cause it to do so by means of the screws F and F.* This adjustment should be most carefully examined in every part of the process of dividing, as it is essentially necessary to the accuracy of the operation.

Place the microscope A as near to the fixed microscope as conveniently may be, (leaving, however, sufficient space to use the cutting point,) and clamp it firmly to the arc. Fix the microscope B at the distance of seventy-two degrees by estimation from A,† and bring the intersections of their wires between the circles which are to limit the divisions. Place an adjustable dot under A, with its centre precisely in the intersection of the cross wires. Unclamp the circle, and turn it on its axis till the adjustable dot arrives at the intersection of the cross wires of B; and should the centre of the dot not pass accurately through their intersection, cause it to do so by means of the screw of the moveable support of the microscope B. The intersections of the cross wires of both microscopes will now be equidistant from the centre of the circle. Adjust both microscopes to distinct vision, in the manner described for the fixed microscope, using the adjustable dot instead of the line of reference. Return the line of reference to the fixed microscope, clamp the circle, and, by means of the tangent screw, bring the line of reference again accurately under the intersection of the cross wires. Place the second adjustable dot precisely under the intersection of the wires of the microscope B. When all has been thus arranged, the line of reference, and the two adjustable dots, should appear in the intersection of the wires of their respective microscopes, and the dot of the cutting frame, if moved through the field of view, should pass through the intersection of the wires of the fixed microscope. This arrangement of the microscopes

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* The same thing might, perhaps, be as conveniently effected by giving a motion to the cross wires of the fixed microscope, and fine lines intersecting each other at right angles may be used instead of the dot (as in the adjustable pieces,) should it be thought preferable.

† This may be readily done by means of the figures usually engraved on the limb previous to the operation of dividing.

is represented in plate LXXXV, from which the manner of placing them in the subsequent parts of the operation will also be readily understood.

Turn the circle on its axis till the dot which was under A, arrives under B. Clamp the circle, and, by means of the tangent screw, bring the centre of this dot under the intersection of the wires of the microscope B. Take off the adjustable dot which was under B, and which will now be found to the left of that microscope, place it beneath A, * and by means of its adjusting screws, bring its centre under the intersection of the cross wires, carefully remarking whether the circle has in the mean time suffered any change of position, which may be known by the centre of the dot which is under B, being no longer found precisely under the intersection of its wires; and, should this have happened the dot must be restored to its former position by moving the circle, previous to the final adjustment of the dot which is under the microscope A. The adjustable dots must thus be made successively to change places, till the line of reference arrives again in the field of the fixed microscope, when it is evident, if the intersections of the wires of the microscopes A and B are precisely distant seventy-two degrees from each other, the line of reference will again be found accurately in the intersection of the cross wires of the fixed microscope, as it was at the commencement: but should this not be the case, its distance from it will be equal to five times the error in the distance of the wires of the microscopes A and B, and this error is to be corrected by the micrometer of the microscope A,† and the whole operation repeated, always remembering to bring, in the first instance, the line of reference accurately to the intersection of the wires of the fixed microscope, and carefully to repeat the various adjustments which have been detailed.

When, by repeated trials, the wires of the microscopes A and B are found to be at the required distance from each other, the divisions are to be cut on the limb of the instrument, the eye being assisted by viewing the cutting point through the

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* The artist will perceive, that five dots in this stage of the process, will be more convenient than two, and obviate the necessity of removing the dots.

† The line of reference may be brought to the intersection of the wires of the fixed microscope, and the distance of the dot which is under A, from the intersection of its wires, be measured by its micrometer screw, and this will be equal to five times the error in the distance of A and B.

fixed microscope. The first line, or zero, is to be made when the line of reference and the two dots are under the intersections of the wires of their respective microscopes, and each of the other divisions successively, after the dots have been made to change their places; and thus the circle will be divided into five equal parts, which seem to be subject to no other error than what may be attributed to the imperfection of vision, or inaccurate execution.

Each division of *seventy-two degrees* is next to be subdivided into three parts. To effect this, bring the line of reference to the intersection of the wires of the fixed microscope, and verify the adjustment of the cutting frame. Place the microscope B, above the first division from the fixed microscope, and the microscope A, at the distance of one-third of a division, or twenty-four degrees by estimation from B. Cause the division which is under B, to bisect the vertical angles of the cross wires, by means of the micrometer screw, and by turning the microscope in its tube, and adjust both microscopes to distinct vision. Place an adjustable dot under the intersection of the wires of A; unclamp the circle, and turn it till the adjustable dot is under B; when, if it does not pass precisely through the intersection of the cross wires, it must be made to do so, as before described, by means of the screw attached to the support of the microscope. Bring back the line of reference to the wires of the fixed microscope, when the adjustable dot should be precisely in the intersection of the wires of A, and the first division (seventy-two degrees from zero,) accurately bisecting the vertical angles of the cross wires of B. Turn the circle round till the adjustable dot arrives under B, and by means of the tangent-screw bring it accurately to the intersection of the cross wires. Place another adjustable dot in the intersection of the cross wires of A, taking care, by examining the dot under B, to ascertain that the circle has not in the mean time suffered any change of position. Bring the dot which was last placed, and which is now under A, to the intersection of the wires of B, when it is evident, if the wires of the microscopes A and B are at the required distance from each other, the next division of the instrument, or zero, will now pass precisely through the intersection of the cross wires of A. But should this not be the case, the distance may be measured by means of the micrometer, and the cross wires of A must be moved one-third of this distance from their first position towards the side opposite to that on which the division appears in the microscope. The line of reference must then be brought again to the wires of the fixed microscope, and the whole operation repeated as before, till the intersections of the wires A and B, are at the proper distance from each other.

In order to cut the divisions; having ascertained that the line of reference, the division which is under B, and the adjustable dot under A, are accurately in the intersection of the wires of their respective microscopes, turn the circle till A and B have each an adjustable dot in the intersection of their cross wires, and cut a division; move the circle till an adjustable dot is in the intersection of the wires of B, and a division in that of A, and trace another line with the cutting point. It is now evident, that one of the primary divisions of seventy-two degrees is trisected. Take off the adjustable dots, which are now no longer necessary, and bringing each of the new divisions, as well as the primary ones, successively under the intersection of the wires of the microscope A, trace a new division with the cutting point, and proceed in this manner round the whole circle, remembering that when a division is in the intersection of the wires of A, another division should be found precisely in that of B, and this affords a very severe test of the accuracy of the work as it proceeds.

Having thus obtained divisions of *twenty-four degrees*, these are again to be trisected precisely in the same manner, and with all the precautions before detailed, placing, should it be necessary, the microscope B at the distance of two divisions, or forty-eight degrees, from the fixed microscope, and transferring the adjustable dots through two divisions instead of one, which will bring the new divisions under the microscope A, when the adjustable dots may be taken off.

The circle is now divided into portions of *eight degrees* each, and these are to be continually bisected, till we arrive at divisions of *half a degree*; but as it is presumed that the centres of the microscopes A and B, cannot be brought nearer to each other than eight degrees, it becomes necessary to take distant divisions, and to bisect twenty-four degrees. For this purpose, having brought the line of reference to the intersection of the wires of the fixed microscope, and verified the adjustment of the cutting point, place the microscope A as near to the fixed microscope as convenient, with the intersection of its cross wires half way by estimation between any two divisions, and at the distance of twelve degrees place the microscope B, causing the angles of its cross wires, by means of the micrometer screw, to be bisected by the division under it. Fix an adjustable dot beneath the intersection of the wires of A, and see that it passes through that of B, as formerly directed. Adjust for distinct vision, &c. in the manner which has already been minutely detailed, and on bringing the adjustable dot to the intersection of the wires of B, if the distance of the microscopes be accurate, a division will be found precisely in the intersection of the wires of A, but should it not be so, the error in the distance of A and B must be determined and corrected by means of the micrometer, as before described. The line of reference is then to be brought back to the intersection of the wires of the fixed microscope, and the trial repeated.

When the distance of A and B is found to be correct, the line or reference being brought to the intersection of the cross wires of the fixed microscope, and a division being in that of the microscope B, it is evident that the intersection of the wires of A, must accurately bisect a division, or be four degrees distant from the next division on the instrument. Bring up this division therefore to the intersection of the wires of A and trace a line with the cutting point; do the like with each division, or every eighth degree successively, and the circle will be divided into parts of *four degrees* each, and by continuing to bisect in the same manner, the division of the circle is to be carried to *thirty minutes.*

The last operation consists in trisecting the divisions of thirty minutes.* Bring the line of reference to the fixed microscope, and examine the adjustment of the cutting frame as before. Place the intersections of the wires of B and A, on any two divisions of the instrument, say ten degrees from each other, and increase their distance by advancing the intersection of the wires of A, by means of its micrometer screw, one-third of a division, or *ten minutes.* Place an adjustable dot under A, adjusting the cross wires, and using all the various precautions which have been before minutely detailed. Bring the dot under B, and place a second dot under A ; turn the circle till this second dot arrives at B, when if A and B are accurately at the required distance from each other, it is

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* The method by which this trisection is effected, is of very general application, and may be used with equal facility to divide an arc into any number of parts.

evident that a division will be seen precisely in the intersection of the wires of A; but if not, the error must be corrected as before described, by means of the micrometer. The line of reference is then to be brought back to the fixed microscope, in which position of the circle the intersection of the wires of A will be accurately one-third of a division, or ten minutes in advance. Turn the circle, and *bring every division both of thirty minutes and those newly cut*, successively, as they arrive in the microscope, to the intersection of the wires of A, tracing a new division with the cutting point wherever there does not appear to have been one previously made, and continue this till the whole circle is divided into parts of ten minutes each.

In the example of the process of dividing which I have given, the diameter of the circle was supposed to be two feet, but should the instrument be of a smaller size, the microscopes cannot be brought so near to each other as eight degrees, and then it becomes necessary to choose a different series of numbers for the divisions. For this purpose, I have added a small table, containing several series which appear to be most convenient, and from among which the artist may select that which may best suit the size of his instrument, and his own ideas of accuracy.

It may not be useless briefly to recapitulate the precautions which are absolutely requisite to the success of this mode of dividing.

The microscopes must be perfectly free from parallax, and the vertical angles formed by the intersections of their cross wires accurately bisected by the divisions which pass through them. The intersections of the cross wires of A and B must appear between the circles which limit the divisions, and be equidistant from the centre of the instrument to be divided.

The dot on the cutting frame, if moved through the field of view, must always pass through the intersection of the wires of the fixed microscope; and the motion of the cutting point must be in the diameter of the circle to be divided.

When the line of reference is in the intersection of the wires of the fixed microscope, a division should always appear precisely in the intersection of the wires of the miscroscope B.

Lastly, previous to cutting each new division, if two divisions do not appear precisely in the intersections of the wires of A and B, it is an immediate proof, (unless the microscopes may have suffered any accidental change of position) of inaccurate execution in the former part of the work

From what has been said, it is evident that the microscope B might have remained stationary after having been placed over one of the primary divisions of seventy-two degrees, and perhaps in practice this may be preferable. My only reason for directing it to be removed, was to obviate the effect of any expansion which might take place in that part of the arc which is between the tracing point and the microscope, by placing it as near as possible to the cutting frame; this, however, will probably be found to be an unnecessary refinement.

This method of dividing is not confined to circles, but may be applied with equal facility and advantage to the division of straight lines and zenith sectors. For the last, it is necessary to obtain the radius of the instrument to be divided, and by continual bisection, its eighth part, which is the chord of seven degrees ten minutes. This chord is to be faintly set off on a part of the arc, and the fixed microscope being placed over the middle point of the arc, or zero, the division may be carried to five or ten minutes, precisely in the same manner as has already been directed for the circle.

Finally, whether the operation of dividing is performed by day-light, or by the light of a lamp, I would strongly recommend the use of shades made of thin oiled paper without wire marks, placed very near the limb of the instrument. The accuracy, and, if I may be allowed the expression, the luxury which they afford in delicate observations, can be fully appreciated only by those, who like myself, have been in the frequent habit of using them.

No. 1. For a circle of two feet and upwards.				No. 2.			
		°	′			°	′
$\frac{360}{5}$	will give	72	0	$\frac{360}{2}$	will give	180	0
$\frac{72}{3}$	. . . .	24	0	$\frac{180}{2}$	. . . .	90	0
$\frac{24}{3}$	. . . .	8	0	$\frac{90}{2}$	. . . .	45	0
$\frac{24}{2}$	. . . .	4	0	$\frac{45}{3}$	. . . .	15	0
$\frac{20}{2}$	. . . .	2	0	$\frac{30}{3}$	. . . .	5	0
$\frac{18}{2}$	. . . .	1	0	$\frac{15}{2}$	. . . .	2	30
$\frac{19}{2}$	. . . .	0	30	$\frac{12^\circ 30'}{3}$	. . . . . .	0 and 0	50 10
$\frac{31^\circ 30'}{3}$	. . . .	0	10				

No. 3.				No. 4. For a smaller circle.			
		°	′			°	′
$\frac{360}{3}$	will give	120	0	$\frac{360}{5}$	will give	72	0
$\frac{120}{3}$	. . . .	40	0	$\frac{72}{3}$	. . . .	24	0
$\frac{40}{5}$	. . . .	8	0	$\frac{24}{2}$	. . . .	12	0
(See No. 1.)				$\frac{36}{2}$	. . . .	6	0
				$\frac{42}{3}$	. . . .	2	0
				$\frac{26}{2}$	. . . .	1	0
				$\frac{5}{2}$	. . . .	0	30
				$\frac{24°30'}{3}$	. . . .	0	15

The preceding very ingenious method of obtaining original divisions, possesses in so high a degree the merit of accuracy of principle, and simplicity of execution, that we cannot doubt it will recommend itself to general adoption. To those at a distance from the metropolis, and who may wish to have their instruments made under their own eye, it will afford the means of accomplishing one of the most difficult processes which can occur in the practice of the arts, and we are anxious to contribute whatever remarks may tend to render the apparatus effective.

The frame HI*a*, HI*a*, in which the cutting point acts, is, as the author justly intimates, p. 254, rather too liable to prove a source of imperfect execution. It would scarcely be possible to apply an equal force to each of the handles *b b*, and unless this be done, the twisting of the cutting point, from the distance of its centres of motion, will almost inevitably be fatal to the accuracy of the operation. Much may be done, however, by a careful construction of the apparatus. The joint formed as at HH, II, by a conical point working in a hole of a corresponding figure, is perhaps the best that can be devised, combining less friction with greater steadiness and facility of correct adjustment, than any other; but to make it well, there are several particulars to be attended to, of which all workmen are not fully aware. It is, for instance, particularly important, that the conical points of the screws should not touch the bottoms of the holes in which they work, and in this and other respects for the present purpose, the construction may be as follows: into the ends of BD, fig. 7, of the plate of brass ABED, screw a small piece of steel, of the shape shown at *a*, fig. 10, where a conical hole is continued by a small cylindrical one, of such a depth that the extremity of a conical point fitting the other part cannot possibly be in contact with any thing. This piece of steel *a*, and the screw *b*, which is to work in it, after having been correctly turned, must be screwed, then ground together with fine emery; and afterwards hardened. They should be left at the temper denoted by a full straw-colour. The shoulder *c* may be filed square, to admit of the screw being turned by a key into its proper situation. In drilling the extremities BD, the greatest care must be taken to make the axes of the holes in the same right line, to facilitate the obtaining of which, let the upper and lower surface of ABED, be made quite flat and parallel, and the fore-edge *m m* exactly at right angles to or square with them, and in the same line with each other; then when the ends BD are also quite square with these surfaces, gauge lines, drawn upon them from surfaces at right angles to each other, will, if drawn from the same surfaces at each end, cross each other in points which will be in the same line, and consequently the proper centres for the insertion of the screws. The shoulders *c*, being truly turned, and pressing upon the extremities of BD, which have been squared as above-mentioned, will respectively tend to preserve the desired opposition of their centres. Equal care must be taken to have the axes of the screws FF in the same line, and the nuts *n n*, by which they are secured, after having been screwed, must be turned, so that the surface which will be applied to the piece H, may be exactly at right angles to the axis of the thread. The joints HI, HI, being thus formed, and the parts they connect being made of brass, hardened by hammering, and sufficiently thick to prevent its bending, they may, without rendering them too stiff, be adjusted so accurately as always to make a stroke in the same direction, if the cutting point be in proper order, and if the power applied to make the stroke, have not a very strong tendency to twist the whole apparatus. To have the cutting point in order, the screw at the end of which the point is made, should be secured in the piece G by a nut on each side; these nuts should be made as directed for those at *n n*, and the surfaces of G, upon which they bear, should of course be parallel to each other and at right angles to the direction of the screw itself. The screw should have the strength of two-tenths of an inch in diameter, and be made of steel, found by previous trial to sustain a good edge; the conical point should be regular in its figure, quite smooth and highly polished: upon these properties depends the ease with which it will make its way through the brass in cutting the divisions, and the less the force required to cut the divisions, the less will be the risk of straining any part of the apparatus, and cutting a false line. On this account an advantage might be found in making the cutting point of a diamond; a diamond point could be accurately figured by the lapidary, and would not only cut a smoother stroke than any other substance, but would cut it with more ease. Diamond points are now very generally used, to draw the lines upon copper, in etching and engraving.

But however well the joints HI, HI, may be made, it still is desirable to obviate the use of the handles *b b*, fig. 7; this might be accomplished by means of a triangular bar, accurately fitting and sliding in a fixed groove of the same form, on a level with the direction in which the part G moves. The triangular bar being connected with the part G, by means of a simple joint, exactly opposite the middle of the cutting point, would always draw the point in a right line by applying the hand to a knob fixed in its upper surface; or, indeed, with this additional assistance to preserve the rectilinear direction, handles like *b b* might be used, by fastening them across the triangular bar instead of the part G. The triangular bar should be of cast iron or steel, the groove in which it slides should be of brass. If all the three sides of the bar be true planes, and all of them of the same breadth, the section of the bar itself will be a true equilateral triangle, and no shape will answer better, or be more easily formed. The piece of brass containing the groove for the bar must have an immoveable support beneath the arc of cast iron which carries the three microscopes, and must admit of a motion sidewise, to place it in the same line with the path of the point, and with the diameter of the circle to be divided. This may be done by means of screws passing through a groove, as used at *s s*, fig. 9; there should be two of these screws, one at each side near each end of the piece containing the groove.

The arrangement proposed is shown in profile at fig. 10. The parts *d e f*, resemble those of fig. 8, but the cutting point is fixed, first by screwing the nut *g* at the bottom, and then the nut *h* at the top; *i* is a triangular bar, which slides in a groove of the same shape, contained in the thick piece of brass *l m*. *pp*, are strong springs with friction rollers at the end of them pressing upon the upper surface of the triangular bar, which is thus kept steady in its situation. A plan of the joint by which the triangular bar is connected with the piece of brass *t*, containing the cutting point, is shown at fig. 11; when the cutting point, with the frame which contains it, is moved sidewise, to bring it under the cross wires of the microscope, the pin *v v* slides along at the same time without disturbing the position of the bar *i*. The bar may afterwards be adjusted separately; it has a line drawn along the middle of its upper surface: if when it is pushed forward, this line coincides with the cross wires of the micrometer, and upon reversing its ends the same is still found to be the case, the position of the bar is correct; and when this is not the case, the direction of its bed must be altered at one or both ends as appears to be required. In this way the bar should be tried, when any alteration has been made in the position of the frame containing the cutting point; to admit of being easily taken out and reversed, it is formed at the joint as shown in fig. 12; and the springs *p p*, admit of being turned sidewise till they rest upon the brass. The whole of the apparatus, fig. 7, when once well made and adjusted, will scarcely fail to remain the same during the whole operation of dividing a circle, though the constant trial whether this is really the case should never be neglected. Very slight alterations of the cutting point, will not require any change in the bar *i*, fig. 11.

The triangular bar, by which motion may be given to the cutting point as above described, would probably answer perfectly well if eight inches long; but as the certainty of its regular motion will be increased in proportion to its length, it is advisable to make it not less than twelve inches long. When knobs are used to draw it along, there should be two of them as *r r*, fig. 10, each at the distance of one-third of the length of the bar from its extremity; when handles, like *b b*, fig. 7, are employed, they should be fixed across the centre of the bar. The two knobs will doubtless be preferable; for with them, if the groove and the bar be well fitted by grinding them together, and they are pressed upon each other, at the same time that the bar is drawn along, the lateral deviation of the bar will scarcely be possible.

The bottom of the groove in which the triangular bar slides should be slit to the depth of the sixteenth of an inch, with a saw or knife edge file, in order that the angle of the bar may not, by coming in contact with it, have an impediment to the steadiness of its motion.

For the easiest and most correct method of making surfaces of metal accurately flat, parallel, and square with each other, see the essays on Filing and Grinding, in the Panorama of Science and Art, vol. i, p. 22, 23, &c.

A Description of a Pendant Planetarium.

Fig. 1, plate LXXXVI, *a a a a,* is a frame, supporting the whole machine.

b b, Is a fixed rod or arbor supporting the segment *c,* and the sun S by a fine wire.

d, Is a wheel fixed to the upper part of the cannon *e,* carrying round by its lower end the arm *f f,* and the planet Mercury suspended by a fine dark wire.

g g, Is an arm, fixed by screws into the frame *a a,* at each end, and also to the upper of the fixed cannon *h h,* which supports by its lower end the frame *i i,* which, as explained in fig. 2, is an elliptic plane, supporting, by four or more studs, *l l,* the concave piece *k k,* forming an elliptic ring.

m, Is a wheel on the moveable cannon *n n,* which carries the arm *o o,* supporting at one end the planet Venus by a fine wire as above.

p p, As before, is a fixed frame attached to the immoveable cannon *q* and the elliptic plane *r r,* supporting by studs the concave rings *s s, ut supra;* and thus the wires, by which the planets are suspended, and the concave rings, are alternately supported by the moveable and fixed cannons, &c. until the whole forms a concave like the heavens; having the small grooves or apertures through which the supporters of the planets move round, forming elliptic lines in the concave segment of a sphere, marking out the planets' paths, according to their eccentricity, and showing at one view the places of aphelion, perihelium, &c. of all the planets.

Concave silver stars, in the position that some of the fixed stars would appear from the centre of the sun, will have a fine effect, especially as the supporting wires of the planets will be dark, and so small as to render them almost invisible, the frame being suspended from the ceiling. Their latitude may readily be ascertained by a line drawn from the centre of the sun through that of the planet's place to the hoop *t t*, encompassing the whole, marked with eight degrees on each side of the ecliptic.

The elliptic orbits and inclined planes are obtained by the method shown in fig. 2, where *a a*, is an elliptic plane, fastened to the lower end of each fixed cannon, having its eccentricity calculated to that of the planet which is to be affected by it. *b b*, is the arm attached to the moveable cannon. *c c*, is a slider moving on the arm *b b* by four little friction rollers. *d*, is a friction wheel on the under side of *c*, turning on a pin, which is fastened firmly on *c*, and moves with it through a groove in *b b*, which wheel, running against the edge of the ellipsis *a a*, forces *c c* out, which is again drawn in by the spring *e*, thus causing the planet to revolve in an elliptic orbit, as it is carried round by the arm *b b*, the moveable cannon and wheel-work.

For the inclined plane, *g* is a wheel turning on a pin fastened into *c c*, and carried round on it by a projecting arm of *b*.* On one side of this wheel is a small pin, whose situation and distance from the centre is to be determined by the place of the planet's nodes, and the inclination of its plane to that of the ecliptic; to this pin is fastened a small waxed silk cord, which, passing over the pulley *h*, supports the planet by a fine hair wire, as before-described, and draws it up and lowers it down in its orbit according to its angle of inclination to the plane of the ecliptic.

The planets should be made of polished metal, to give them weight and brilliancy, or of small glass globes filled with mercury. The sun may be a globular glass fountain-lamp, with a cork fitted to the tube, containing a tin pipe for the wick, so that the blaze being in the centre of the globe, and surrounded with oil, will be magnified on every side, and exhibit a splendid sun.

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* The circumference of the wheel must be commensurate with the distance *c c* moves out.

It will be readily understood that motion is to be given to the wheels turning the cannons, &c. by an arbor having as many wheels as the planets have, all firmly fixed to the arbor, and calculated to move them in their proper periods. The whole may be made of wood, if required, and the wheels turned by elastic wire bands. To the machinery may be attached a simple movement, whose weight may descend down the wainscot of the room in any convenient place. Thus the planets will be seen moving round the sun in the concave above, in elliptic orbits and inclined planes, apparently revolving in the heavens without any support.

It is easy to conceive how the same principle, as far as it respects the eccentricity and angles of inclination, may be applied to either vertical or horizontal orreries; by having the wires which support the planets sufficiently stout to bear their weight either in a perpendicular or horizontal position, and sliding in and out of small tubes as they pass round in the elliptic grooves on the face of the orrery. They may be drawn in by the wheel-pin and cord, as described in fig. 2, and forced out by small springs. In this case their latitude may be marked on the supporting wires, and the top of the tube in which they slide will serve as an index; or the degrees may be marked on the edge of the groove cut in the tube, through which an index, fastened to the moving wire or stem which supports the planets, may pass; and thus give the latitude.

Description of a reflective Goniometer, or Instrument for measuring the Angles of small Crystals.

From the advances that have been made of late years in crystallography, a very large proportion of mineral substances may now be recognised, if we can ascertain the angular dimensions of their external forms, or the relative position of those surfaces that are exposed by fracture. But though the modifications of tetrahedrons, of cubes, and of those other regular solids, to which the adventitious aid of geometry could be correctly applied, have been determined with the utmost precision, yet it has been often a subject of regret, that our instruments for measuring the angles of crystals are not possessed of equal accuracy, and that in applying the goniometer to small crystals, where the radius in contact with the surface is necessarily very short, the measures, even when taken with a steady hand, will often deviate too much from the truth to aid us in determining the species to which a substance belongs.

A means of remedying this defect has lately occurred to me, by which in most cases the inclination of surfaces may be measured as exactly as is wanted for common purposes; and when the surfaces are sufficiently smooth to reflect a distinct image of distant objects, the position of faces only 1-50th of an inch in breadth may be determined with as much precision as those of any larger crystals.

For this purpose, the ray of light reflected from the surface is employed as radius, instead of the surface itself; and accordingly, for a radius of 1-50th of an inch, we may substitute either the distance of the eye from the crystal, which would naturally be about twelve or fifteen inches; or for greater accuracy we may, by a second mode, substitute the distance of objects seen at a hundred or more yards from us.

The instrument which I use, consists of a circle graduated on its edge, and mounted on a horizontal axle, supported by an upright pillar, plate LXXXVI, fig. 3. This axle being perforated, admits the passage of a smaller axle through it, to which any crystal of moderate size may be attached by a piece of wax, with its edge, or intersection of the surfaces, horizontal and parallel to the axis of motion.

This position of the crystal is first adjusted, so that by turning the smaller axle, each of the two surfaces, whose inclination is to be measured, will reflect the same light to the eye.

The circle is then set to zero, or 180°, by an index attached to the pillar that supports it.

The small axle is then turned till the further surface reflects the light of a candle, or other definite object to the eye; and, lastly, (the eye being kept steadily in the same place,) the circle is turned by its larger axle, till the second surface reflects the same light. This second surface is thus ascertained to be in the same position as the former surface had been. The angle through which the circle has moved, is in fact the supplement to the inclination of the surfaces; but as the graduations on its margin are numbered accordingly in an inverted order, the angle is correctly shown by the index without need of any computation.

It may here be observed, that it is by no means necessary to have a clean uniform fracture for this application of the instrument to the structure of laminated substances; for since all those small portions of a shattered surface, that are parallel to one another, (though not in the same plane,) glisten at once with the same light, the angle of an irregular fracture may be determined nearly as well, as when the reflecting fragments are actually in the same plane.

In this method of taking the measure of an angle, when the eye and candle are only ten or twelve inches distant, a small error may arise from parallax, if the intersection of the planes or edge of the crystal be not accurately in a line with the axis of motion:* but such an error may be rendered insensible, even in that mode of using the instrument, by due care in placing the crystal; and when the surfaces are sufficiently smooth to reflect a distinct image of objects, all error from the same source may be entirely obviated by another method of using it.

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* I cannot omit mentioning, that Mr. Sowerby had thought of employing reflection for this purpose, nearly at the same time as myself; but did not succeed to his satisfaction, in consequence of an attempt to fix the position of the eye. For when the line of sight is determined by a point connected with the apparatus, the radius employed is thereby limited to the extent of the instrument, and the error from parallax is manifestly increased.

For this purpose, if the eye be brought within about an inch of the reflecting surface, the reflected image of some distant chimney may be seen inverted beneath its true place, and by turning the small axle may be brought to correspond apparently with the bottom of the house, (or with some other distant horizontal line.) In this position the surface accurately bisects the angle, which the height of that house subtends at the eye (or rather at the reflecting surface); then, by turning the whole circle and crystal together, the other surface, however small, may be brought exactly into the same position; and the angle of the surfaces may thus be measured, with a degree of precision which has not hitherto been expected in goniometry.

The accuracy, indeed, of this instrument is such, that a circle of moderate dimensions, with a vernier adapted to it, will probably afford corrections to many former observations. I have already remarked one instance of a mistake that prevails respecting the common carbonate of lime, and I am induced to mention it, because this substance is very likely to be employed as a test of the correctness of such a goniometer, by any one who is not convinced of its accuracy from a distinct conception of the principles of its construction.

The inclination of the surfaces of a primitive crystal of carbonate of line is stated, with great appearance of precision to be 104° 28′ 40″: a result deduced from the supposed position of its axis at an angle of 45° with each of the surfaces, and from other seducing circumstances of apparent harmony by simple ratios. But however strong the presumption might be that this angle, which by measurement approaches to 45° is actually so, it must nevertheless be in fact about 45° 20′; for I find that the inclination of the surfaces to each other is very nearly, if not accurately 105°, as it was formerly determined to be by Huygens;* and since the measure of the superficial angle given by Sir Isaac Newton† corresponds with this determination of Huygens, his evidence may be considered as a further confirmation of the same result; for it may be presumed, that he would not adopt the measures of others without a careful examination.

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* Huygenii Opera Reliqua, Tom. I. p. 73—Tract. de Lumine.

† Newton's Optics, 8vo. p. 329. Qu. 25, concerning Iceland Chrystal.

In plate LXXXVI, fig. *a b* is the principal circle of the goniometer, graduated on its edge.

c c, The axle of the circle.

d, A milled head by which the circle is turned.

e e, The small axle for turning the crystal, without moving the circle.

f, A milled head on the small axle.

g, A brass plate supported by the pillar, and graduated as a vernier to every five minutes.

h, The extremity of a small spring, by which the circle is stopped at 180°, without the trouble of reading off.

i i and *k*, Are two centres of motion, the one horizontal, the other vertical, for adjusting the position of a crystal. One turned by the handle *l*, and the other by the milled head *m*.

The crystal being attached to a screw-head at the point *n*, (in the centre of all the motions,) with one of its surfaces as nearly parallel as may be to the milled head *m*, is next rendered truly parallel to the axis by turning the handle *l* till the reflected image of a horizontal line is seen to be horizontal.

By means of the milled head *f*, the second surface is then brought into the position of the first, and if the reflected image from this surface is found not to be horizontal, it is rendered so by turning the milled head *m*, and since this motion is parallel to the first surface, it does not derange the preceding adjustment.

A Drawing-board and T-square, designed to facilitate the accurate delineation of architectural, mechanical, and mathematical designs.

The invention of ruling machines, in the art of copper-plate engraving, produced such a degree of perfection in the tints ruled by them, that a corresponding degree of accuracy was immediately required in all the other departments of the art, wherever the use of the machine was introduced.

But unfortunately for the credit of this department of the art, a most general opinion was directly formed, that engraving done with a machine required but little exertion in the artist to attain perfection, and that nearly the whole secret lay in the possession of a ruling machine :—Experience has most indubitably proved, that in general practice, the invention of a ruling machine, at the same time that it produced a portion of perfection in the tints ruled by it, never before seen, presented a degree of difficulty in the drawing and finishing department, such as had never been experienced. Indeed, such an excess of difficulty as might have prevented its adoption in the hands of any other person than that of its most ingenious inventor.

One of the most formidable difficulties which presents itself to an engraver of machinery and scientific subjects, is that of getting a correct outline tracing upon the copper-plate. To effect this, transparent oiled paper (commonly called tracing paper,) is used for subjects of the free picturesque kind. But in plans, elevations, and sections of buildings, machinery, &c. such means are of little or no use; because, when such tracings are passed through the rolling-press to transmit the outline to the copper-plate, its unequal expansion while under the process of wetting, and likewise in its passage through, produces such a degree of error (especially when the ruling machine is employed) as to render such tracing completely useless.

To obviate this evil, the engraver has no other resource than to make a very correct outline reversed from his original drawing upon thin bank post paper, and having smeared the back with red chalk, carefully trace over each line, when the outline is laid down upon the varnished copper-plate.

Hence it appears evident, that much will depend upon the nicety of the outline thus made, and as a means of ensuring accuracy of form and delicacy of execution, it became necessary to improve the construction of the drawing boards employed,

Whenever very thin paper is used for making outlines upon (and which is absolutely requisite in the case alluded to) considerable difficulty is found by the surface of the board giving way, wherever compasses are used for taking dimensions; but more particularly in all cases where a number of concentric circles are to be described from the same point, the large holes produced in the drawing rendering it very unsightly, at the same time that all accuracy is destroyed by the centre hole frequently shifting into a hollow produced by the grain of the wood.

To avoid errors of this kind, the Inventor some years ago had recourse to a drawing board, covered with a plate of copper, which answered tolerably well, but when a point was pricked through the paper, it was scarcely visible, owing to the colour of the copper, which, being reddish, rendered the dot or puncture very indistinct, while the surface was likely to have a very unpleasant oxide produced upon it, owing to the necessity of stretching the paper while in a wetted state. He therefore covered the drawing board with a plate of rolled zinc, which may be had of almost any dimensions, at Knight's in Foster Lane, Cheapside, London; and having made use of drawing boards of this kind for nearly two years, he can speak with confidence of their advantages, and assures those artists who may be inclined to sacrifice a small additional expense to obtain the means of making their drawings with neatness and accuracy, that they will not be disappointed if they possess a board of this description.

The advantages of zinc for this purpose are found to be, that it is soft enough to admit of the insertion of a point sufficiently deep to be plainly seen, and yet hard enough to prevent the point from going to any considerable depth, so as to permit large holes to be made in the paper, and the drawing being complete, whatever holes are made in the zinc, may be burnished down by rubbing the thumb-nail over them, which will sufficiently close them.

When oxidation of the metal takes place, it should be suffered to remain, because its whiteness helps to render the thin paper opaque, and consequently the lines drawn upon it will be the more plainly seen.

When the sides of the frame of a drawing board are straight lines, and nicely perpendicular to each other, parallel and perpendicular lines may be very correctly drawn with a good T-square; but as wood is continually warping with every change of weather, accuracy cannot be expected from such imperfect means.

To prevent any error arising from this circumstance, it is a further improvement of the drawing board to screw a solid rim of brass upon its upper surface, permitting it to project a small distance beyond the outer edges of the wooden frame, so that the stock of the T-square may slide against either edge. This brass rim being dressed very true and at right angles, will remain so for any length of time, as nothing but extraordinary violence can injure it.

The present invention sprung from necessity, originating in the very minute size of the engravings of the present day, added to which, a degree of accuracy is required, that can only be attained by a corresponding improvement in the apparatus; and for effecting such purposes, the zinc plate may be applied to a common drawing board, and the brass rim to the frame; therefore those persons who possess a set of drawing boards, may have them improved at a small expense.

The same objection that applies to the frame of a drawing board, applies equally to a T-square made with a wooden blade, and fixed immoveably to its stock; for if ever any injury happens to the fiducial or drawing edges, by a blow causing an indentation, or by the wood warping through a change of weather, it must remain, because the blade being glued fast to the stock, does not admit of being corrected without considerable difficulty.

The new square now proposed, therefore, is so constructed as to permit the blade to be withdrawn from the stock, for the purpose of correction, should any accident occur to it; and the same means which permit the blade to be removed for the purpose of correction and adjustment, enables the draughtsman to use it as a bevel at any angle, where it may be fixed by a clamp and thumb-screw.

Should the weight of this invention be deemed an objection to its use, it may be stated that it may be made in ebony or boxwood, which would render it as light as a common square. The blade may be very easily set to a right angle by making it coincide with a line drawn on the arc for that purpose, where it may be fixed by the clamp.

Fig. 1, plate LXXXVII, respresents a plan of the drawing board and frame. The surface AA, shows the zinc plate, fastened round its edge with small copper pins, the heads of which are sunk and made smooth with the zinc surface. BB, represent the brass rim, made in one piece, and screwed to the wooden frame of the drawing board by counter-sunk screws. The edges of this brass rim should be finished and set at right angles after it is screwed down to the frame.

Fig. 2, shows a section of fig. 1, taken through the line AA. In this figure it may be seen that the upper surfaces of the brass and zinc are so fitted as to be in the same plane. The small buttons CCCC, being formed like small wedges, may be pressed into the grooves made in the frame to receive them. These, as a mode of fastening the board to the frame, will be found preferable to the wedges in common use, as they may be applied to a greater number of points, which will be found requisite when the board is large.

Fig. 3, shows a view of a T-square with an adjusting blade, consequently it can be set to any angle, and fixed to the arc G, by the thumb-screw D.

Fig. 4, represents a section of fig. 3, in which the action of the thumb-screw D, and the clamp E, may be more distinctly seen, as likewise the screw F, upon which the blade turns as a centre.

The screw F being withdrawn, permits the blade to be taken out, and the edges repaired, if they should receive any injury from wear or accident. The arc G, being divided into degrees, permits the blade to be placed at any angle, where it may be fixed by the thumb-screw D.

The frame and pannel of the drawing board should be made of hard, dry, and knotty mahogany, wood of that description being least liable to warp; and the frame, for a board of the smallest size, should be about an inch thick. As it will scarcely be possible to produce a perfect contact throughout, between the plate of zinc, and the pannel of the drawing board, it will be advantageous to smear the surface of the pannel with a thick solution of common glue, immediately before the plate is screwed down upon it: though glue will not adhere to the metal, it will fill interstices which might otherwise give a spring to the surface of the plate; and it has this advantage over other cements, that while it is every-where procurable and cheap, it is not injured or displaced by any moderate increase of temperature.

To render this drawing board complete, the surface should be a true plane, and to obtain this will not be found an easy task, by ordinary artisans or by ordinary modes of working. The easiest mode of effecting the purpose, might perhaps be to have the surface ground by the stone-mason, upon a flat surface of fine sandstone; but as water must be used in this operation, it would be apt to warp the wood in drying;—an effect which cannot by any means be with certainty guarded against, although it may be obviated in some degree, by wetting every part of the wood equally, and afterwards suffering it to dry very slowly, by placing it in the shade, and in a cool situation. The surest mode, however, of obtaining the desired object will be by filing, agreeably to the directions given in the "Panorama of Science and Art," Vol. I: and to that work, and to page 221, of this volume, we refer for the art of obtaining a true plane by grinding.

Although the ingenious inventor of the improved drawing board described in this article, recommends the small studs CCCC, in preference to the usual wedges, yet this mode of fastening the pannel, is not probably, on the whole, equal to that shown at fig. 5, which represents a transverse section of a drawing board, as from B to B, fig. 1: AA, the pannel of the drawing board: BB, the longitudinal sides; FF, a bar of wood which reaches across the drawing board, and the ends of which enter grooves extending the whole length of the longitudinal sides BB of the frame. The bar FF should be about an inch broad for the smallest board according to the size of which it may be increased to the breadth of two inches. No board should have less than two such bars, and for large drawing boards it will be proper to have one at the distance of every eight inches. These bars retain the pannel in a steady, flat position, and resist not only the tendency it may have to warp, but the pressure to which drawing boards are occasionally subjected by leaning upon them.

An Instrument for drawing Ellipses.

Fig. 1, plate LXXXVIII, is a general view of the instrument, consisting principally of a frame, wheel, and arm, for carrying the pencil, tracer, or pen. The whole being supposed to be placed upon a table or drawing board, may be thus described: CC, CC, feet of the frame, which are placed in parallel lines longitudinally upon the table or drawing board.

DD, DD, turned pillars of brass firmly fixed to the feet CC, CC.

EE, a horizontal beam with a groove AA, fixed to the tops of the pillars DD.

BB, BB, guides, each consisting of a brass bar and a steel plate, attached to the horizontal beam EE; the straight edges BB, BB, of the steel plates, being parallel to the feet CC, CC: or to the table; and at right angles to the longitudinal middle of the beam EE; *c c c*, a wheel, grooved on the edge, so as to fit and slide upon the steel plates BB, BB, and to move freely and exactly thereon, so that the centre of the wheel may be compelled to describe a straight line parallel to the table or drawing board, and at right angles to the longitudinal groove or slit AA, in the beam EE.

The arms of the wheel are placed at right angles to each other, and one of them is made double, so as to contain a groove *d d*, in which is inserted a slider, made to fit the groove exactly, and move freely therein.

a b, A handle, consisting of a milled head *a*, and turned pillar *b*, made to fit the slit or groove AA, in the beam EE; and having a screw at its end, which may be screwed into the slider at pleasure, and make it fast in the groove *d d*, of the wheel.

e e, A vertical piece of brass, firmly attached to the under face or rim of the wheel, at one end of the groove *d d*.

f f, *h h h*, An arm jointed at *f f*, to the vertical piece *e e*, so as to move only in a vertical plane passing longitudinally along the middle of the groove *d d*, in the double arm of the wheel.

i i, A tube or case, to contain a pencil, pen, or tracer; made to slide along the arm *h h h*, and to be fixed by a milled headed screw; (which in this view, is hid by the rim of the wheel;) the tracer, when fitted in the tube, being of such a length, as when the point is resting on the paper, the arm may be parallel to the plane of the board; and the tracer is fixed in the tube by a small milled headed screw, shown at the lower end of the tube.

The parts of the perspective view of the instrument being thus described; suppose then, the handle *a b*, is fixed in the centre of the wheel; it is plain that when it is turned round with the wheel, the centre will have an invariable position: but if it be fixed out of the centre, it is evident, then, that the centre will describe a straight line, parallel to, and equidistant from, the steel edges BB, BB, of the guides: and because the arm *h h h*, is in the same vertical plane with the groove *d d*, in the double arms of the wheel; and all the points in the longitudinal direction of the arm, fixed with respect to those which pass longitudinally along the said groove; there is therefore a certain point *k*, in the arm *h h h*, in the same vertical line with the centre of the wheel; and since the centre of the wheel is always in a straight line parallel to the board or table, and at right angles to the beam EE, the said point *k*, in the arm, will also be in a straight line, parallel to the board or table, and in a vertical plane passing through the line described by the centre of the wheel; and because the axis of the handle *a b* is likewise in the line which passes longitudinally along the groove *d d*, included by the arms of the wheel, there will be two points in this longitudinal line passing along the groove of the wheel; the one which is in the axis of the handle *a b*, moving along the middle of the groove AA, of the cross beam EE; and the other, which is the centre of the wheel, moving at right angles therewith, parallel to the board;

and consequently, the arm $h\,h\,h$, will also have two such points moving horizontally; the one which passes through the handle $a\,b$, in a vertical plane passing along the middle of the groove AA in the beam EE; and the other, in a vertical plane, passing through the line $d\,d$, described by the centre of the wheel; and as the horizontal section of these two vertical planes are two horizontal straight lines, at right angles to each other, the one point of the arm $h\,h\,h$, will move in the one line, and the other point in the other line.

It is therefore evident, when the axis of the handle $a\,b$ and the centre of the wheel are coincident, that every point in the arm $h\,h\,h$ must describe the circumference of a circle; but when these two points are separated, every point in the arm $h\,h\,h$ will describe an ellipsis.

Fig. 2, the face of the wheel; $d\,d$, the middle of the groove, referred to in the general view.

Fig. 3, profile or edge of the wheel, showing its connection with the arm $h\,h\,h$. From this figure, the method of setting the instrument, in order to describe an ellipse of any given dimensions, will be shown. Thus, let k be the point in the arm $h\,h\,h$ corresponding to the centre of the wheel, which is here a fixed point; make $k\,l$ equal to the difference of the two semi-axes: l will then be the centre of the handle $a\,b$, which ought therefore to be screwed at that distance from the centre of the wheel in the groove $d\,d$, and also make $k\,i$ equal to the lesser semi-axis; and the instrument will then be set, so as to describe the ellipse.

It is obvious, that as the arm $h\,h\,h$, has no interruption upon it, the point i may be made to coincide with k, by which means the tracer will describe a straight line, which may be in length the double of $f\,k$. In using the instrument, the milled head of the handle should be twisted round with the thumb and fingers, at the same time letting it obey the direction given to it, by sliding along the groove AA. in the beam EE, without impediment or hinderance.

In adjusting the instrument, the two grooves, namely the groove AA in the beam EE, and the groove $d\,d$, in the wheel, should be brought underneath each other, so as to be in one straight line; then move the handle $a\,b$, until its centre shall be in the point l, fig. 2 and 3;—its distance from the point i, in the arm $h\,h\,h$, will be equal to the semi-transverse diameter of the ellipse; and make the distance of [illegible] tracer, from the point k, equal to i, which will be equal [illegible] semi-conjugate diameter.

Fig. 4, shows the upper side of the arm *h h h*, with the slider *i*, and the form of the joint at *f f*.

Fig. 5, the side of the vertical piece of brass, shown at *e e*, fig. 1.

Fig. 6, the horizontal beam, with the two pillars DD; and the ends of the straight edges, or transverse pieces BB, along which the wheel slides.

The steel plates shown at BB, keep the wheel always in the plane of its face.

Fig. 7, shows the cross beam EE, with its groove AA; and the two transverse pieces BB, in their real proportions; see its connection in the general view, fig. 1.

Figs. 8 and 9, the slider, with a socket screw to receive the screwed end of the handle *a b*; its longitudinal direction is shown at fig. 8, and its section at fig. 9; when the end farthest from the handle is made to touch the rim of the wheel, the handle will be in the centre of the wheel.

Fig. 10, the handle for turning the instrument by, consisting of a pillar *b*, with the screwed end, and a milled head *a*; shown in the general view, fig. 1, at *a b*.

Fig. 11, the tracer or steel point, which will be useful upon copper; it will, however, be much better to have a small conical diamond point, fitted into the steel; for a steel point, applied to copper in a machine, does not, however well tempered, perfectly clear away the etching ground.

Fig. 12, the drawing pen, for describing the elliptic curve upon paper with ink.

The simplicity of the construction of this instrument, which the Inventor proposes to call an *Ellipsifex*, is certainly no small recommendation of it; and in the facility of its adjustment, and extent of its range, it can scarcely be excelled. It will be observed, that if the centre screw is placed in its greatest, or, indeed, any eccentricity, and the pencil immediately under it, the pencil, on turning the wheel, will be found to describe a right line. If, on the contrary, the centre screw is placed in the centre of the wheel, the pencil will describe a circle, which may be diminished down to a point, without making any centre mark, and hence the instrument is capable of describing every proportion of ellipse between the circle and the right line.

of the line to be divided between the end points, and the proportional part will be given by the distance between the two sliding points.

Fig. 1, plate LXXXIX, a general view of the angulometer, which answers the purposes of a protractor, a three-legged compass, and also a proportional compass.

AA, the legs, jointed at B: B the joint, with a projecting pin from the under side, shown at F: CC, sliders, moveable at pleasure upon the legs AA, to which are attached the projecting points DD.

The extreme point F, of the pin, is in the line of the axis of the centre-pin of the joint.

The points EE, the extremities of the legs AA, and the points DD, which project from the sliders, are all in a plane passing through the axis of the centre-pin, when the instrument is shut; and, when open at any angle, the point F, and the points DD, are in a plane perpendicular to the axis of the centre pin; the quadrant is of the same piece of brass with one of the legs: H, the vernier, in order to divide the degrees into minutes.

Fig. 2, one of the legs of the instrument, shown on the edge, with the centre-pin and point at the end of it.

Fig. 3, side of the same.

Fig. 4, edge of the other leg.

Fig. 5, edge of the other leg, with the quadrant.

Fig. 6, one of the sliders, shown separately.

Fig. 7, the vernier, shown on the face, with the hole through which the centre-pin passes.

Fig. 8, the vernier, shown on the edge.

Fig. 9, the milled headed nut, which tightens the instrument, shown on the edge.

Fig. 10, washer under the milled headed nut, shown on the edge and face.

Fig. 11, a milled headed nut, next to the point.

Fig. 12, view of the upper part of the instrument, taken edgeway.

Method of preparing Charcoal, to answer the purpose of Black Chalk for Drawing.

Take the finest grained charcoal that can be procured, and saw it into slips of the size and form required: put the slips into a pipkin of melted bees'-wax, and permit them to remain near a slow fire for half an hour or more, in proportion to the thickness of the charcoal; they are then to be taken out, and when perfectly cool, are fit for use. By adding a small quantity of rosin to the wax, they may be made considerably harder; and, on the contrary, should they be required softer, a little butter or tallow will answer the purpose.

The advantages these pencils possess, are, that they can be made at the most trifling expense, and at any time; and that drawings made with them are not liable to injury by being rubbed, or remaining in the damp. The charcoal thus prepared answers the purpose of black-lead, not only for drawings but for making memorandums.

The same process will harden both red and black chalk, and make them permanent also.

The softest charcoal that can be of any use for this purpose, is made of willow-wood; the hardest, of box-wood; that of maple is of intermediate hardness, and probably the most useful. The easiest mode of preparing a small quantity of charcoal is to put slips of wood upright into a crucible or iron pot, and cover the whole with sand; then to place the pot in a fire, and suffer it to remain till, upon trial, the slips are found to be charred to the centre. The pieces generally warp in the operation, and therefore, if wanted straight for pencils, they should, when cut in their raw state, be thicker than they will be required for use, in order to allow for shaping them afterwards. They must not be taken out of the sand till cold.

The willow charcoal is the sort used by engravers, in polishing copper-plates, and for giving a fine even surface to other soft metals; the pencils made of it are excellent for working freely.

The less free the access of air, during the process of charring, the harder the charcoal of the same wood becomes; but the method above proposed, to cover the wood with sand, is best adapted to the present purpose.

An improvement of the Theodolite; and a new method of cutting an accurate Screw.

The proposed improvement of the theodolite is this, that instead of reading the divisions by a nonius or vernier, they are read by a micrometer,—a method certainly calculated to facilitate the accurate reading of them, but it renders indispensable a very correct screw, and a new and simple method of cutting such a screw is therefore combined with the account of it in this article.

Fig. 1, plate XC, part of the theodolite, divided to half degrees, showing the endless screw, *a*, clamped close in: *b*, the screw that fastens it, by loosening which it is disengaged; the screw-frame then moves freely on the axis *d*, on which it turns. The theodolite is divided into half degrees; the edge is cut into as many (720) threads, consequently one revolution of the screw moves the theodolite half a degree: *e*, a micrometer on the screw *a*, divided into thirty, which gives minutes, and these subdivided into four, give quarter minutes.

Fig. 2, a section of the circle, the parts a little separated to show the construction; the rack in the edge is parted in the middle: the upper half, *g*, is a ring screwed to it, with twelve screws, thirty degrees apart. *h*, The rim of the under plate, on which the circle moves: *i*, the plate, carrying the screw-frame: *a*, section of the screw: *k*, the needle.

Fig. 3, part of the screw-frame, showing the split head for holding the screw, and the axis, *d*, on which the frame moves.

Fig. 4, the end of the axis of the screw, with the micrometer *e*, taken off: *b*, the small screw, which fixes the micrometer when adjusted.

Fig. 5, the frame for cutting screws: *n*, the stock, which holds the cutter or half die *m*: *o o*, two chaps, which hold the cylinder to be cut; they are fastened to a plate which slides in the dovetail, *p p p p*: *q*, the screw which forces the cylinder against the cutter.

The cutters are originally tapped in their place, consequently true to the chaps. The tap being made similar to the screw *a*, which is represented in the chaps, a small winch is to be put on the square end *r*, to turn it round in the chaps: *o o*, must be apart full twice the length of the screw to be cut; two cutters are used to cut the screw: the cutter, fig. 6, is first put in; the outer dotted circle is the diameter of the cylinder or top of the thread; the inner dotted circle is the bottom of the thread: this first fits the outside diameter of the cylinder, by which it gives a true lead: when this has cut a quarter or a third down, it is taken out, and fig. 7 is put in, which fits the bottom of the thread, (as shown by the dotted circle.) Though the cutters (being made in their place) are sure to give a truly cylindrical screw; yet if the end moving in one chap, is bigger than the other, it will give a screw taper the contrary way; therefore the parts taken hold of by the chaps must be of the same size; and if there should be any fault in the cutter when the screw is cut, passing it once through the contrary way will equalize it, and the thread must then be perpendicular to the axis, and perfectly concentric.

Fig. 8, a top view of the stock *n*, and cutter *m*.

Fig. 9, a side view of the frame.

The above only shows the method of setting screws for common use, but the machine also generates original screws perfectly true, of any number of threads, and right or left handed. In this case, the stock and cutter are made as fig. 10, and fig. 11; the back of the stock is made into the segment of a circle, *s*: and the top of the cutter is continued into an index, *t*; the cutter is a single thread, and moves on its edge *v*, as a centre; this must fit true, and the stock fit close to the cutter to keep it perfectly steady: *u*, *u*, two screws, to adjust and fasten the cutter at any required angle. The cutter should be rather elliptical, for it is best to fit well to the cylinder at the greatest angle it will ever be used. When one turn has been given to the cylinder, fig. 12, a tooth *w*, is put into the cut, and screwed fast: this tooth secures the lead, and cause every following thread to be a repetition of the first; and, though it might do without, yet this is a satisfactory security.

A true screw is, in many branches of mechanics, of the first importance, and would always be preferred to an imperfect one, if it could be easily obtained; but the difficulty of producing such an one is known by skilful workmen to be very great, and in fact quite impossible by the dies, screw-plates, or any of the means in ordinary use. The machine, invented by the late Jesse Ramsden, to cut the screw of his dividing engine, would at this time cost about fifty guineas, and it only cuts a short screw, such as the above invention will execute.

It is always advisable to have two dies or cutters, the one larger in diameter than the other; the largest, proper to begin with, should be of such a size as to receive and fit, at the beginning, the part that is to be cut; when this is the case, the very first turn is sure to form a proper screw, for the whole of the teeth will be in contact at once with the part that is to be cut. The finishing is to be done with the smaller tool, and in case there should be any difference in the bearings, it will be proper to shift or reverse the screw in finishing; by which means the error, however small, will be split, and consequently a screw, as near perfection as imaginable, cannot fail to be produced.

By this means, it is simple and easy to cut a good screw. Any one, who works in metal, can make the tool, the expense of which will not exceed that of stocks. It not only makes the screw true in itself and to its bearings, but affords an opportunity of making a screw of considerable length proportionably true, that is, each thread shall be in its proper place. This is to be done by dividing it, and beginning to cut at different stations.

One of the most valuable applications of an accurate screw, besides that to the theodolite already mentioned, is to the dividing engine; but there are various instances, in the adjusting screws of mathematical and astronomical engines. where an exact screw will be of very considerable service. For example, the Inventor had found great difficulty in cutting with common dies, for telescopes of five and seven feet, the two screws, one of which gives the horizontal and the other the vertical motion of the stands. He could not get them free from two faults, one of which was, that the thread had not a true and regular inclination; the other, that they were more or less bent and twisted; in consequence of which they were not sufficiently true in their bearings to act pleasantly. These were the circumstances, which, so long as twenty years ago, suggested to him the instrument which has now been described.

In this machine, it is of great consequence that the plate which slides in the dovetail *p p p p*, should fit so correctly as to be incapable of any lateral motion; to secure which property, perhaps the easiest mode will be to have one of the plates, *r r*, forming the dovetail, moveable, and to have screws bearing against the outside of it to press it inwards, in addition to the screws which fasten it down to the plate *k k*.

Dissertations upon Painting in Oil, in a manner similar to that practised in the ancient Venetian School.

DISSERTATION I.

The method of painting practised in the ancient Venetian School appears to have been the following:—

The cloth was primed with colours in distemper, of a brownish hue, such as would properly enter into the darkest parts of the picture. The most transparent colours were preferred. Umber appears to have been most generally used, broken with red, yellow, or blue, according to the tint intended to be produced, and diluted with chalk or whiting to the proper degree of strength. Upon the ground so prepared, the subject was correctly drawn with umber, pure or mixed lake, blue or black; and with the same colours, the shadows that were darker than the ground were then painted in.

The artist next painted the lights *with pure white*, in a solid body where the light was brightest, or where the full effect of colour was to be produced; and, where the demi-tints were afterwards to be, scumbled it thinner by degrees, till it united with the shadows.

In this manner the chiaro-oscuro was finished as much as possible, and the local colour of every object in the picture glazed over it. All the colours used in this part of the work were ground in oil, which was absorbed into the ground, the picture remaining flat, something like a picture in water-colours or crayons; it was then varnished, till saturated with varnish, and the full of every colour being thus brought out, the picture was complete.

Upon the most superficial view of this process, it will be evident that a picture painted by it is, as to all visible properties, a varnish picture: for the small quantity of oil that has been used, sunk into the ground, and never can rise again to be hurtful; while the varnish being laid on after the colours, gives them all the brilliancy and durability they can derive from that vehicle, without being liable to the objections that are made to painting in varnish, supposing it to be used in the same manner as oil in painting with oil. It is true that this mode of painting is itself liable to some objections, though it will hereafter be shown that these are not incapable of being obviated. Here it may be observed, that as any varnish may be used, it is to this circumstance we must attribute the different degree of durability in pictures of the Venetian school; some of which resist the most powerful solvents, while others would be destroyed by the weakest; though both possessing the apparent properties that distinguished Venetian pictures from all others.

Painting is not a mere mechanical art, that may be infallibly practised by a receipt, but such appears to have been the general system of the Venetian school, though variously modified in the works of different artists, both of that and of the Flemish school, which was derived from it. It is susceptible of almost an infinite number of modifications, in proportion to the talents and judgment employed upon it, and of the objects to be painted. This being the case, if it is proved by experiment, that effects similar to those of the Venetian pictures may be produced by this method, and that the system has a strong tendency to produce that brilliancy and harmony of colouring which are so much admired, with more certainty and facility than those qualities can be obtained by any other mode of painting, it may certainly be allowed that this view of the practice of the Venetian school is correct.

The Author of this essay having once asked Sir Joshua Reynolds, by what circumstances, in the management of a picture, he thought the harmony of colouring was to be produced? he replied, "A unity of light and a unity of shadow should pervade the whole." He explained the difficulty of reducing the various colours of all the objects that may be included in a picture, and the various modifications of those colours, to this simple harmonious state; and remarked, that "a picture, to possess harmony of colouring, should look as if it was painted with one colour, (suppose umber and white) and when the chiaro oscuro was complete, the colour of each object should be glazed over it."

This observation, from such authority, was impressed with peculiar force on the Author's mind; and in retracing its operation on a subject which has long engaged his attention, he considers it as the clue which guided him through all his experiments, and which will enable him to prove that the beautiful and simple practice thus suggested as a simile, was literally the practice of that school, upon whose works his ideas of colouring were founded. That this was the fact, however, appears not to have struck Sir Joshua, or he would not have given his observation the form of a simile, to simplify his description of a practice which he thought both difficult and complex.

It is the Newtonian doctrine of light and colours, that all colours are inherent in light, and are rendered visible by the action of various bodies, which reflect particular rays and absorb the rest. Without disputing the truth of this doctrine, it is to be observed, that a painter must consider the objects he represents as being analogous to the materials he uses to represent them; and, in this view of the subject, colour is to be considered as a property inherent in bodies, which is rendered visible by the contact of light, a colourless, or at least a mono-coloured substance; and shadow the mere privation of light.

A picture may represent either a group of pictures, or other objects, in a room, or any objects in the open air; whatever the situation may be, it represents certain objects in a given space, possessing individually their peculiar colours, and generally exposed to the operations of light. The quantity of light each can receive must depend upon its form, and its position respecting that part whence the light comes; for, in proportion as other parts recede from the light, the shadow becomes visible: but shadow is only privation of light, and privation of colour in proportion as the light is diminished. Some attention to these circumstances will, perhaps, enable us to demonstrate the truth of Sir Joshua's position.

If a globe of one colour be exposed in a painter's room, properly darkened, that part which is nearest the light will partake of its colour; the next part will show the true colour of the object: that which first recedes from the light will be a little obscured, the next a little more, and so on progressively, till that part which is farthest from the light will lose its colour, and appear equally dark with the shadiest part of the room. Now we know that this globe is of one uniform colour; the variations we see in various parts of it are only deceptions, occasioned by the accession of light in some parts, and the privation of it in others.

What is true of this one object and its parts, would be equally true of any number of objects, whatever their colours or relative situations might be: if they were placed together in the same room, each would possess its own individual colour, each would partake of the general light, in proportion to its situation, and of the general darkness in proportion as it recedes from the light. All this may be easily conceived; but it is found to be a serious difficulty, in the ordinary modes of painting, to represent such objects with the appearance of truth, and preserve the harmony necessary to constitute a whole. The Venetian painters, however, effected this by a method so simple, that perhaps no other can produce such brilliant effects, and undoubtedly not with facility and certainty at all comparable with theirs.

In this account of the Venetian method of painting, nothing has been said of the manner of producing those demi-tints which conduce so much to the brilliancy of a picture, which are so difficult to execute, and in which failure is so frequent. Those tints are, in the ordinary modes of painting, produced by the mixture of black, grey, blue, or brown, (according to the judgment of the artist,) with the local colours of the objects. It is these tints which, from their being made with such colours, it is difficult to get clear, and which never are so clear in any other as in the Venetian, and in some of the Flemish pictures, which are painted upon analogous principles. The fact is, that those painters produced all such tints without the admixture of any colour to represent them, and by a method so like that by which they are produced in nature, that this circumstance alone ensures a degree of brightness to their colours, and of harmony to their shadows, that it is perhaps impossible to produce, in an equal degree, by any other mode of painting.

It is a singular fact, that if upon any degree of brown, between the deepest and the lightest brown yellow, we paint pure white, in gradations, from the solid body to the lightest tint that can be laid on, *all the tints between the solid white and the ground will appear to be* GREY, intense in proportion to the depth of the ground, and the thinness of the white laid upon it. But in every case, all the tints laid upon one ground will harmonize with each other, and will form gradations that will perfectly unite the highest light with the darkest shade.

If then we examine the component substances of a Venetian picture, we shall find the lighter parts to consist only of white, to represent the light; and of the local colours of the objects it represents, the demi-tints are imitated by an *appearance* almost as deceptive as the similar appearances in nature; but in every other method of painting, these demi-tints are produced by mixing some dusky colour with the local colours and the light. The comparison of these methods will afford a demonstrative reason why the Venetian must be brighter than any other mode of painting.

It being thus shown, why those parts of a Venetian picture that are connected with light and colours, are brighter than the corresponding parts of any other pictures, it remains to explain the cause of similar superiority in the darker parts of the same pictures.

It has been said, with much confidence, that as white represents light, so black is the representative of darkness; but though this may be true in natural philosophy, it certainly is not so in painting; for the painter's art is to represent objects as they *appear*, in point of colour, to be, not as they really are. Thus, if we know an object to be perfectly black, and are to represent it as it appears to be at the distance of fifty feet, black from the pallet will not produce a good imitation of it, because the interposition of fifty feet of the atmosphere will cause it to appear of a colour different from what it really is; and *vice versâ*, if we go into a cavern, a cellar, or a room so darkened that the colour of no object can be distinctly seen, and if we there hold any solid black substance near the eye, the difference will be visible at once; the black object will be immediately distinguished, by its solidity and colour, from the surrounding space, and such remote objects as may be obscurely visible through it. These objects actually possess their individual colours, and only appear indistinct from the absence of light. The black object may appear solid, and of that colour, from its proximity to the eye; but the circumjacent ones will appear of a colour perfectly distinct from it, more or less transparent, in proportion to their distance from the eye, and showing a portion of their individual colours, according to the quantity of ill-defined light that may be admitted. Shadows, then, though existing only by the absence of light, give to objects an ill-defined appearance, distinct from, though in some instances mixed with, light and colours in different degrees; but as the painter must represent the *appearance* by something *real*, he chooses the colours most analogous, viz. browns, and the most transparent of their class, to represent this transparent, but imperfectly defined appearance in nature.

It has been supposed that the Venetian painters had some peculiarly rich and transparent brown colour, which is seen to pervade all the works of that school; the effect of which no modern artist has been able to imitate, and which therefore is supposed to have been lost. It is not very probable that a colour so common, as to pervade the works of the worst as well as of the best artists of that school, should be so unaccountably lost; and, as the effect attributed to it may be easily produced by the mode of painting above described, it is not unreasonable to conclude that this much-lamented colour has never existed.

It is well known that chalk, and other earths of the same kind, lose, when wetted, much of their whiteness, and become semi-transparent, it is equally certain, that if umber, or other earths, are mixed with chalk, and saturated with varnish after they are laid on the cloth, they in like manner become diaphanous, and are far more brilliant than the same colours can be when mixed with white lead and oil. Such appears to have been the basis of the Venetian method of painting, and all its peculiar effects.

It would be difficult, if not impossible, to conceive a theory more simple, more beautiful, or more true, than that of Sir Joshua Reynolds; and that the practice above described is conformable to his theory, will be evident on recapitulating the particulars.

The artist having determined what hue should pervade his picture, formed his ground with that colour prepared in distemper; upon this the subject was drawn, and the darker shades painted in with transparent colours, which sunk into the ground; with pure white he then painted in all the lights and demi-tints; and, lastly, glazed in the colours, each in its place. Upon applying the varnish, the darker shades were, as to body, incorporated with the ground; and thus, though different in colour, appeared thinner and more transparent than any colours could be when laid upon any ground; the full effect of every colour was brought out, and the picture was complete.

Whoever has been accustomed to paint, or to mark the progress of painting in the common way, and will reflect on the practice now described under the hand of artists brought up to it, must see that such artists would paint with a degree of facility, expedition, and certainty, as to effect,* that could never be equalled in the ordinary way of painting in oil; besides, it will be evident, that an artist would not only paint a picture himself with more facility, but could employ a number of subordinate artists upon large works, and put those works out of hand with more uniformity, as to merit and effect, than if he were to employ such assistants in similar works, according to the modern practice.

Little attention is generally paid to the observations of those who are not professionally artists: practical men, indeed, acquire a kind of knowledge that can never be obtained in any other way; but at the same time they contract prejudices that often prevent them from fully investigating any novelty in practice that may be offered to their notice. The speculative man, on the contrary, who investigates the properties of matter unshackled by practical prejudices, and with ideas purely chemical or philosophical, will be more likely to ascertain all the facts relative to any theory that may become the object of inquiry. In this investigation, pictures have been considered as masses of matter, possessing the properties, but differing from each other in degree of brilliancy, transparency, and duration. With what success and utility the causes of this difference have been developed, must hereafter be determined by the practice of those for whose use the investigation was designed.

It has already been intimated, that there are some difficulties in the method of painting which has been supposed to be that of the old artists, and which would form objections of considerable force to the practice of it by artists who are well acquainted with the usual modes of painting. These difficulties are, first, the ground absorbs the oil from the colours so fast, that they are not so manageable as in oil-painting; secondly, the effect of the picture is not seen till the finishing varnish is laid on; and, thirdly, as the effect is not seen till the picture is finished, it will sometimes disappoint the artist, and in that case it will be difficult, if at all practicable, to alter it. These difficulties occurred in the Author's attempts to paint, and to obviate them he adopted the following process:

The ground was prepared in distemper, and the dark parts painted in the way that has been described; the ground was then varnished with the copal oil-varnish, till it was fully saturated, and by this means the effect of that part of the picture was seen; upon this the lighter parts were painted with white, using much of the vehicle where the colour was thin, and little in the solid parts, leaving the white in them dead: thus the effect of the chiaro-oscuro was evident, as the effects of the demi-tints was seen nearly as well as when the picture was finished. Upon this the colours were glazed, in the way described at the beginning of the present dissertation.

Where any deficiency of effect is observed for want of white, more may be added, and fresh colours glazed over it, which will unite perfectly with what has been done before, without evincing any appearance of a mended picture. It is also easy to increase the effect of the picture, by painting upon the principal mass or masses of light, with the local colours, only mixed with white; those parts will thus be brought more forward, and being made to appear solid, will be contrasted with the transparency of the rest of the picture. Colours tempered with copal, may be used in this way without difficulty.

DISSERTATION II.

On the Preparation of Linseed Oil, for Painting, and of Varnishes

If linseed oil be exposed to the rays of the sun, in a transparent glass bottle, closely stopped, the mucilage it contains separates from it, and gradually sinks to the bottom. Some samples of this oil yield one-third of mucilage, others much less; nut-oil does not in general yield above one-third, and poppy oil scarcely a sixth, of the mucilage obtained from a like quantity of linseed-oil.

The colour of oil diminishes as the mucilage is abstracted; but the mucilage itself is colourless, and it is miscible with water. It must always be favourable to colours to be mixed with colourless oil, and this vehicle cannot be colourless unless free from mucilage; but as the separation of the mucilage may be considered troublesome by artists, it will at least be advisable to use those oils which naturally contain the smallest portion.

The processes by which the Author dissolved amber and copal, to make oil-varnishes, are to be found in many books, and as it will be better for artists to purchase than to make those varnishes, it can scarcely be necessary to detail those processes here; but the following methods of dissolving copal, in spirit of turpentine and spirit of wine, are not so generally known:—

TO DISSOLVE COPAL IN SPIRIT OF TURPENTINE.

Reduce two ounces of copal to small pieces, and put them into a glass vessel capable of containing at least four times as much, and high in proportion to its breadth. Mix a pint of spirit of turpentine with one-eighth of spirit of sal-ammoniac; shake them well together; put them to the copal; cork the glass, and tie it over with a string or wire, making a small hole through the cork. Set the glass in a sand-heat, so regulated as to make the contents boil as quickly as possible, but so gently that the bubbles may be counted as they rise from the bottom. The same heat must be kept up exactly till the solution is complete.

It requires the most accurate attention to succeed in this operation. After the spirits are mixed, they should be put to the copal, and the necessary degree of heat be given as soon as possible. It should likewise be kept up with the utmost regularity. If the heat abates, or if the spirits boil quicker than is directed, the solution will immediately stop, and it will afterwards be in vain to proceed with the same materials; but if properly managed, the spirit of sal-ammoniac will be seen gradually to descend from the mixture, and attack the copal, which swells and dissolves, except a very small quantity, which remains undissolved.

It is of much consequence that the vessel should not be opened till some time after it is perfectly cold; for if uncorked, even when not warm enough to affect the hand, the contents will most probably blow out with considerable violence. It is likewise of consequence that the spirit of turpentine should be of the best quality.

This varnish is of a rich deep colour when viewed in the bottle, but seems to give no colour to the pictures on which it is laid; if left in the damp, it remains sacky, as it is called, a long time: but if kept in a warm room, or placed in the sun, it dries as well as any other turpentine varnish; and when dry, it appears to be as durable as any other solution of copal.

TO DISSOLVE COPAL IN ALCOHOL.

Dissolve half an ounce of camphor in a pint of alcohol; put it in a circulating glass, and add four ounces of copal in small pieces; set it in a sand heat, so regulated that the bubbles may be counted as they rise from the bottom; and continue the same heat till the solution is completed.

Camphor acts very powerfully upon copal. If copal be finely powdered, and a small quantity of dry camphor rubbed with it in a mortar, the whole becomes in a few minutes a tough coherent mass.

The process above described will dissolve more copal than the menstruum will retain when cold. The most economical method therefore is, to set by the vessel which contains the solution, for a few days; and when it has perfectly settled, pour off the clear varnish, and leave the residuum for a future operation.

The above solution of copal is remarkably bright; it is an excellent varnish for pictures, and may perhaps be found to improve fine Japan works, as the stoves used in drying those articles may drive off the camphor entirely, and leave the copal pure and colourless on the work.

Copal will dissolve in spirit of turpentine by the addition of camphor, with the same facility, but not in the same quantity, as in alcohol.

Where the quick drying of the vehicle is a disadvantage, the following preparation may be employed.

Put a pint of nut or poppy oil into a large earthen vessel; make it boil gently before a slow fire; put in by degrees two ounces of ceruse, and stir it continually till the whole is dissolved. Have ready a pint of the solution of copal in spirit of turpentine. heated in a separate vessel; pour this by degrees into the hot oil, and stir them together till all the spirit of turpentine is dissipated; let it then be set by till cold, when it will be ready for use.

It is obvious, that as this is a compound of the copal varnish with the least exceptionable of the drying oils, it will partake of the properties of each of its component parts. It gives less brightness and durability to colours than the varnish will, but more than oil; it may be used in painting in the same manner as any other drying oil, and it gives more brightness and durability to colours than they can derive from any oil by itself.

It may be proper to remark, that whenever the mixture is to be made, both the ingredients should be hot, because if either of them is cold, the mixture becomes turbid, and a part, often the whole, of the copal is precipitated. It must likewise be observed, that after some time a spontaneous alteration takes place, which diminishes, and at last destroys, the drying quality of this mixture: it is therefore advisable to use it fresh, or at least not to use it after it has been made more than a month or six weeks.

DISSERTATION III.

On the nature and preparation of Drying Oils, with a view to the improvement of such as are used by Artists, as vehicles for painting.

Expressed oils, considered with a view to the painter's use of them, may be divided into two kinds; first, such as are capable of drying in some circumstances by themselves, and always with certain additions; and, secondly, such as cannot be made to dry by any means whatever.

Of the first kind, called drying oils, there are three in common use, viz. linseed, nut, and poppy oil. The first is darkest coloured, and dries the soonest; the second is lighter, but does not dry so soon; and the third has least colour, and dries slower than either of the others.

By the process described in the last dissertation, a mucilage or gum separates from each of those oils, in a liquid state, and capable of mixing with water in every proportion, though, when dry, not soluble in cold water. Linseed oil affords the most of this gum, nut oil the next largest quantity, and poppy oil the least of all.

Olive oil, treated in the same manner, affords none of this mucilaginous substance; whence it appears that the essential difference between the drying oils, and those which do not dry, consists in this:—that the latter either contain no mucilage or gum, or that it is so intimately combined with its other principles, that it cannot be separated from them in that peculiar manner which always takes place in oils which dry by themselves, or when mixed with colours.

If drying oil is exposed to the air, in a shallow vessel, and left at rest, a pellicle is soon formed on the top, and becomes externally perfectly dry. If this be removed, a second will be formed in the same manner; and if this experiment be repeated many times on the same quantity of oil, without moving or shaking the vessel, it will be found that the second pellicle will require more time to form it than the first, and so on, till it will be found difficult to get it fairly skinned over in a considerable time. The same effect takes place, in a less visible manner, in every quality of drying oil which is united with colours in a picture.

From this experiment it is to be concluded, that drying oils exert that faculty by throwing up their mucilaginous parts, which become solid when at rest, and in contact with the air.

The ingredients added to oils to make them dry faster, viz. oxides of lead, saline substances, earths or gums, are such as unite with and increase the quantity of those parts which float to the top, and form a skin, more or less dark, over the colours originally mixed with them. If we consider the nature of these ingredients, we shall be at once enabled to account for a fact universally known, viz. that in proportion to the strength of drying oil used in painting a picture, its colour becomes depraved. It will be injured, and finally destroyed, by being kept in a damp situation, excluded from a free circulation of air, or placed under a glass.

The desideratum is, to prepare oil or other vehicle for painting, so that the colours, when mixed with it, shall not be debased under any of the above-mentioned circumstances. It must be so prepared or used, that it shall serve as a cement to unite and bind the colours, without skinning over them. It must likewise not contain those principles which always exist in oxides of lead, saline or earthy substances, which from the first deprave the colours, and attract particles from the air, under peculiar circumstances, which increase that depravity, till at last the appearance of the colours is totally destroyed.

It is only among the resins or bitumens that we can expect to find a substance possessing the properties requisite to give to colours all the brilliancy and durability of which they are susceptible. Solutions of mastic and sandarac in the painter's oils, possesses more brilliancy than the common drying oils, but they are liable to considerable objection: they do not dry readily, and when dry, are easily acted upon by all the common solvents for resinous substances, and on that account would prove very deficient in durability.

The difficulty with which amber is in any way dissolved, suggested the propriety of trying that substance. Accordingly it was dissolved, by Dr. Lewis's process, without injuring its colour, and also in the common way. The latter solution, though darker coloured in itself, produced scarcely any difference in effect when mixed with colour. With these solutions the following facts were ascertained :—

Every colour, and all the tints compounded from it, were more brilliant than corresponding tints and colours mixed with the best drying oils to be procured from the shops.

Colours mixed with amber, after having been shut up in a drawer for several years, lost nothing of their original brilliancy. The same colours tempered with oils, and excluded from the air, were so much altered, that they could scarcely be recognized.

Colours tempered with amber were laid on plates of metal, and exposed (both in the air and close boxes) for a long time, to different degrees of heat, from that of the sun in summer to the strong heat of a stove, without being injured. It is needless to observe, that oil colours cannot undergo the same trials without being destroyed.

These colours, when perfectly dried in any way, were not acted upon by spirit of wine and spirit of turpentine united. They were washed with spirit of sal-ammoniac, and solutions of pot ash, for a longer time than would have destroyed common oil colours, without being injured.

They dry as well in damp as in dry weather, and without any skin upon the surface. They are not liable to crack, and are of a flinty hardness; whence it appears that this vehicle possesses every desirable property, and it is presumed may be a discovery of some importance to artists.

Solutions of gum copal afforded the same results as those of amber, except that the colours were something brighter.

The artist who may think it too troublesome to dissolve copal or amber himself, may employ the solutions of these substances sold in the shops, which, when good, will answer extremely well.

METHOD OF USING THE SOLUTION OF AMBER OR COPAL, AS A VEHICLE FOR PAINTING.

The cloth or other substance to be painted on, should be prepared with some colour saturated with drying oil; or it will be better done with the same vehicle as that to be used in painting. If it is not fully saturated, it will absorb some of the vehicle from the colours, which is what is commonly termed the colours sinking in.

All the colours which require grinding, should be previously ground in spirit of turpentine. All the pure parts should be tempered with such a quantity of the vehicle as will enable them to lie on the pallet. The white should be tempered as stiff as possible. All the tints should be made by mixing the colours so prepared without any more of the vehicle, but they should be diluted with spirit of turpentine, if necessary for working.

If the ground is properly prepared, and the above caution observed in tempering the colours, it will be found that all the dark colours in the picture will bear their full tone, and have a demi-transparency, which increases their native brilliancy, without the dingy appearance so common in ordinary oil-painting. The admixture of white increases the body of the colours progressively, till there will be left in the lightest parts only so much of the vehicle as will bind the colours, and give them their full tone, but with very little of a shining appearance. When the picture is perfectly dry, it should be varnished with a mastic or similar varnish. Perhaps, the best would be copal varnish made by solution in spirit of turpentine, or spirit of wine.

The rationale of this vehicle seems to be this:—The amber and copal, when dissolved in oil, form a homogeneous mass, which dries by inspissating, instead of skinning over like the common drying oils, which consist of heterogeneous parts, some of which separate and dry on the top.

As the amber and copal are not soluble in any of the menstrua which dissolve most resinous substances, pictures painted with them cannot be injured if cleaned with those menstrua; and as they are extremely hard, and the most durable substances of their class, they protect the colours from every kind of injury, more effectually than any other known vehicle.

Whether the vehicle above described was used by the older Italian painters, so eminent for their skill in colouring, cannot now be decided by any direct or positive information transmitted to us. But a variety of circumstances indicate that such is probably the fact. Leonardo da Vinci, who was highly celebrated for the richness of his colouring, mentions the solution of amber in nut-oil. Many of the Italian pictures possessing a brilliancy of colour independent of what may be attributed to the painter's skill, or what the colours with oil alone would exhibit, there seems no alternative but to conclude that the vehicle employed had a brightening effect on the colours; and as resins afford the only resource to attain this effect, the attempt to imitate ancient paintings is limited to the introduction of substances of this class. Again, upon chemically examining Venetian and other Italian paintings, it is found that some of them are nearly as tender as ordinary oil-paintings; whilst others, similar in point of colour, either wholly or in a great measure resist the action of alcohol, spirits of turpentine, and alkalies: whence it is obvious, that to imitate that latter class of paintings, which are alone worthy of imitation, those resins only can be employed which equally resist the action of the same powerful menstrua under the like circumstances; and of this description none are known but copal and amber. Copal could not have been known, as an article of trade, before the seventeenth century, and therefore, previous to that period, amber appears to have been the only substance on which the artist could rely for the durability of his works.

A Perspectograph, or Instrument for drawing in Perspective.

There are few persons who have a taste for drawing, who have not felt the want of a method of readily delineating objects in perspective, independent of geometrical knowledge; and for the use of such persons, many machines have been invented. To the description of one of the most elegant and best of these, by Turrel, we have already given a place in the present division of this work; but as different means of accomplishing the same end, may afford the opportunity of suiting different individuals, we shall in this article give an account of another graphic instrument, in principle the same as Turrell's, but rather more simple in its construction.

The instrument proposed consists of a metal frame, 9 inches by 6, having two graduated scales moving upon its surface, at right angles to each other, for the purpose of finding both the horizontal distances, with the height and proportions of the different objects to be drawn; and at right angles to the frame is attached a small beam with a sight point, the distance of which from the frame can be varied at pleasure, and determines the quantity of objects introduced into the drawing. The instrument is supported by a triangle, which, when folded up, forms a walking-stick.

Fig. 1, plate XCI, is a general view of the instrument.

AAAB, a three-legged staff, for supporting the whole: AAA the legs, jointed at B.

C, a square horizontal trunk, with a brass socket in the bottom of it, by which it is screwed to the legs.

DDDD, a vertical brass frame screwed upon the end of the trunk, and pierced round the inner edges for the threads, which form the reticulated aperture, to pass through; the aperture being six by nine inches, and the horizontal threads being five in number, and the vertical ones eight, divide the whole aperture into 54 square inches.

EE, a thin slip of brass, bent at the ends, so as to slide freely on the outer edges of the brass frame, in order to be set parallel to the inner horizontal edges of it, at any distance from either edge.

FF, another vertical thin slip of brass, made to slide on the outer horizontal edges of the brass frame, in the same manner; the slip EE, is divided into nine equal parts or inches; and FF, into six inches; and each inch is subdivided into twelve parts, for the greater accuracy in taking the different bearings and amplitudes of objects.

G, a slider made to fit the elbow of the trunk C, and to slide freely therein.

H, the eye-piece, hinged to G at I, and which, when required, may be folded down so as to be entirely even with the upper surface of G, and the slider G may be shut into the trunk C, or drawn out at pleasure, so that when the eye-piece H, is perpendicular to the horizon, it may be regulated so as to give the size desired to the drawing.

The stem I, is a tube, and the eye-piece H, is fixed on a wire, which slides up and down within it to adjust it to the horizon.

Fig. 2, the brass socket shown at B, fig. 1, for receiving the upper ends of the sectoral parts of the three-legged staff, and thereby forming the joints: KL, is a cylindric pin passing through the centre of the brass piece B, which forms the sockets, having a male screw at the end L, which is received by the screw of the socket in the bottom of the trunk C. This cylindric piece K, is so fitted into the hole passing through B, as to allow the socket-piece B, to be turned round stiffly, so that the frame may be turned towards any object without risk of altering its position.

Fig. 3, the staff, shown as put together, and which is kept so by a cap at each end, and rings in the middle of it.

Fig. 4, a view of the upper side of the trunk C, the slider G, and the eye-piece H. In this geometrical representation, the slider is drawn almost its whole length out of the groove which is made to receive it; and the eye-piece is folded down into the cavity on the upper side of the slider.

Fig. 5, is the front of the frame.

Fig. 6, the back part of the same.

Fig. 7, a view of the box which contains the whole of the apparatus, except the three-legged staff; and the sketch book is also contained in the centre of the box, so that the whole is rendered portable, and easy of carriage.

Fig. 8, is a screw-driver, for screwing the frame to the end of the horizontal trunk.

The graduation of the two sliders affords an easy mode of transferring to paper the different points as they are ascertained.

CLASS III.—INVENTIONS RELATIVE TO RURAL AND DOMESTIC ECONOMY, AND MISCELLANIES.

Improved Method of Ventilating Hospitals, &c.

This valuable essay on ventilation was communicated by its Author to the Society for the Encouragement of Arts, &c. in a letter to their Secretary, and we shall preserve its original form. It embraces an exposition of principles not only directly applicable to the ventilation of hospitals, but of dwelling-houses, and of all places of crowded resort.

I have been favoured with your letter, stating the terms of a premium offered by the Society of Arts, &c. for "A mode of permanently ventilating the apartments in hospitals, gaols, and other crowded places, superior to any now known or used;" and that the Society had done me the honour "to direct you to express their wish to receive from me communications on this subject."

I not only agree with the Society, that "the subject is important to the health of persons destined to inhabit such places" as are specifically mentioned in the proposal for the premium; but I also believe that the morbid effects of impure air are felt in all situations of life where education, business, or social intercourse, may aggregate mankind.

From observations made during a pursuit which of late years may be said to be habitual to me, I fear I must *also* admit that ventilation is improperly performed, by the means now generally employed—where those means act on persons in a sickly or convalescent state, or accustomed to delicate habits of life.

The transverse passage of outward air through a room (which I shall term free ventilation) is no *doubtful* mode of obtaining vital air; yet, certainly, if the attendant consequences render such a mode inadmissible (to an efficient degree) in the abodes of sickness or infirmity, the Society are justified in considering the subject as open to much further improvement.

Desiring to be understood as not addressing the Society as a claimant of their premium; I conceive I may assist them in the pursuit of their laudable purpose, by submitting to their perusal some practical observations on the modes of ventilation hitherto practised, and by communicating the outline of a design already conceived, and in a limited degree adopted, for correcting their admitted imperfections.

It may be necessary to premise, that the peculiar inquiry, the result of which will be detailed in the following pages, was excited by some objections, originating in a most respectable quarter, and directed against a system, on which I had heretofore *solely* depended, in providing for the ventilation of such public establishments as have been placed more particularly under my direction.

It may be inferred, from the note annexed to the proposed premium, that similar objections are entertained by the Society: I shall therefore, as you requested, submit my observations, without that delay which would necessarily be occasioned by my modelling them in conformity to the rules you have communicated, and waiting for certificates to accompany them. If there really does exist a doubt as to principle or fact, on a question so important, should not that doubt be made the subject of a previous special consideration, so that a point of direction may be given to the mechanical exertions intended to be excited?

Although particular conclusions may be controverted, I may venture to assume, as the basis of all observations on this subject,

First,—That a certain and frequently renewed supply of vital air is essential to the purposes of animal life; and the more regular and uninterrupted that supply, the more favourable will it be to health.

Secondly,—That where the quantity of atmospheric air introduced into an apartment, is less than nature has bestowed in free circulation, her purpose is in a degree counteracted; and although the breathing of impure air (that is, air despoiled of its natural proportion of vital air) for a short time, may not produce an immediate sensible effect, an injury may arise to the constitution, proportionate to the extent of that time. And further, when (as in the ordinary intercourses of society in London) persons are in the habit of placing themselves, during a considerable portion of every twenty-four hours, in a situation to breathe in this defective atmosphere, the accumulated consequences may be serious and important.

Thirdly,—That in rooms from which currents of fresh air may not be excluded, they may be so injudiciously directed as to be useless and injurious. And,

Fourthly,—That if, in addition to the consumption of vital air by the lungs, the persons of those assembled in any apartment should be filthy,—should their clothing (particularly that made of woollen) have been so long worn as to have absorbed any considerable portion of the perspiration of the body,—or should the apartment itself be damp and foul, the vital properties of the air will be contaminated, and although instant death may not ensue, (which has been known to be a consequence,) the fever emphatically termed the goal, hospital, or ship fever, from its usually originating in these places, will be generated with a degree of malignancy proportionate to its causes, and being so generated, will become infectious with a like degree of malignancy.

It is about twenty years since the deleterious consequences of inattention to ventilation were set forth by Howard. So strong and so general was the conviction of the public mind, not only as to the evil pointed out, but regarding the remedies proposed by that indefatigable philanthropist, that the legislature thought fit to adopt the whole of his principles, and to make them the basis of several positive laws, under the direction of which the greater number of prisons of the kingdom have since been reconstructed, and the remainder (with few exceptions) altered in conformity to the principle recommend by him, namely, *that of introducing currents of fresh air* INTO *and* THROUGH *every apartment.*

In these prisons, where attention is also paid to personal cleanliness, I venture to say, the goal fever is unknown, unless brought into them by prisoners committed in a state of previous infection.

By equal exertion on the like principles, the healthiness of the ships of war has been so improved, that they are no longer sources of this desolating pestilence.

Regarding hospitals, I fear it cannot be proved that a relief so complete has been effected. Howard was not sparing in his strictures on the management of this important branch of our public institutions; but the improvement he suggested went no farther than simply the introduction of fresh air. The reconciling this advantage with that generally diffused warmth, necessary in sick rooms, seems to have escaped his contemplation.

Of the several hospitals constructed since his observations were made public, most have been planned with a view to facilitate the passage of outward air through the wards. The Directors of old hospitals have adopted alterations more or less tending to the same purpose; but all seem to have rested at this point: yet, considering the importance of pure air to patients, during the tedious cure of compound fractures, and other accidents or diseases, together with the no less important object of securing them from currents of cold air, it cannot be denied that much still remains to be effected.

In the construction of the larger workhouses, termed hundred houses, similar principles of ventilation have been attended to with evident success, in preserving the health of the inhabitants; but with respect to parish workhouses on the *lesser* scale, school-rooms, (both for boys and girls in every rank of life,) manufactories, apartments for public lectures, and ladies' assembly-rooms—these, together with the circumscribed cottages of the poor, remain in a state most dangerous to health from imperfect ventilation. To these sources, and to no other, may be traced the few putrid and contagious diseases which occasionally show themselves amongst us; and which, to the credit of *free ventilation*, can no longer justly be called goal or ship fever.

At a period of demonstrated success of the doctrine recommended by Howard, and adopted by his disciples, the valuable essays and experiments of Count Rumford appeared before the public: whilst opening to the world a new and most useful system of domestic philosophy, he has advanced opinions unfavourable to those means by which these important effects have been produced.

In theory, this ingenious philosopher and friend of mankind, has decidedly negatived the necessity and questioned the propriety 'of ventilation by the admission of currents of air. In the construction of those buildings most immediately under his direction, he has certainly adopted a *practice* of a directly opposite tendency. Opinions of such authority could not fail to be respected: they must at least raise a doubt in the mind of the most confident advocate of an opposite theory.

As the Count's observations and practice tended to invalidate a material part of that system, in the pursuit of which immense sums had been *confidently* expended in the kingdom, and respecting which I bear a more than common share of responsibility, I felt myself peculiarly called upon to scrutinize his objections, and to obviate such as should appear to be denied by experience; but at the same time, certainly to abandon whatever ground could not be fairly maintained by a result.

As my conclusions on the point disputed, are formed on circumstantial observations made within a prison and hospital immediately under my own eye, and as these particular institutions have not unfrequently been resorted to as examples for imitation, a detailed reasoning regarding them may serve for general application.

The county goal at Gloucester is constructed on the principles of admitting air to pass into and through it in straight lines, from one extremity to the other. There is no obstruction to a freedom of current, other than as the streams of air passing through the long passages, open at each end, move with the greater velocity, they of necessity carry with them the weaker currents, passing into and through the cells at right angles.

From the time this prison was opened in 1791, until the years 1800, about 1300 persons were committed to it; and, on the average, about one hundred prisoners were constantly confined in it. In these nine years, the number of deaths has been thirteen; and of these, four sunk under the effects of disease brought into prison with them. During the last year, the prison has been crowded in an uncommon and very improper degree; two hundred and fourteen have been confined; and the average number her been one hundred and sixty-seven. One prisoner only has died (a woman aged sixty) in the month of October last. At the opening of the Spring Assizes, 1801, (the time of the greatest number) there was not one prisoner sick, or in the hospital ward.

By this statement it appears, that the proportions of deaths is so much below the common average, in the ordinary situations of life, that the healthiness of this abode may be said to be peculiar; and it is in proof, that however currents of air may be found injurious to particular constitutions, they are not unfavourable to general health.

Every prisoner in this goal, when not in the infirmary-ward, sleeps in a room containing from fifty-two to fifty-seven feet of superficial space, built with brick, resting on an arch, and arched over; so that no air can enter it but through the openings provided for it. As air is constantly passing immediately under it, and round it on every side, it is necessarily dry: it is ventilated by opposite openings near the crown of the arch. To that opening, which is towards the outward air, there is a shutter, which the occupant may close at will; but it is so imperfectly fitted, that when closed, a considerable portion of air must enter by its sides. The opposite opening to the passage, the prisoner has no means of closing in any degree.

During the ten years these rooms have been inhabited, there have been three winters in which the cold has been intense. As I had considerable apprehensions of the effects of this situation in severe weather, I directed the surgeon of the gaol to be constant in his attention; and particularly in the report of his observations during the inclemency of these seasons. I also made a point frequently to visit the prison, and to examine every prisoner as to the effects apprehended; and, as much to my surprise as to my satisfaction, notwithstanding the querulous disposition of persons in their situation, I never heard a complaint from old or young, from male or female, suffering by cold in the night apartments.* And further, it is the decided opinion of the two able physicians who have most liberally undertaken to superintend the health of this prison, that no ill consequences have arisen from prisoners sleeping in the situation above described.

I must contend, therefore, it is a fact established by experience, that in a room containing not more than from 415 to 439 cubical feet of air, in which there is no fire, the body of a person sleeping under a proper allowance of woollen bedclothes will so far warm the atmosphere around him, or, to speak more comformably to modern doctrine, so little of the heat generated in the body will be carried off by the surrounding air, that he will not suffer by a current† passing at a distance over him, provided the apartment be secured from damp. On the points, therefore, of warmth and ventilation *combined,* it must surely be allowed (regarding rooms so constructed) there is no further *desideratum.*

Prisoners, on their rising in the morning, are removed into small working rooms or wards situated on the ground-floor. These day-apartments are, in like manner, constructed with cross openings near the ceiling or crown of the arch; but there is also in each of them an open fire-place. Respecting these apartments, my observations tend to *confirm* Count Rumford's objection to open fires, and his preference to closed stoves. Nay, further, I am disposed to admit that openings for free ventilation are incompatible with strong fires in open fire-places.

It is certain that, in rooms so provided, the danger arising

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* Fahrenheit's thermometer has never been observed to be below 38° in the severest nights, in the middle region of a cell in which a prisoner was sleeping; whereas in the ordinary apartments of a dwelling-house, water is frequently known to freeze by a bed-side.

† The term "current" is not to be understood in a stronger sense than merely to signify that species of circulation of air which is directed in straight lines from point to point, by the action of any efficient cause.

from impure air is completely guarded against; yet this advantage is gained at the risk of another evil, which though not so important, should, if possible be avoided.

The air, which in the same room without an open fireplace, would pass inwards by one opening, and outwards by the other, being attracted by the fire to supply the constant rarefaction in the chimney, passes inwards from both openings towards the fire-place, and the body of a person placed near it, being in its current, is exposed to the danger of partial chill. To this circumstance, in these apartments, I am inclined to attribute the few complaints of a dysentery or aguish tendency, which have occasionally interrupted the general health of this prison.

In the hospital, the scene of my observations, the morbid effects of foul air in the wards have, until lately, been no otherwise relieved than,

First,—By introducing currents of fresh air by the windows, with an improved mode of hanging the upper sash, peculiar to this hospital, by the effect of which the current of air admitted is turned towards the ceiling, and prevented from descending upon the patients, whose beds are placed under the windows.

Secondly,—By piercing holes in the ceiling of the wards, and by means of plastered channels or wood funnels, leading the foul air arising into them, to the roof.

In warm weather, when the doors of the wards are open, and the fires low, these channels or funnels operate with considerable effect. Much foul air will, by its relative specific lightness, (not being counteracted by a stronger power,) ascend them and escape; a further portion will pass off by the windows opening to the leeward, and ventilation may be duly effected.

But, on the contrary, when the doors are shut, and strong fires are made, these will inevitably attract the currents of air *inwards* and towards them, from all the openings; and should patients be situated in their course, the effect cannot fail to be injurious.

Besides, as the windows are generally closed in the night (the most important time for ventilation,) no other change of air takes place but what is effected by the open fires, which, whilst supplied immediately from the middle region, are constantly consuming the best air of the room.

Hence it appears that free ventilation, or the transverse passage of outward air, may be inconsistent with the general warmth required in the apartments of the sick; and that channels for the escape of foul air, unassisted by a power more constant and decisive than the relative specific lightness of that air, is a mean inefficient to preserving a healthful respiration in the crowded wards of an hospital.

As a remedy to these apparent defects in the ordinary mode of ventilation, it has been imagined that the draught, or determination of the air to the funnels in the ceiling of the rooms requiring ventilation, is accelerated by the operation of fire; and by causing an increased degree of rarefaction, at the termination of the funnel, to discharge the air rising to the ceiling in a degree depending on the correct application of the apparatus and quantity of fuel consumed.

In all rooms or apartments requiring ventilation, it is presumed that (according to the old system) channels or funnels are provided for the discharge of air ascending into them. These channels or funnels, so provided, should be rendered air-tight, and brought to terminate immediately under the fire intended to work them. The ash-pit and fire-place should be closed, by doors, to prevent the fire from drawing the air from the room surrounding it. The whole draught or consumption occasioned by the fire will then be supplied from the further termination of the channel or funnel.

This effect may be applied, according to circumstances, either to the ceiling of the room in which the fire is made, to the room below, or that above it; and draught thus produced may, by a proper apparatus, be increased or diminished at will.

In the hospital in which I have made the first experiment of this design, I have caused a stove to be so formed as to answer the culinary purposes of the ward in which it is fixed, and at the same time to ventilate the ward beneath it; and no additional expense is created in fuel by the operation.

By a fire made in one of these stoves, a ward beneath it, containing about 18,000 cubical feet, filled with patients, (and which, in spite of all former means, was ever remarkably offensive,) was in a few minutes so relieved of contaminated air, as to be sensibly felt by all the patients in it, without their perceiving any increased current.

The principle of the means of ventilation adopted in this hospital, may be applied with perfect facility to ships.

By carrying the funnel from a cabin or ship stove, of any kind or dimension (observing *only* to exclude the admission of surrounding air,) to the hold or under-decks, they may be as completely ventilated as the wards of an infirmary. In stormy weather, when the decks of a ship must of necessity be closed, the fires would perform a service which could no otherwise be attained; whilst by the nature of the apparatus, the fire itself would be secured from the effects of the wind.

If the stove or grate over a lady's drawing-room were properly fitted to this purpose, on the evening of her assembly, it might be set in action, and the room beneath cleared of its impure air, without recourse being had to the opening of windows: the openings in the ceiling might be rendered ornamental.

By applying the same principle to German or other closed stoves, the chief objection to their use in crowded rooms would be obviated; and I should then agree with Count Rumford, that in all rooms, where the indulgence of the habit of open fires was not in question, such stoves (if constructed of earthen materials) would afford a more "genial warmth," and a "due circulation be at the same time effected."

So fitted and constructed, they would be incontestably better than open fires for the wards of hopistals, poor-houses, manufactories, theatres for lectures, school-rooms, and prisons. Respecting the last-mentioned structures, I must further observe, that if public kitchens and a sutler were appointed, under due regulations, the present necessity of open fires for prisoners to cook individually for themselves, would be superseded much to their advantage.

On the other hand I must also observe, that if closed stoves, acting on this principle, were adopted, Count Rumford's objections to the introduction of fresh air would be obviated, with regard to any room in which they should be in action, provided the opening through which it entered was made on a level with the ceiling.

Air entering at this level would, in the absence of open fires, be acted upon by no other draught than the mouth of the funnel in the ceiling, and could not descend in currents to the lower region of the room.

In a room so filled with company as to vitiate the air within it, the atmospheric air entering being specifically heavier, would indeed descend, and be replaced by the ascending impure air; but, as it would not descend by a stronger impulse than its difference of specific weight, it must be slow in its motion, and would produce no sensible current.

EXPLANATION OF THE PERSPECTIVE VIEW OF THE STOVE FOR VENTILATING THE WARDS OF HOSPITALS.

AA, fig. 1, plate XCII, a chimney-piece of ordinary dimensions.

B, a bath-stove, made to fit the chimney: the hobbs of which, NN, project two inches and a half before the fire-grate.

CC, folding doors to close the fronts of the ash-pit, and to fall back against the hobbs.

DD, folding doors to close the front of the fire-grate, and to fall back against the hobbs.

E, a door to close the top of the fire-grate when a very strong draught is required. When put down, the smoke is directed through the open space, H, and the door is used as a hot table for culinary purposes; when open, it serves as a chimney back.

F, a flat bar projecting two inches and a half before the fire-grate, as a stop to the upper and lower doors.

GG, holes left in the castings of the ash-pit, to receive the mouths of air-tunnels in the back, or on either side, as circumstances may require.

H, the opening to the back flue, used as a passage for the smoke, when the top door is closed on the fire-grate.

II, a double register:—first, to close the back flue when the fire-grate is open; secondly, to close the front flue when the back draught is necessary; and, thirdly, to prevent the heat being carried up the chimney.

Fig. 2, a back view of the ventilating stove, on which similar letters are marked as denote the same parts already mentioned in fig. 1.

KK, are shoulders for tunnels cast with the ash-pit fixed at the openings GG, mentioned in fig. 1.

N. B. There should be doors or regulators to the mouths of the air-tunnels KK, to close them when the doors of the stove are open, otherwise (there being at that time little or no draught by the tunnels towards the fire) the dust will pass by them into the rooms with which they communicate.

LL, air-tunnels to be fixed on the shoulders KK, and to be prolonged in any direction required, either downwards to any room below which wants ventilating, or upwards to the ceiling of the room in which the fire is made, or to any rooms above it requiring ventilation.

N. B. The direction of the first length or piece of the tunnel should, in all cases, be upwards, to prevent sparks of fire, which may fly into it, being conveyed into a room ventilated by a descending tunnel.

The tunnel should, at least, rise so far that the lower edge of it may be higher than the upper edge of the shoulder on which it is fixed.

M, a back flue to conduct the smoke when all the doors are closed, and the stove made to act with its utmost force.

NN, the hobbs on each side of the fire-place.

Fig. 3, a side view of the ventilating stove, in which the letters correspond as before.

Fig. 4, a view from above of the two chimneys which convey away the smoke, and of the register which closes one or other of them, as occasion may require.

DESCRIPTION OF THE SASH WINDOW FOR A HOSPITAL.

a a a a, Plate XCII, fig. 5, a common sash window-frame, the upper extremity of which should be level with the ceiling of the room.

b, The lower sash fixed.

c, The upper sash working inwards on the pivots *e e*, at each side of its lower end.

d d, Inclined edges fixed, with a proper inclination inwards, on the jambs to which the sash is fitted. These jambs and ledges should be made as exactly as possible to fit the sash in its working, to prevent air from passing inwards by its sides.

e e, The pivots on which the upper sash-frames move.

f, A regulator, notched on its lower part, and moving in a groove *g*. At the extremity of the regulator is a loop or ring, to receive a hook fixed to a long pole, by which the sash may be worked by the apothecary or nurse. The notches in the regulator resting on the groove, admit the sash to be placed at any intermediate distance required. The pole may be afterwards removed out of the reach of the patients.

A Fire-escape Ladder, formed instanteously by the external application of a jointed pole to a Window.

Having given the description of a fire-escape, suitable to be kept in parishes, as a public convenience and safeguard, we shall now give an account of one adapted to the use of individuals, and the possession of which may prove a great relief to persons apprehensive of fire.

This fire-escape ladder is so constructed as to be carried under a person's arm with the greatest ease, and the expense of making it is trifling. It will be particularly serviceable to the person possessing it, in case of a fire happening in apartments below him, as it can be hooked to the front window of a room, and he will be able immediately to descend. Or should his neighbour's house be on fire, and any one in need of assistance, he can raise it to the highest part of the house from the street, by fixing together the joints at the end of each step, in the manner of a fishing-rod, beginning with the hook, which is to be placed in the socket of the top step, the other end of the top step to be placed in the socket of the one beneath it, and the same with the other steps, which will altogether form a rod. This rod must be raised perpendicularly close to the wall, and directed to the window from which the person is to escape. On catching the extremity, the person in danger will easily fasten the hooks properly, as they are made sufficiently wide to embrace the thickness of a wall, and then, by pulling the ropes at the bottom, each step will be drawn from the socket of the other, and the ladder will be formed. The ropes at the bottom will enable persons in the street to steady the escape, and keep it from the wall.

This general description will be rendered perfectly evident by the representation of the contrivance in plate XCII, figs. 7 and 8. The rounds, A, form the steps of the ladder by being united with two ropes BB, which are suspended from an iron frame C, terminating in hooks *a*, which can very conveniently be lodged on the sill of a window, and thus form an ascent very nearly similar to the rope ladders used on board a ship. The principal part of the contrivance is the ladder; which must be made so that the rounds can be put together in the manner of fig. 7, forming a pole, by which the frame C, can be raised up to the window from below. To effect this, the ends *e*, of the rounds A, have ferrils fitted fast upon them, and the other ends *f*, are reduced, so as to enter the cavities of the ferrils, which project beyond the end of the wood, so as to form sockets for their reception. The iron frame C, at the top, has a projecting pin *d*, which is connected with the end socket *e*, of the upper round, thus fixing it at the top of it; the small end of this is inserted into the ferril of the second, which is again fixed at the top of the third, and so on to the bottom; thus a pole is formed as in fig. 7, of all the staves of the ladder united together, by which the hooks *a*, *a*, at the top of the iron frame, may be raised up to a window sill, and then a single jerk or pull at the lower end, disunites the staves from one another, and they assume the form of fig. 8, ready for ascending or descending.

The ropes BB, of the ladder, are composed of three small lines plaited together, which method affords the means of fastening the staves very securely to them. This is shown by fig. 9; a hole is bored through the stave at the place where the rope is to be fixed, large enough to receive one of the three lines, and a groove is turned round the outside of it at the same place; then one of the lines is passed through the hole, and the other two passed round in the grooves on opposite sides, so as to surround the stave, and all the three being plaited together, they make as firm a connection as possible.

The frame C, at the top, has two iron rods *b b*, fixed to its sides, which are useful as hand-rails, to a person getting out of a window upon the ladder. This frame, though large, does not take up any room when the ladder is packed up, because all the staves are laid parallel, and rolled up into a bundle, which fits into the curved inside of the frame C, and the whole is tied together by two lines fixed to the ends of the ladder, and which, when the ladder is used, serve to guide and keep it free from the area, rails, &c. of any house.

Apparatus or Jacket to secure Persons from sinking in Water, or to act as a Life Preserver when Shipwrecked.

A, plate XCIII, fig. 1, represents the body of the machine, which is double throughout, made of pliable water-proof leather, large enough to admit of its encircling the body of the wearer, whose head is to pass betwixt the two fixed straps, BB, which rest upon the shoulders; the arms of the wearer pass through the spaces on the outside of the straps; one on each side, admitting the machine under them to encircle the body like a large hollow belt. The strap C, on the lower part of the machine, is attached to the back of it, and by passing betwixt the thighs of the wearer, and buckling at D, holds the machine sufficiently firm to the body, without too much pressure under the arms. The machine being thus fixed, is inflated with air by the wearer blowing in from his lungs, through the stop-cock E, a sufficient quantity of air to fill the machine, which air is retained by turning the stop-cock. The machine, when filled with air, will displace a sufficient quantity of water to prevent four persons from sinking under water.

The Inventor recommends the Life-preserver to be prepared as follows; viz. to select sound German horse-hides, and to cut a piece six feet long, and two feet six inches wide, free from blemish or shell: it is first to be curried, and then rendered water-proof by Mollerstein's patent varnish, (of Osborn-street, Whitechapel, London,) which preserves the leather more supple, and admits it to be easier inflated than any other water-proof leather.

The leather is to be nailed on a board, and the varnish applied upon it; it is then to be passed into an oven several times, the varnish being each time repeated, till the leather is completely covered; it is then cut in the form of a jacket, as above described, and neatly and firmly stitched; the seams and stitches are afterwards to be perfectly secured by the following black elastic varnish:—

Gum-asphaltum, two pounds; amber, half a pound; gum-benzoin, six ounces; linseed-oil, two pounds; spirits of turpentine, eight pounds; and lamp-black, half a pound; united together in an earthen vessel with a gentle heat.

The machine, when properly made according to the drawing and description, resembles a broad belt, or circular girdle, composed of two folds of pliable leather attached together, and perfectly impervious to water. When used, the wearer introduces his head and arms within the circle, the stop-cock in front, the two fixed straps BB, rest one upon each shoulder, to prevent the belt from sinking down; the lower strap C, is then brought between the thighs, and buckled in front, which prevents the machine from being forced back. The machine is then inflated by the application of the mouth to the stop-cock in front, and when properly filled, the turning of the cock retains the air in the machine, and expands it so much as to displace a quantity of water amply sufficient, not only to sustain the wearer, but a further weight, if necessary, buoyant in the water.

A great number of cases have occurred, by which the efficiency of this life-preserver has been fully manifested. Among others the following may be adverted to.

The Alert, privateer, on the 22nd September, 1805, struck on a rock near the Western Isles, and went to pieces in five minutes. Thirteen of the crew saved themselves by clinging to pieces of the wreck; but the rest, consisting of sixty-four foremast men, and all the officers, except the surgeon, perished. The surgeon, though unable to swim, supported himself, amidst waves running mountains high, by one of these life-preservers, with which he happened to have provided himself, until the arrival of a Portuguese boat, which put off to his assistance, and took him up about a mile from the shore.

In another instance of the utility of this life-preserver, two gentlemen and two ladies, in a pleasure-boat, set sail about four o'clock in the afternoon, with a view to reach the city of Norwich, a distance of thirty miles, that evening. The wind blew hard at south-west, and one of the life-preservers was taken on board, though without the smallest fear that any occasion for the use of it would occur; and it was, with a view to amusement, rather than otherwise, jocosely filled as they went along, by one of the two gentlemen. The precaution proved most fortunate; for on tacking to enter Norwich river, at a part of the water called Braydon, two miles over, a sudden gust overset the boat, and plunged the whole company into the water, which was extremely rough. The gentleman with the machine having reached the other, who, inexpert at swimming, could scarcely suppport himself, directed him to lay hold of the collar of his coat, over which the machine was fixed; this being done, he proceeded to the ladies, whose clothes kept them buoyant, though in a state of fainting when he reached them; and taking one of them under each arm, the violence of the wind drifted all four on shore upon Burgh Marshes, where the boat had already been thrown, with every thing belonging to her that would float. Here, after procuring such assistance and refreshment as they required, they again set sail in their own boat, and arrived at Norwich by eleven o'clock the same evening.

It would be useless to multiply testimonies of this nature; as those adduced very clearly show the services which this very simple machine is capable of rendering, in cases of the greatest peril from shipwreck. At sea-ports, and wherever accidents on water are likely to occur, nothing has yet been devised better calculated for general utility, and it is highly desirable that the plan should be adopted, of keeping one or more of these life-preservers in known and convenient situations. Sadler, the celebrated aeronaut, was provided with one of them, which he considered a necessary part of his apparatus in his aerial voyages, and which enabled him to contemplate, without being appalled, the circumstance of being compelled to descend, even upon the sea; a disaster which actually occurred, near the mouth of the river Mersey, Liverpool, while accomplishing the adventurous excursion in his balloon from Ireland to England.

Although this life-preserver, in its present state, possesses so much simplicity of construction, yet the various experiments and attempts made in perfecting it, cost the Inventor nearly £1500.

A Wheel Drag for two-wheeled Carriages.

In plate XCIII, fig. 2, *a a a*, is a piece of wrought iron, curved to the exact form of the cart or carriage wheel, with the thickest part at *b*, on which the weight of the cart rests.

1, 2, 3, 4, Are shoulders which keep the wheel within the drag, and should be about four inches high.

C, the wheel made of solid iron, nearly as wide as the drag, and seven inches in diameter. It runs on its axis at D, has a strong shoulder, and standing forward, resists the sudden jolts of rough roads.

E, the chain to be fastened to the near shaft, to keep the drag properly under the wheel, which from jerks might be apt to pass over the drag, and leave it behind.

In the shoulders, 1, 2, are shown holes, by which the drag, when out of use, is hung on hooks, at the under part of the tail of the cart.

This simple contrivance has never failed to be effectual in retarding carts, or any two-wheeled carriage, while descending hills, taking off the great burden from the shaft-horse, and permitting the carriage to descend with the greatest ease and safety, in the most mountainous country. It may be applied to any kind of road, and is not subject to the inconvenience of locking poles, which on rough roads, among loose stones, or deep ruts, are very apt to overturn carts by the sudden resistance they meet with.

The wheel C of the drag, should not be less than has been mentioned, and indeed the enlargement of it would render it less liable to be choked with mud, at the same time that the machine would more easily adapt itself to declivities of different degrees of steepness. The strain upon the wheel is not such but that it might be made of cast-iron, with spokes for the sake of lightness. The drag is usually made to weigh from sixty to eighty pounds, including the chain, and is fastened to the near-wheel: instead of allowing a loaded cart to press upon the shaft-horse, it supports and elevates the wheel, so that the horse draws only a small burden.

The shoulders, 1, 2, 3, 4, should be sufficiently wide to admit the wheel of the carriage freely. As the part which receives the greatest pressure will inevitably wear away before any other, it should be soled with a plate of iron, which when worn through, may be detached and renewed.

Deep ruts, or loose stones, have not been found to lessen the advantages of this drag.

An improved Stop or Drag for Carriages going down hill.

This drag is to be applied to the naves of the carriage wheels, with a chain attached, fastened to the breeching of the horse, and a small pin on each side of the shaft is to go into the hole of the bar of the drag. If one of the pins be taken out, one wheel will be dragged and the other not. By leaving out both pins, the two wheels are dragged in going down hill, by the breeching bearing against the horse. The wheels will revolve round on a level road, and in going up hill undrag themselves. When the wheels are braced, two or three tons weight have very little pressure on the horse in going down hill.

If two loaded carts should meet on a narrow hill, by unhooking the drag-chain from the breeching, and hooking it to the tub-chain, the horse can be put back with the greatest ease and safety. When the horse is put back against the hill, the two pins must be put in the bars of the drags.

The drag consists of a wooden brake, applied round the nave of each wheel, in pieces which are encircled and connected by a jointed iron plate.

The small bar attached to one end of this brake slides freely through a corresponding hole in a plate fixed at right angles to the shaft; a hole is drilled through this sliding bar, for the purpose of admitting a pin or forelock chained to the shaft.

To each end of the breeching is attached a chain, which, passing through a horizontal sheave or pulley on the upper surface of each shaft, is ultimately fixed to the bar of the drag; while the bolts or forelocks remain in the holes behind the perforated plate before mentioned, it is evident the brake cannot tighten upon or drag the wheel; but on either of those pins being removed, the wheels becomes immoveable.

Fig. 3, plate XCIII, shows the brake, united on the outside by a strong jointed iron hoop; the wood pressing upon the nave of the wheel. The first, a fixed pivot A, from the hoop, is fixed to the under side of the frame of the cart; from the other extremity of the hoop of the brake proceeds a bar B, which slides through the plate or socket C, fixed to the side of the cart frame; a vertical perforation is made through the bar B, just behind the plate, to receive the pin D, which is likewise chained to the shaft: this pin, so placed, prevents any force applied to the chain from tightening the brake on the nave of the wheel.

Fig. 4, represents the interior of a wheel on level ground, the nave surrounded by the brake, which, by its own gravity, is hanging loose, leaving the wheel perfectly free.

Fig. 5, shows a wheel on a declivity, the chain drawn tight by the pressure of the breeching on the horse; the brake of course closely surrounding the nave, and forming an effectual drag.

Fig. 6, is a bird's-eye view of the whole apparatus, exhibiting the framing of the cart, the shafts, wheels, and brakes; the chains also are shown, passing from the bars on each side, each round a horizontal pulley on the shaft, and attached to the ends of the breeching. Thus it is evident, that when a cart, furnished with this drag, is going down hill, the load, pressing the breeching against the horse, draws the brake tight by means of the chain, and produces a friction on the nave proportioned in some measure to the declivity.

When backing upon level ground, by inserting the pin D, fig. 3, through the bars of the brakes, the wheels will be kept free.

Description of an Augre, or Peat-borer, for draining boggy Land.

The greatest obstacle to the effectual draining of many boggy lands consists in the earth in the bottoms of the ditches or drains when newly cut, and especially if made to any considerable depth, rising from the pressure of the waters contained in the bog, by which the newly cut drains and ditches are frequently so nearly filled up, as to impede the flowing of the water they were intended to carry off, thereby rendering the work comparatively ineffectual.

There are different layers, or strata, in moss or peat lands, which will not allow the water easily to filtrate through them, yet are of so soft and spongy a nature as to rise from the pressure of the water contained in the bog.

It becomes necessary to give a free vent to the above confined water, effectually to drain such lands. This has been most effectually done by the augre described below.

A common augre, or even a pole, will force a passage, and give vent to water for a short time; but owing to the peat being only pressed sideways, and not cut out, the parts soon join again, and the passage of the water of course becomes completely obstructed; but by means of this augre, a cylindrical column of peat, six inches in diameter, will be clearly cut out and taken thence, and a free passage maintained for a very considerable space of time.

The first experiment made with the instrument, produced a clear hole, of the above dimensions, four yards in depth, in one hour; and the water, which had been pent up in the bog, rose above the level of the bottom of the ditch, from four to six inches; and the bottom of the ditch, which was previously very soft, and had begun to swell and rise, in a few days became more firm and solid, and this in so great a degree, that when cleared, it remained without swelling or rising in the least. It will considerably reduce the expense of draining such lands, by rendering them so firm as to cause the first end-drains to stand.

The most proper depth to bore depends on the situation. Where the moss lands lie low, and are in danger of being flooded, no greater depth than what is absolutely necessary for draining the surface should be bored, as by deep boring, the land may be sunk so low as to be liable to inundation.

A, fig. 7. plate XCIII, the cutter of the borer, which penetrates the peat.

B, a hollow cylinder, forming the body of the borer; its interior six inches in diameter.

C, the aperture through which the peat, introduced by boring, is drawn out.

D, a portion of the iron bar of the borer, to the upper part of which a cross handle is to be affixed.

The whole of the instrument, except the handle, must be made of iron; the cutter should be steeled.

An Instrument to work the Addition of Numbers with accuracy and despatch.

Casting up bills is what falls to the lot of most people in business, and many who are moderately clever at it, often find it a troublesome task before they can place any dependence upon their being right; they have need to cast them up two or three times, and even then have often as many different sums, and therefore find themselves much confused and puzzled in the operation. In these cases, the present instrument will be very acceptable; it will take the work from the *mind*, and give it to the *hand*, which will perform it with greater ease, accuracy, and expedition: a person who can only *read* figures, may, by this help, add up a bill with as much accuracy as a mathematician.

The principal wheel of this instrument has four circular rows of figures upon its face. The first row, which is nearest the teeth on the circumference, denotes *pence*, the second *shillings*, and the third and fourth denote the *total number of pence or shillings*, &c. Thus, if 64 in the third row should be under the index, in casting up pence, there will, in the first row, be 4 under or next before the index, and the next red figure* passed over by the index will be 5, which signify 5s 4d, the red figure or figures nearest the index signifying *shillings*, and the black figure or figures before the index the odd *pence*. In the second row, the black figure before the index signifies the number of odd shillings, and the next red figure the number of pounds.

In using the instrument, the red figures 360, 180, 9, 15, should, at the commencement of the work, always be placed next before the index, then beginning with the pence, if 5s 4d, for example, should be the amount, set down 4 under the pence, and bring back the red figures 360, &c. again before the index; then with the brass handle move round the wheel five divisions, and go on with the row of shillings, &c.

The particular construction of this instrument will be fully illustrated by the four figures of plate XCIV. A brass hoop is fixed to a flat circular plane of wood, and is divided on its upper edge into 180 ratchet or saw-like teeth. The wooden plane or circle has a number of concentric rows of figures upon its face, in radial lines corresponding with the teeth. A supporting circle, bears a fixed index, reaching across these lines of figures; and has a circular row of 20 divisions, and another of 50, corresponding to the ratchet teeth. A brass central index takes into the teeth, and in one direction will turn the ring to one certain place or stop only; and then, the numbers on the circle, close to the fixed index, will show the sum total of the different numbers to which it has been turned round, at any number of intervals.

Fig. 1 is a plan, showing a portion of the moveable hoop and circle, and the numbers which are upon its face.

Fig. 2 is a section of the instrument, answering to the same.

Fig. 3 is a plan, on a smaller scale, of the under side of the instrument: and fig. 4 an edge-view corresponding with it. The same letters of reference are used in all the figures.

AA represents parts of the principal upper or moveable circle, on which the numbers are marked. This circle is at-

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* Those figures, which in the instrument itself are marked in *red*, or otherwise made easily distinguishable from the rest, the engraver has surrounded with a small circle.

tached by a centre-pin R, to another circle BB, figs. 2, 3, 4, which is held in the hand when the instrument is used; these two circles turn round freely upon each other, and upon the centre of the upper one, a radial lever, or index, CL, is fixed, which has a free motion round the centre-pin R. The circle AA, has a ring or hoop of brass MM, fitted to its circumference, which is cut into 180 serrated teeth, as shown in fig. 2. The centre index, CL, slips over the sloping sides of these teeth, when moved in one direction, but when moved in the other, its edge *c* catches into the perpendicular sides of the teeth, and carries the circle round with it.

EE, fig. 3, are two brass cocks, screwed to the side of the lower circle BB, and projecting from it beyond the circumference M, of the upper circle; the ends of them support a flat circular wooden or brass limb, FF, which (as shown in fig. 1) has other correspondent divisions and figures upon it, over which the index passes. At one end of the limb, a wire stop, *b*, is fixed, and when the index is pressed against this, its edge *c* will stand upon the figure 1 of the limb FF, which is numbered progressively, 1, 2, 3, 4, &c. to 50; which numbers are the same distance apart as the teeth upon the edge of the great circle A, so that by moving the index to any of these numbers, its edge C will have passed over the same number of teeth of the circle, as the number of the limb to which it is carried denotes; but in passing in that direction, it slips over the sloping edges of the teeth, without moving the circle: now the edge C having arrived at any intended number, as 19, for instance, the edge of the lever is pressed into the teeth, and being brought back again, till it touches the stop *b*, it will have moved the circle A round 19 teeth.

At the extreme end of the limb FF, a piece of brass, PP, is fixed, so as to form a reading index for the numbers on the several circles which are described on the face of the great circle AA, and of which circles of numbers there are four, viz. one for the pence, one for the shillings, and two circles for the pounds. The external circle, which is the one for pence, is numbered 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, then 1, marked in red, to denote 1 shilling: then 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, again, and 2, in red to denote 2 shillings, and so on, up to 180, which will be 15 shillings. The next circle towards the centre, is for the pounds; this is numbered 1, 2, 3, 4, 5, 6, up to 19, then 1, in red, for 1 pound; then 19 numbered successively again, and 2, in red, for 2 pounds;

and so on to 9 pounds, which fills the circle, because 9 pounds contain 180 shillings. The third circle towards the centre is for the addition of pounds, or any other whole numbers; the circle therefore is numbered in a regular ascending series, from 1 to 180; but to enable the instrument to count higher than 180, the fourth circle is introduced; this begins at 181, and proceeds by a regular increase to 360.

G, figs. 3 and 4, is a detent, moveable on a centre-pin attached by a stud H, to the lower circle BB, and its tail is pressed by a small spring *h*, which causes it to press constantly upon the under side of the great circle AA, and produces such a friction as prevents the upper circle from slipping loosely round. A screw, *k*, fig. 3, is fixed in one part of the under side of the lower circle, so that in turning round, it intercepts the detent G, and in this position, the edge of the index PP, is at the zero, or point of commencement of all the numbered circles. In this position the instrument is ready for use, in the following manner; suppose the sum in question to be this:

£	*s*	*d*
23	14	3
18	5	2
12	3	4
47	6	5
21	4	3
12	3	4
134	16	9

Having adjusted the instrument as before described, that is, having brought the circle to the zero, hold the circle BB in one hand, and take the end L, of the lever CL, in the other, then move the end of the lever CL, till its edge *c*, cuts the figure 4 of the limb FF, which is the first figure in the sum; in this movement, the index is to be held up so as not to touch the teeth, but having arrived at the intended figure, it is pressed down into the teeth, and is brought back again (the circle with it) until it touches the stop *b*, when it will have moved the circle, so that 4 will stand before the index P, on the pence circle; then the index L, is carried back again to 3, the second figure of the sum, and returned to its stop, carrying with it three divisions more; it is next moved to 5, and so on following the pence column, till the number 3, at the top, is counted; then, examining at the edge of the index PP, it will be found to stand at 9, in the pence circle, and the nearest red figure which has passed by the index, will be 1, denoting 1 shilling and 9 pence; therefore 9 must be put down, and 1 carried to the next column; and to recollect this, a small pin *x*, must be stuck into the hole, No. 1, upon the outside of the limb F: the circle is then returned to the zero, which is readily performed, by returning it backwards as far as it will go, and the stop *k*, fig. 3, prevents its going farther than the right position. The column of shillings is then to be added up by the same process, taking the numbers 3, 4, 6, 3, 5, 14, by successive steps of the index L; then, on examination of the second, or shillings' column, 16 will be found beneath the index, and the nearest red figure which it has passed by will be 1, denoting 1 pound 16 shillings; 16 therefore is set down, and the pin *x* still kept in the same hole to denote that 1 is carried forwards; the circle is again brought to zero, by bringing it back as far as it will go: and lastly, the column of pounds is added, in exactly the same manner.

Method of painting Canvass or Linen Cloth, with Oil Colours, to be more pliant, durable, and longer impervious to Water, than in the usual mode; together with directions for converting old worn-out painted Canvass into Paint, and hints relative to Colours and Colour-grinding.

Canvass, when painted in the usual way, gradually hardens to such a degree, as to crack, and eventually breaking, it becomes unserviceable. In this way, immense quantities of canvass, painted for covering seamen's hammocks, and for other uses in the Navy, completely perish in a short period, and require to be renewed. It is therefore an object of great importance, to use some ingredient along with the paint, which will prevent the bad effects in question; and the one recommended below, has been proved effectual by the experience of above three years.

The ingredient alluded to, is nothing more than a solution of yellow soap, and the composition for painting is made in the following manner:—

To one pound of soap, add six pints of water in a vessel over the fire. In a few minutes after the boiling of the water, the soap will dissolve; whilst hot, it is to be mixed with oil paint, prepared as hereafter directed, and this composition is then fit for immediate use.

The above quantity of the solution of soap will be sufficient for one hundred weight of paint. The first coat laid upon the canvass is to be entirely of this composition, without first wetting the cavass, in the usual way. A very small proportion of it, or none, is necessary in the second coat; and the third coat should be of oil-paint alone.

The method heretofore practised in the royal dock-yards for painting canvass, was as follows: the canvass was first wet with water, then primed with Spanish brown; the second coat was of a chocolate colour, made from Spanish brown and black paint; and lastly, it was finished with black. The canvass thus prepared, was not only liable to destruction, by its cracking, as already stated, but is more expensive than that painted by the improved method; in performing which, to ninety-six pounds of English ochre ground in boiled oil, add sixteen pounds of black paint, being one-sixth of the quantity of ochre; this, when mixed, forms an indifferent black. The solution of one pound of soap in six pints of water, is to be added to this paint, and well united with it; and without previously wetting the canvass, this composition is to be laid upon the canvass as stiff as can conveniently be done with the brush. This first coat will form a tolerably smooth surface; the second coat is to be formed of the same proportion of English ochre and black, without any solution of soap; and the third, or finishing coat, is to be done, as usual, with black paint alone.

The canvass, painted agreeably to the foregoing directions, was deemed by the Navy Board, upon full inquiry, to possess such a decided superiority over any other, that general directions are now given to adopt the plan for all the painted canvass required in the royal dock-yards, and the saving, independent of that arising from increased durability, actually amounts to one guinea in every hundred square yards so painted.

The solution of soap is not only serviceable for ship's canvass, but also for the canvass to be used for paintings, for floor-cloths, and for painted coverings in general. Probably its utility may be extended much further, as from actual trials of nearly four years, it has been found a preservative of red, yellow, and black paints, when ground in oil and put into casks. When the paints were examined at the expiration of the time alluded to, they discovered no improper hardness; but when laid on the work with a brush, they dried in a remarkable manner, without the usual addition of any ingredient as a dryer. This hint may be important to colourmen, and to those who purchase paint for exportation.

Painted canvass, which has been rendered wholly unserviceable by age or accidents, may, by careful calcination, be reduced to a pigment, which is again fit to be mixed with oil, and then forms as valuable a paint as before. While the old useless canvass is burning for this purpose, rake aside the ashes, and sprinkle them with water, to prevent as much as possible the loss of weight. Pass the calcined matter through a fine sieve, and it is then fit for grinding; it grinds easily, possesses a good body for covering with, dries well, and remains glossy. Its bulk exceeding that of an equal weight of common colour, it has the advantage of covering more work. The colours yielded by the calcination of differently coloured canvass, were as follows, viz. canvass which has been painted with black paint only, produces a black; canvass finished with black, but which has previously had a red or yellow ground, will produce a dark chocolate colour: canvass painted a lead colour, will yield a good dark lead colour.

By three experiments which were tried in Portsmouth yard, it appears that one ton of unserviceable canvass, will yield, upon an average, four hundred weight of dry colour, the value of which to Government is nine pounds six shillings; the expense of the process, does not exceed six shillings. Previous to the discovery of this process, immense quantities of old canvass had been buried or burnt.

In painting canvass by the method above described, the space of time which should elapse between laying on the first coat, containing the solution of soap, and the second coat, ought to be one entire day; but when the saving of time is an object, the second coat may be put on the day following the first; for if the canvass is placed in an advantageous situation for drying, the composition will dry or harden so as not to rub off. Canvass finished entirely with the composition, leaving it to dry or harden one day between each coat, will not stick together if laid in quantities.

Great quantities of canvass, painted upon this plan, have been executed by order of the Navy Board, and for the painting and drying of which not more than one week was allowed. The practice observed was to lay on the composition the first day; the canvass was hung up to coat it the second day; and, leaving one intermediate day, to finish it on the fourth. Three days were then allowed for it to dry and harden, and when afterwards taken down and folded in cloths containing sixty or seventy yards, there was no adhesion of the surfaces to each other.

The following testimonials, dated March, 1807, in favour of the improvement here proposed in the plan of painting hammock-cloths, may be acceptable to the reader:

A. STOW, lieutenant and commander of the gun-brig Steady, states, that in the preceding month of October, he had received on board his ship a set of hammock cloths, painted after the method invented by W. Anderson. These cloths had been constantly in use since the time above mentioned, and appeared fully to answer the end proposed, of rendering the canvass soft and pliable, of preventing its cracking, or the paint peeling off, and which in the old method of painting had been the subject of much complaint.

JOHN PRIDY, lieutenant and commander of the Gladiator, and formerly commander of the Dapper, on which latter ship there were a set of hammock-cloths, painted after W. Anderson's plan, testifies to the same effect.

P. F. WYATT, oil and colourman, Portsea, states that he had seen canvass painted after W. Anderson's new method, which, after a trial of sixteen months, remained perfectly soft and pliable, the paint by no means cracking or peeling off, and that the gloss was retained, though it had been exposed to all weathers. He further observes, that he had seen the paint prepared by him from old painted canvass found unserviceable, and had worked and painted therewith; that it was, in his opinion, very good, and would answer either on canvass, wood, or iron.

NS. DIDDEMS, master shipwright, Portsmouth dock-yard, states that W. Anderson had proposed to him to obtain by calcination, from old, unserviceable, painted canvass, the paint which had been laid thereon; that such experiment was made, and four hundred weight of dry serviceable paint prepared from one ton of such canvass; that he had seen it when ground in oil, and laid on work, when it appeared to possess all the properties of good paint, and had therefore been recommended by him to the Navy Board.

A set of hammock-cloths, containing sixteen hundred yards, having been painted by W. Anderson, for the king's ship Hibernia, Captain HICKS, the commander, and W. Trounsell, the carpenter of that vessel, having had them nearly a year in use, certify that they were pliable, and did not crack, nor the paint peel off, and that they were, in their opinion, preferable to those painted in the common way.

PROCESS FOR MAKING A LEAD-COLOURED PAINT FOR IRON.

Take a fire shovel, and having put a small quantity of common litharge upon it, place it over the fire. Then take a small portion of flour of brimstone between the fingers, and scatter it over the litharge, as soon as the latter is hot enough to light it. The litharge, by this means, instantly becomes blackish, and when ground in oil, makes a good dark lead colour, that dries quickly, gets remarkably hard, and resists the weather more than any other lead colour.

In concluding this paper, it may be useful to advert to a plan by which the labour of three men out of four was saved in grinding by hand, with the common colour-mills, the immense quantities of colour required by the Inventor for painting canvass. One mill has ever been considered sufficient for one man to turn, whereas one man can now, with perfect ease, turn four mills. This is effected by placing two mills on each side of the winch, so close as only to leave room for the fly-wheel to play between them. The spindles of each on either side are locked together by a small iron collar with a pin passing through it. The distance from each other, of the mills thus paired, in order that the man may stand between them to turn, is two feet six inches. The distance of the arms of the winch screwed on the end of the spindles on either side, is two feet two inches; the length of the arm is one foot six inches from the spindles to the bar across which the man clasps in order to turn. Fly-wheels at the extremity are only impediments. When the mills are arranged as described, it can scarcely be believed with what ease they are moved. If a little extraordinary motion is given them, and they are then left alone, they will continue to go round sixteen times: hence they may be turned by a man with one hand.

A Thrashing Machine.

The Inventor of this machine being largely concerned in agriculture, and having 800 acres of arable land, found that a thrashing machine became absolutely necessary for the continuance of his occupations. He therefore erected one that had been recommended to him, but from the complication of its structure, its being frequently out of order, and from its bad performance of the work at all times, he resolved to try to have a thrashing machine made under his own directions, more simple in its construction, and more efficacious in its operations. With this view, he continued his experiments for nearly three years, and after an expenditure of about three hundred pounds, he succeeded in the construction of the machine represented in plate XCVI, figs. 1 and 2, which answered his purpose in the most satisfactory manner.

Figs. 1 and 2 give a side and end view of the machine. A, in both figures, represents the framing of the machine. B is the shaft of a cog-wheel C, which is turned by cog-wheels, from the great horse-wheel, in the same manner as the ordinary thrashing-mill. The cog-wheel C, turns a small pinion D, to which it gives a rapid revolution; on the axis of the pinion the beaters EE are fixed, and revolve with it, within a segment or drum, formed of iron plates, grooved or ribbed, parallel to the axis, as the figure represents, and connected together by wooden curbs FF, to which they are screwed.

a a Is the feeding board, upon which the corn is placed to enter the machine. The end of this board is fixed very near to the four vanes, or beaters, *b b b b*; as these revolve rapidly, they strike the heads of the corn upwards, with such a jerk as to beat out all the corn from those ears which they meet fairly; but if any escape, they are drawn in, together with the straw, and rubbed round by the beaters against the inside of the ribbed drum or cylinder F, so as to open the ears and let out the corn, though the ears come in any position whatever.

At H is a grating, upon which the beaters deliver the corn, chaff, and straw together; the two former fall through upon the ground at X, and the latter slides down upon the grate. The corn is afterwards to be dressed in a winnowing machine, which separates the light and heavy corn from the chaff.

The curbs FF, are fixed by screws, which can be adjusted so as to bring the cylinder nearer to, or farther from, the beaters, to adapt the machine for thrashing different kinds of grain; for it is evident that peas, beans, &c. must require more space to rub them in than the smaller grain, as wheat and barley.

L, fig. 1, is one of the uprights of the frame which supports the bearing for the axis B of the cog-wheel; and M is an oblique brace, which strengthens the frame.

N is the stage on which the man who feeds the machine stands.

This machine requires no rollers for entering the corn to be thrashed. It is about two feet six inches in length; two horses are sufficient to work it; and from half-past seven to two o'clock, they will, without fatigue, thrash two loads of oats, each of forty bushels.

The vanes within the cylinder revolve from one hundred to one hundred and twenty times for one round of the horses, in a space of twenty-two feet in diameter. The four vanes within the drum or cylinder, are each one inch and a half thick, and inclosed to within about three inches of their exterior edges. The drum or cylinder within which the vanes turn, is close-fluted with wood of about an inch thick, and is in moveable parts, so as to admit of being placed, as above noticed, nearer to, or farther from, the vanes, as the corn to be thrashed may require.

William Wright of Henley-upon-Thames, Oxfordshire, is a maker of these machines, and his usual charge for one of them, including the horse-wheel, is forty-eight pounds.

Expanding Harrows for cleaning foul Land and harrowing in Seeds.

These improved harrows admit of contraction or expansion, so as to cover an extent of land from five to ten feet; their teeth may be set at twelve different distances between these dimensions; and their tracks will always be at equal distances, according to the state of the land. They will either serve for harrowing in seeds, or cleaning foul land.

For cleaning foul land, this harrow will be found particularly useful; for in such land, the teeth ought to be at a greater distance in the first harrowing, and at the subsequent harrowings to be brought nearer together by degrees, till at last the teeth are brought very near together. One pair of these harrows answers the purpose of three or more pair made upon the old construction with fixed teeth. They are so constructed as to be contracted or expanded in two or three minutes, and the teeth, which are thirty-four in number, set at any equal distances required, having only two screws to confine them. They are more durable than other harrows, as there are no mortises or tenons in them to weaken the woodwork, or admit the rain; they being put together with iron nuts and screws. They are also more readily conveyed from field to field, and when not used, will fold up in a small compass.

A pair of these expanding harrows is represented by fig. 3, plate XCVI. It consists of two sets of moveable bars of wood connected by hooks in one set, and eyes in the other. Each set is composed of four bars of wood, A B C D, furnished with teeth; these are connected, and held parallel to each other by three other bars, or braces, EFG, united to the former by screw-bolts; the iron loops HI are the points for the chains by which they are drawn.

KK are two iron braces, joined to the bars EE, at one of their ends, and have a number of holes, any of which can be put over screw-pins fixed upon the middle bars FF, provided with nuts; when these nuts are removed, and the iron braces detached from their pins, the frames may be either closed up, or extended, so as to bring the teeth of the harrow nearer together, or remove them farther asunder; and they can be fastened at any point by the different holes in the iron braces, so as to work with the teeth at any requisite distance from each other.

A screw-adjusting Plough.

This invention is a material improvement of the wheel-plough in common use in Norfolk. It works with greater ease to the horses, on account of the line of draught being at right angles to the horses' shoulders. It lays the furrow slice particularly level, and cuts an even bottom furrow. It is less liable to wear, on account of having less friction on the ground irons. It is particularly well calculated for breaking up stiff old land, and less liable to be put out of order than any plough generally used. By the adjusting screw, the furrow may be set from one to nine inches in depth, and secured by a lock at these or any intermediate depths, with the greatest exactness.

It may be easily converted into a swing plough, by disengaging the axle-tree and wheels. Its beam may be made particularly light, on account of the line of draught lying so near the heel.

This plough is represented by fig. 4, plate XCVI. A is the beam carrying the coulter B, the share D, and the handle E. F is the mould board.

The draught of the plough is taken by two iron rods G, connected at one end with a hook *a* in the beam A ; and at the other with an iron bridle H by a swivel-bolt. This iron bridle has several notches to receive the draught-chain I, by means of which the point of traction is adjusted sideways.

The adjustment for height, and in which the improvement consists, is made by an iron frame K, at the top of which a nut is placed, acting upon a screw *d*, fixed into the beam A. The axle-tree *e*, of the wheels *f f*, is connected with the iron rods G, by a bolt or pivot projecting from the end of them, which passes through the axle-tree. By these means, the wheels always apply themselves to the inequalities of the ground without influencing the motion of the plough.

The nut of the screw *d* being turned, raises or lowers the iron rods G, and elevates or depresses the point of traction, so that the plough will cut a greater or less depth of furrow.

A Thistle Extirpator.

This simple instrument affords the agriculturist very effectual assistance, in eradicating thistles, docks, and other weeds of a similar kind. It is so contrived, that if the root, in attempting to draw it, breaks in the claw, by turning the instrument, the root may be cut so far below the turf, as to prevent its growth.

In fig. 5, plate XCVI, A is the handle of the thistle extirpator: B the claws, between which the thistle is received. The curved iron C is the fulcrum, over which the purchase to extract the weed is obtained. D is an iron rod or bar upon which the foot is placed to thrust the claws into the ground.

In case the root of the weed breaks in endeavouring to extract it, the curved blade E, which has a sharp end like a chisel, is thrust into the ground to cut off the root of the thistle some inches below the surface, and prevent its vegetation.

Method of making Clover-Hay, in wet Weather, as practised in Courland.

In this method of making hay, not only a number of hands are saved, but the hay is better and more nourishing. The hay is prepared by self-fermentation, whereby it retains its nutritious juices, and only loses its watery particles; it is dried more expeditiously by the dissipation of its humidity, and the contraction of the sap-vessels, and thus its nutritious juices are concentrated. This process is conducted in the following manner, viz. the sap-vessels are expanded by the circulation of the liquid juices by heat, and the superfluous humidity is exhaled: on cooling, the sap-vessels contract, and thus future intestine fermentation is prevented, and the nutritious quality is preserved.

Upon this principle, the clover intended for hay, after having been mowed, remains till four o'clock in the afternoon of the following day, in the swathe, to dry; it must then be raked together into small coils, and afterwards made into large cocks in the form of a sugar-loaf, and such as it would require six or eight horses to remove. To prevent the air from penetrating these cocks, and to produce a quicker fermentation, they must, whilst forming, be trodden down by one or two men. If it be a still, close warm night, the fermentation will commence in four hours, and manifest itself by a strong honey-like smell: when a proper fermentation is begun, the cocks will, on being opened, smoke, appear brownish, and may then be spread abroad. If in the morning the sun is warm, and a little wind arises, the clover-hay will quickly dry; it may then, towards noon, be turned with the rake or pitch-fork, and, about four in the afternoon, it will be sufficiently dried, so that it may be immediately carted into the barn, without any danger of a second fermentation.

By this method of management, the clover will require only three days, from the time of mowing, to its being housed, and very little work; whilst, in the common way, even in good weather, it requires six or eight days. In the old method it frequently becomes of a black colour; but in the new method it is only brown, has an agreeable smell, and remains good and unchangeable in the barn. The farmer has also another advantage, that if he has not carts enough to carry it into the barn, he need only at sun-setting, heap it again into large well-trodden cocks, and thatch them with straw, in which state they will remain the whole summer without damage or loss. This clover-hay is not only greedily eaten by sheep and lambs, but also by horses, calves, and cows.

The last, in particular, prefer it to the meadow-hay: it produces a great quantity of rich milk; and the butter made from it, is almost as yellow as summer butter.

As this new mode of making hay depends principally upon two circumstances—first, that the mown clover, when brought together into large heaps, may ferment equally and expeditiously; secondly, that the day succeeding fermentation be dry, sunny, and windy—on this account it may be proper to point out what should be done when circumstances are unfavourable.

Let us suppose, therefore, that the night after the clover-grass has been placed in the great cocks, is cold, damp, or rainy, the fermentation will yet take place, although it may require a term of twelve, sixteen, or twenty-four hours to effect it. If it be a second or a third crop, at which season the nights are colder, it may even require from thirty-six to forty-eight hours before the fermentation ensues: it will, however, commence, and may be ascertained from this circumstance, that you can scarcely bear your hand in the interior of the cock.

Even if the night be dry, yet if a strong cold wind blows, the cock may not ferment equally, but only in the middle, and on the side opposite to the wind; the other parts may still remain green. In such a case the following rules must be attended to:—

First,—If the cock has only fermented in the middle, and on that side where the cold wind did not act upon it, the whole heap must nevertheless be opened the following morning. That which has already fermented must be separated and spread to dry; it must be turned towards noon, and may be carted into the barn in the evening; but that part of the cock which has not fermented, must be again put together into large cocks, and fermented in the same manner as the preceding part, after which it may be spread to dry, and brought into the barn.

Secondly,—When a small portion of the cock has fermented thoroughly, but not the greater part, the heap must be spread abroad in the morning, but must be again made into a close cock in the evening, in such a manner that the part which has fermented be placed at the top or outside of the cock, and that which has not fermented be inclosed within it; then on the ensuing morning, or, if the weather be cold and rainy, on the morning afterwards, the clover-heap may be again spread abroad, and the clover treated as in the case first mentioned.

Thirdly,—If in spreading the heap abroad, it be found that nearly the whole of the clover has fermented, it will not be necessary to delay the housing of the whole on account of some small portion; but the clover may be dried, and carted into the barn. The small portion which remained unfermented, will not occasion any disaster to the other which has fermented; for there is a material difference betwixt hay thus managed, and the meadow-grass which is brought whilst damp, or wet with rain, into the barn, which will grow musty and putrid.

Fourthly,—When some of the cocks have been thoroughly fermented, and it rains on the morning, they ought to be spread abroad, for the clover must be opened and spread, even if it rains violently; since, if it was suffered to remain longer in the heap, it would take fire, or its juices would be injured by too much fermentation; the leaves and stalks would become black, and the clover unfit for food: therefore, if the rain continues, the spread clover must be turned from time to time, but not carted into the barn till dry. This drying takes place, if the rain discontinues for a few hours, much more expeditiously with the clover which has fermented than with that made in the common way. Besides which, it must be remarked, that the fermented clover remains good, even if it continues some weeks exposed to the rain, provided it is at last suffered to dry before it is put into the barn; otherwise the wet from the rain will render it musty and bad. The clover which has been so long a time exposed to the rain, will not, however, be so nutricious as that which has been well fermented and sooner dried; but it will be far superior to that which has been exposed to the rain, and got up in the common method.

This new mode has been adopted with success, during the years 1798 and 1799, in Silesia, and found, in every respect, preferable to the old practice. On one of the estates there, it rained much during the hay-time; they were obliged to spread the clover out of the large cocks, owing to its having fermented only in the middle; the parts which had not fermented were carefully separated, and made again into large cocks, which fermented at the expiration of thirty-six hours, rainy weather and cold nights continuing during this period; after which time it was again spread abroad. The former, as well as the latter, remained for three days exposed to the rain, during which period it was turned several times; the rain ceased on the fourth day, so that the clover-hay was turned towards noon, and carted into the barn that evening. This clover-hay remained in the hay-loft without change, and was a very nutritious food. Several milch-cows were fed with it, which not only ate it greedily, but also increased in their milk. Lambs and calves also throve with it greatly.

This method of making clover-hay prevents its taking fire; for clover which has been once well fermented and dried, does not change or spoil in the hay-loft.

Such is the practice related by Klapmeyer; when the hay-season proves wet in England, it would doubtless prove a valuable resource. If the weather be remarkably hot, the farmer may, by the adoption of it, prevent a frequent accident; for grass hastily made into hay, however dry it may appear to the hand, contains within its fibres much humidity; and when trodden down in the stack will ferment rapidly, from this humidity endeavouring to escape, which often fires the stack. A certain degree of fermentation is necessary in the making of hay, in order to develop its sacharine qualities, and make nutritious food. This saccharine fermentation is evident, from the smell and colour of the hay in common stacks, and from tasting an infusion of it; it resembles, in some degree, the process of making malt from barley, and requires a similar attention. The method above related is likely to be generally advantageous, in making clover, lucern, and meadow-hay, in this country, and to lead to valuable improvements in agriculture.

On preparing Broom Flax.

To procure the flax of broom, it is only necessary to steep the twigs, or former year's branches (and the most vigorous shoots are the best) for two or three weeks, more or less according to the heat of the season, in stagnant water, or to boil them for about an hour in water. This done, the flax comes freely from the twigs; and, when there is not machinery for the purpose, may be easily peeled or stripped off, by children or others, at any time when not quite dry, in the same way as hemp is peeled from the stalks. And what adds to the value of the discovery, if it may be so called, is, that in being cleared of the flax, and steeped for some time in boiling water, the twigs, or wood, become tough and beautifully white, and are worth, at a medium, from a shilling to eighteen-pence per pound for making carpet brooms, &c.

When stripped from the twigs, the flax requires only to be well washed in cold water, then wrung and shaken well, and hung out to dry, previously to its being sent off to the paper manufacturers.

N. B. The fibres of all kinds of mallows are uncommonly beautiful, particularly the malva sylvestris: they are finer than camel's hair, which they somewhat resemble.

On preparing from Bean Stalks a Substitute for Hemp.

The Author of this discovery observes, that though it has not been attended to, so far as he knows, yet it is certain that according to its size, every bean plant contains from 20 to 35 filaments, or fibres, running up on the outside, under a thin membrane, from the root to the very top all round, the one at each of the four corners being *rather thicker* and stronger than the rest. It is also certain that, next to Chinese, or sea-grass, in other words, the material with which hooks are sometimes fixed to the end of fishing-lines, the filaments, or hempen particles of the bean plant, are among the strongest yet discovered. These, with a little beating, rubbing, and shaking, are easily separated from the strawy part, when the plant has been steeped ten or twelve days in water; or is damp, and in a state approaching to fermentation, or what is commonly called rotting. Washing or pulling it through hackles, or iron combs, first coarse, and then finer, is necessary to the dressing of bean-hemp; and is perhaps the easiest mode of separating the filaments from the thin membrane that surrounds them.

From carefully observing the medium number of bean-plants in a square yard, in a variety of fields on both sides of the Tweed, as well as in Ireland, and multiplying them by 4840, (the number of square yards in an acre,) and then weighing the hemp or filaments of a certain number of these stalks, the Author found that there was, upon a medium, about two hundred weight of hemp, or of these filaments, in every acre, admirably calculated for being converted into a thousand articles, where strength and durability is of importance, as well as, with a little preparation, into paper of all kinds, even that of the most delicate texture.

Now since there are at least 200,000 acres of ticks, horse and other beans, planted in Great Britain and Ireland, and since, where there is not machinery for the purpose, a portion at least of the poor, both old and young, females as well as males, belong to each of the 9700 parishes, &c. where beans, are raised, might be employed in peeling, or otherwise separating these filaments from the strawy part of the plant, after the beans have been threshed out; it is obvious that a prodigious quantity of a valuable material, at present used only as a manure, might be made to supply our manufactures.

A parcel of bean-hemp, exposed for nearly twelve months to all the varieties of the air within doors, and another parcel kept for nearly the same length of time constantly under water, were not found to be in the least injured. The chief difference appeared to be, that the parcel constantly kept under water had assumed a rich silky gloss, and a much more agreeable colour than it had before.

But though this is the case with bean-hemp *after* it is cleaned and dressed, and which, though stiff and hard when dry, is pliable and easily managed when rather damp or wet, it seems otherwise with it *previous* to its being separated from the straw. If bean-straw be kept for years under water, or quite dry, it produces hemp as good and fresh as at first; but if the straw be sometimes wet, and sometimes dry, the filaments or fibres are apt to be injured. If the straw of the bean be scattered thin on the ground, and exposed to the weather for two or three months, the hemp or fibres are loosened, and easily separated from the strawy part, without any other process than merely beating, rubbing, and shaking them, and perhaps this is the easiest way of obtaining bean-hemp; but then from being thus exposed, and the fermentation that takes place in the strawy part, which is of a spongy nature, communicating itself to the fibres or hemp, these are generally more or less injured, though probably not so much so as to prevent them from being excellent materials for making paper.

The Author of this discovery found, that though the water in which bean-straw has been put to steep, in a few days generally acquires a black colour, a blue scum, and a peculiar taste, yet cattle drink it greedily, and seem fattened by it;

though his experiments have been on too limited a scale to ascertain this last circumstance decisively. When the water in which bean-straw has been put to steep, becomes fœtid, to which state it is scarcely more inclined than common stagnant water, on being stirred by driving horses or cattle through it, by a stick, or in any other way put in motion, (as is the case with all putrid water, even the ocean itself,) the fœtid particles fly off, and the effluvia dies away.

When straw is to be steeped for bean-hemp, the beans are to be threshed in a mill: the beans should be put to the mill, not at *right angles*, but on a *parallel*, or nearly so, with the rollers, else the straw, particularly if the beans are very dry, is apt to be much cut. If the straw is *not* to be steeped, on putting the beans to be threshed at right angles or nearly so, with the rollers of the mill, a certain proportion of the fibres, or hemp, may easily be got from the straw, these being in general not so much cut as the straw; but often torn off, and hanging about like fine sewing threads. The hemp thus taken off, though its lying under water for months would do it no harm, requires only to be steeped a few minutes, drawn through a hackle, and washed, previous to its being laid up for use. If the hemp, or fibres, collected in this way (which is a fine light business for children and such as are not able to perform hard work, and which requires no ingenuity) are intended only for making paper, they require neither steeping nor hackling, but only to be put up in parcels, and kept dry till sent off to the manufacturer.

The straw of beans contains a saccharine juice, and is highly nutritive, perhaps more so than any other; and, like clover, the prunings of the vine, the loppings of the fig-tree, &c. produces a rich infusion, and uncommonly fine table-beer, as well as an excellent spirit by distillation. It is the hemp or fibres that prevents cattle from eating it. These, like hairs in human food, make cattle dislike it. The collecting of it, therefore, should never be neglected, nor the children in workhouses and other places be permitted to be idle, while business of this kind would evidently tend both to their own and their employers' advantage.

It is a fact, that about the generality of mills for beating and dressing hemp and flax, a large proportion, in some inland places both of Great Britain and Ireland, amounting nearly to one-half of what is carried thither, is either left there to rot, under the name of refuse, or thrown away as of no use, because too rough and short for being spun and converted into cloth. Now from experiments which the Author has tried and caused to be tried, it is evident, that though too rough and short for being converted into cloth, even of the coarsest kind, the refuse of hemp and flax, on being beaten and shaken, so as to separate the strawy from the stringy particles, (which can be done in a few minutes, by a mill or hand labour, as is most convenient,) becomes thereby as soft and pliable, and as useful for making paper, as the longest, and what is reckoned the most valuable part of the plant, after it has been converted into cloth and worn for years.

In its natural state, it is true, the refuse of hemp and flax is generally of a brown and somewhat dark colour; but by the process of bleaching, now so much in use, it may, without injuring it for making paper, be made as white as the finest cambric.

There are at a medium, published in London, every morning, 16,000 newspapers, and every evening about 14,000. Of those published every other day, there are about 10,000. The Sunday's newspapers amount to about 25,000, and there are nearly 20,000 other weekly papers, making in all the enormous sum of 255,000 per week. At a medium, 20 newspapers are equal to one pound—hence the whole amount to above 5 tons per week, or 290 tons per annum. But though this, perhaps, is not one-half of the paper expended in London on periodical publications, and what may be called fugacious literature, and not one-fourth of what is otherwise consumed in printing-houses in the country at large, yet there are materials enough in the refuse of the hemp and flax raised in Great Britain and Ireland, for all this, and much more.

Nor is this all, for as the bine or straw of hops contains an excellent hemp for making many articles, so also will it prove a most excellent material for making all kinds of paper. And it is a fact, that were even one-half of the bine of hops raised in the counties of Kent, Sussex, and Worcester, instead of being thrown away, or burnt, after the hops are picked, as is commonly done, steeped for ten or twelve days, and beat in the same way as is done with hemp and flax, independent of what might be got from bean-hemp, there would be found annually materials enough for three times the quantity of paper used in the British dominions.

On the Utility of the common Nettle as a Substitute for Hemp.

The growth of nettles is general throughout this country, particularly in strong fertile soils, where, on every bank, ditch, and place, which cannot be reduced to tillage, they are produced in such abundance, that the quantity, if collected, would be of great magnitude.

The growth of them might be encouraged in such waste places, or a vast quantity of land of that description might, at a moderate expense, be made to produce a valuable crop of a useful article heretofore regarded as a nuisance. The shady places in woods, parks, and coppices, are particularly favourable to their growth, and they are accordingly found in such situations in the greatest perfection.

The harl, or fibre, of this plant, is very similar to that of hemp or flax, inclining to either according to the soil and situation in which it grows; and it has been shewn by experiment, that it may be used for the same purposes as hemp or flax, from cloth of the finest texture down to the coarsest quality, such as sail-cloth, sacking, cordage, &c.

Another use, of great magnitude, is the application of the fibres of nettles to the manufacture of paper of various qualities. The late impediments to foreign commerce depriving us of a supply of linen rags, and occasioning the extensive use of cotton rags in the paper manufactory, the quality of writing and printing papers has been materially deteriorated. It is therefore, on this account, desirable to find some abundant substitute for hemp.

For the purpose of writing and printing papers, the nettles might be gathered twice in one season; as for these purposes an extraordinary length of staple is not required, and the fibre would be increased in its fineness; and in point of colour, the prudent use of bleaching would render them a delicate white, without injuring them.

The kind of nettle capable of being manufactured into cloth, &c. it is scarcely necessary to say, is that which in general is denominated the stinging nettle. The most valuable sort, in regard to length, suppleness, fineness of the lint, brittleness of the reed, which dresses most freely, with least waste of fibre, and yields the greatest produce of fine strong harl, is most common in the bottom of ditches amongst briars, and in shaded valleys, where the soil has been a blue clay, or strong loam. In such situations, the plant will sometimes attain the height of twelve feet, and upwards of two inches in circumference: in general they are from five to nine feet in height; and those growing in patches on a good soil, standing thick and in a favourable aspect, will average about five feet and a half, will work kindly, and the stems are thickly clothed with lint. Those which grow in poorer soils, and in less favourable situations, with rough and woody stems, and have many lateral branches, run much to seed, are stubborn, and work less kindly; they produce lint more coarse, harsh, and thin. In every situation and different soil, the most productive nettles are found to be those which have the smoothest and most concave tubes, the largest joints, the fewest leaves, and which produce the least quantity of seed.

In gathering them, as they are perennial plants, they should not be pulled up by the roots, but cut down, with a view to obtain a second crop where the situation will allow of it, and to secure the propagation of them the subsequent year.

The most favourable time for collecting them is from the beginning of July to the end of August; but it may be continued even to the end of October, only the lint of those which remain growing till that time will be less supple, and will not work so freely; and if the season happens to be unfavourable, it is probable there would not be sufficient time to steep and grass them, in which case they should be dried by the heat of the atmosphere, or, if the state of the weather would not permit that, then by means of artificial heat; and when dried, they should be housed or stacked till the spring, when they might successfully undergo the same operation of steeping as those of the first collection. Such as grow in grass fields, when the grass is intended for hay, should be cut when the hay is cut, in order to prevent their being spoiled by the cattle when feeding; the harls of these will be fine in quality, and well suited to be wrought up with the second crop, which may very generally be obtained where the situation will admit of the plants being preserved.

After the nettles are gathered, they should be exposed to the atmosphere till they gain some firmness, in order to prevent the skin being damaged in the operations of dressing off the leaves, the lateral branches, and seeds, which should be done a handful at a time, and afterwards sorted, viz. those which are both long and fine by themselves, and those which are both short and coarse by themselves; then made up into bundles as large as can be grasped with both hands, a convenient size for putting them into water, and taking them out: for this purpose, a place should be previously prepared, and may be either a pond or a pit free from mud, or a brook or river. The bundles should then be immersed and placed aslant with the root-end uppermost, and to prevent their floating on the surface, some weight should be laid upon them.

The time required for steeping them is from five to eight days; but it is better they should remain rather too long in the water than too short a time; yet great care should be taken not to overdo them: when the fibre approaches to a pulp, and will easily separate from the reed, and the reed becomes brittle, and assumes a white appearance, the operation is finished.

The bundles should then be taken out singly, very carefully, to avoid damaging the fibres, and be rinsed as they are taken out of the water, to cleanse them from the filth they may have contracted; they must next be strewed very thinly upon the grass, and be gently handled. When the surface has become sufficiently dry, and the harl has obtained a degree of firmness, they should be turned repeatedly till they are sufficiently grassed; the time required is known only by experience, so much depends on the state of the weather during the process; when they are sufficiently done, the hard blisters and the stems become brittle; they must then be taken up and made into bundles, and secured from the weather.

The harl is now to be separated from the reed, after the manner practised on flax and hemp, either by manual labour, or machinery now in use in those manufactories.

The harl being separated from the reed, it requires next to be beaten, that it may become more ductile for the operation of dressing, and which may be performed with such implements as are used in dressing flax or hemp.

This operation being accomplished, the produce of the nettles is arrived at a state ready for spinning, and may be spun into various qualities of yarn, either by hand or by machinery constructed for the purposes of spinning flax or hemp, and which yarn may be successfully substituted for the manufacturing everysort of cloth, cordage, &c. which is usually made from hemp or flax; and this new material is particularly calculated for making twine for fishing-nets, equal to the best Dutch twine imported for that purpose, the fibres of the nettles being stronger than those of flax, and not so harsh as the fibres of hemp.

The most favourable condition of the lint, with a view to the paper manufactory, is to begin with it after it is hackled; in order that the fibres may be divested of the skins which inclose them; as, when it is intended to make white paper, having gone through that process would greatly facilitate the bleaching, and render it more easily disencumbered of the gross particles.

After the lint is bleached, it should be reduced to a proper length for paper, and then macerated in water after the manner of rags, and undergo similar processes till the substance is converted into paper, which may be easily accomplished by the manufacturers, and the substance of nettles made to produce substantial paper of the first quality.

On the medical Properties of Furze or Whins.

The utility of furze or whins, as food for cattle, has been long known, though probably not sufficiently appreciated; but as a medicine it has scarcely been noticed. It may be useful therefore to record, that a gentleman, whose veracity may be depended upon, found his sight much strengthened by drinking an infusion of whin or furze blossoms, dried in the sun in summer. The infusion was made from a tea-cup full of the blossoms, in a tea-pot in the manner of tea, and the dose half a tumbler at night; he never had a cough since he used this preparation, which he has now taken for fifty years; it acts as a diuretic, and by perspiration, and when the dose is increased, promotes sleep. Although seventy-five years of age, his health is good; his skin is remarkably fine and sleek, which he attributes to the use of this medicine. He supposes that the young shoots of furze will answer, if the blossoms cannot be obtained.

The gentleman above alluded to, who has been an officer in the army, had the care of a troop of horse in Ireland, at a time when an epidemical cold detroyed vast numbers of these animals. He was in so poor a village, that he could get neither bran nor malt for mashes, which were ordered for the horses, with sulphur, after bleeding. He therefore ordered the men to cut furze, and directed them to give it to the horses, after they had beaten it well on the pavement; at first they had to mix it with oats, but in two or three days the horses devoured it like clover. By this means they all recovered, though every other troop lost two or three, and his was the only troop in good condition at the review.

Cement for Curing Damp Walls.

The utility of a cement capable of curing damp walls, and suitable for use in flooring damp kitchens, and other purposes, where the prevention of wet is necessary, will be generally acknowledged. The following composition has been successfully used by many persons, who have certified their experience of its efficacy, and it will probably be found a valuable remedy.

Boil two quarts of tar with two ounces of kitchen grease, for a quarter of an hour, in an iron pot. Add some of this tar to a mixture of slaked lime and powdered glass, which have passed through a flour sieve, and been dried completely over the fire in an iron pot; in the proportion of two parts of lime, and one of glass, till the mixture becomes of the consistence of thin plaster.

This cement must be used immediately after being mixed; and therefore it is not proper to mix more of it at a time than will coat one square foot of wall, since it quickly becomes too hard for use, and continues to increase its hardness for three weeks. Great care must also be taken to prevent any moisture from mixing with the cement.

For a wall which is merely damp, it will be sufficient to lay on one coating of the cement, about one-eighth of an inch thick; but should the wall be more than damp, or wet, it will be necessary to coat it a second time.

Plaster, made of lime, hair, and plaster of Paris, may be afterwards laid on the cement.

This cement, when put in water, will suffer neither an increase nor diminution in its weight; and it has the peculiar advantage of joining Portland stone, or marble, so as to make them as durable as they were prior to the fracture.

Cement which resists the action of Fire and Water.

Take half a pint of milk, mix with it an equal quantity of vinegar, so as to coagulate the milk; separate the curds from the whey, and mix the latter with the whites of four or five eggs, well beaten up. The mixture of these two substances being complete, add to them quicklime which has been passed through a sieve; make the whole into a thick paste to be of the consistency of putty when it is used.

This cement has been applied to close the fissure of an iron cauldron, for the boiling of pitch, and which has been in use for five years, without requiring further repairs.

Method of preparing Paste from Potatoes, for the use of Weavers, Bookbinders, Trunkmakers, Upholsterers, &c.

Take one pound of raw potatoes, well washed from dirt, grate them fine on a common tin grater, without paring them, with two and a half pints of water, then boil the whole mixture immediately, and stir it well during the whole time of boiling, which should be about two minutes; then remove it from the fire, and add to it about half an ounce of finely powdered alum, by gradually sprinkling it into the paste, and stirring it with a spoon till the whole is perfectly incorporated. It will then be fit for use, and forms a beautiful transparent paste.

This paste answers all the purposès of that prepared from wheaten flour, and may be made at one-third of the cost It is easily made free from lumps, and does not admit the air to get under the paper like common paste, nor injure the colour. It is free from any offensive smell, and after having been exposed to the air for ten or twelve days, it will not appear to be in the least changed. One peck of potatoes will make upwards of thirty-eight pounds of paste.

Uses of the mucilaginous Liquor from Potatoes.

Take raw potatoes, in the state they are taken out of the earth, wash them well, then rub them on a grater over a vessel of clean water to a fine pulp; pass the liquid matter through a coarse sieve into another tub of clean water; let the mixture stand till the fine white particles of the potatoes are precipitated, then pour the mucilaginous liquor from the fecula, and preserve this liquor for use.

The article to be cleaned should be laid upon a linen cloth on a table, and having provided a clean sponge, dip the sponge in the potato-liquor, and apply it thus wet upon the article to be cleaned, and rub it well upon it with repeated portions of the potato-liquor, till the dirt is perfectly separated; wash the article in clean water several times, to remove the loose dirt: it is then ready for drying or smoothing.

Two middle-sized potatoes will be sufficient for a pint of water.

The white fecula which separates in making the mucilaginous liquor, will answer the purpose of tapioca, will make a useful nourishing food with soup or milk, or serve to make starch.

The coarse pulp, which does not pass the sieve, is of great use in cleaning worsted curtains, tapestry, carpets, or other coarse goods.

The mucilaginous liquor of the potatoes will clean all sorts of silk, cotton, or woollen goods, without hurting the texture of the article, or spoiling the colour.

It is also useful in cleansing oil-paintings, or furniture that is soiled.

Dirty painted wainscots may be cleaned by wetting a sponge in the liquor, then dipping it in a little fine clean sand, and afterwards rubbing the wainscot.

Method of cleaning Feathers from their Animal Oil.

Take for every gallon of clean water one pound of quicklime; mix them well together, and when the undissolved lime is precipitated in fine powder, pour off the clear lime-water for use.

Put the feathers to be cleaned in another tub, and add to them a quantity of the clear lime-water, sufficient to cover the feathers about three inches, when well immersed, and stirred about therein.

The feathers, when thoroughly moistened, will sink down, and should remain in the lime-water three or four days; after which the foul liquor should be separated from them by laying them on a sieve.

The feathers should be afterwards well washed in clean water, and dried upon nets; the meshes of which may be about the fineness of those of cabbage-nets.

The feathers must from time to time be shaken upon the nets, and as they dry they will fall through the meshes, and are to be collected for use.

The admission of air will be serviceable in the drying; the whole process will be completed in about three weeks: after being prepared as above mentioned, they will only require beating previous to use.

Method of turning Spheres in Wood.

This invention applies to the art of turning a truly spherical figure between two centres, principally on a large scale, by means of the large wheel commonly made use of by turners.

Prepare of wood as near a cube as may be; plane one side true, and guage a line down the middle, from which line the centres are at each end found by a pair of compasses. Then form the piece to an octagon by taking off the four corners; place it in the lathe, and lay the band on about one-third from the end: then strike each end to the exact length of the intended diameter. With a pair of compasses divide the piece; which gives the centre or curve line, and bisects the guage stroke; strike it with a chissel, then with a small gouge; by this means a groove is made for the band to work in (care being taken not to diminish the size of the diameter.) From the middle work down each end with a gouge to a round by the eye, or with callipers; then take the piece out, and carefully prick the second centres, which the guage stroke and curve line give: place in the lathe the last pricked centres, and pass the piece round by hand: work down with a small firming chissel, in order to form a second curve line, until it bisects the first diameter or curve line: then strike the piece to the first centres, and work off the remaining wood with a large firming chissel, until it becomes flush with the second curve line: it may then be polished. Throw off the band, and turn round the ball by hand, to work off the groove the band played in.

The turning of the sphere by hand, to work off the groove, may be dispensed with, by shifting the rest to the opposite side, and reversing the motion of the wheel. To polish the remainder, the band will play on the surface of the ball, if steadied by the hand.

A Loom to be worked by Steam or Water.

A loom having been invented, which may be wrought by steam, water, or any other first mover of machinery, and its practical value having been ascertained by an extensive trial, it will be interesting and useful in this publication, to show what has been accomplished in this branch of ingenuity, by a record of its properties. A plate of any ordinary size would not be adapted to shew with clearness the principles and construction of this curious machine; but a working model is in the possession of the Society for the Encouragement of Arts, &c. and looms upon this plan possess the following advantages.

1. From 300 to 400 of them may be worked by one water-wheel, or steam-engine, all of which will weave cloth, superior to what is done in the common way.
2. They will go at the rate of 60 shoots in a minute, or two yards of a nine-hundred web in an hour.
3. They will keep regular time in working, stop, and begin again, as quickly as a stop watch.
4. They will keep constantly going, except at the time of shifting two shuttles, when the weft on the pirns is done.
5. In general, no knots need to be tied, and never more than one, in place of two, which are requisite, in the common way, where a thread breaks.
6. In case the shuttle stops in the shed, the lay will not come forward, and the loom will instantly stop working.

7. They will weave proportionally slower, or quicker, according to the breadth and quality of the web, which may be the broadest now made.

8. They may be mounted with a harness, or spot headles, to weave any pattern, twilled, striped, &c.

9. There is but one close shed, the same in both breadths, and the strain of the working has no effect on the yarn behind the rods.

10. The bore and temples always keep the same proper distance.

11. There is no time lost in looming, or cutting out the cloth; but it is done while the loom is working, after the first time.

12. The weft is well stretched, and exactly even to the fabric required.

13. Every piece of cloth is measured to a straw's breadth, and marked where to be cut, at any given length.

14. The loom will work backwards, in case of any accident, or of one or more shoots missing.

15. Every thread is as regular on the yarn beam as in the cloth, having no more than two threads in the runner.

16. If a thread should appear too coarse or fine in the web, it can be changed, or any stripe altered at pleasure.

17. They will weave the finest yarn more tenderly, and regularly, than any weaver can do with his hands and feet.

18. When a thread either of warp or weft breaks in it, the loom will instantly stop, without stopping any other loom, and will give warning by the ringing of a bell.

19. A loom of this kind occupies only the same space as a common loom; the expenses of it will be about half more; but this additional expense is more than compensated by the various additional machinery employed for preparing the yarn for the common loom, and which this loom renders entirely unnecessary.

20. The reeling, winding, warping, beaming, looming, combing, dressing, fanning, greasing, drawing bores, shifting headles, rods, and temples, which is nearly one-half of the weaver's work, together with the general waste accompanying them, which is about six per cent. of the value of the yarn; and all which occur in the operations of the common loom, do not happen with this loom, which, by its single motion, without further trouble, performs every operation after the spinning, till the making of the cloth be accomplished; by which, independently of the saving of the waste, the expense incurred

for reeling, warping, winding, &c. is saved, amounting to above twenty per cent. of the yarn.

21. The headles, reed, and brushes, will wear longer than usual, from the regularity of their motion.

22. More than one-half of the workmanship will be saved; one weaver and a boy being quite sufficient to manage five looms of coarse work, and three or four in fine work.

The first attempt of the Inventor of the above loom, towards constructing such a machine, was made in the year 1789; at which time he entered a caveat for a patent, but relinquished the idea of obtaining one, and afterwards made many improvements upon the original plan. In 1796, a report in its favour was made by the Chamber of Commerce and Manufactures at Glasgow; and in 1798, a loom was actually set at work, in J. Monteith's spinning works, at Pollockshaws, four miles from Glasgow, which answered so well that a building was erected by J. Monteith to hold thirty of the looms, and afterwards another to hold two hundred.

Method of weaving Cloth of extremely fine quality.

This improved mode of weaving consists in adding more thread of the warp within each dent or split of the reed than in the common way; for instance, where in the common mode there are only two threads in the reed, there are upon this plan three or four.

The weft or shoot is thrown in the common way with a single thread.

When the cloth is woven and taken out of the loom, it has the appearance of being barred or striped, the cane of the reed occasioning that part of the cloth struck with it to look thinner, owing to the threads of the warp being further apart.

The cloth is then to be wet in water, and in that state to be repeatedly stretched across by the hands backwards and forwards corner-ways; by this means, the threads which apparently formed the stripe, or close part of the cloth, separate from each other, and become diffused at equal distances. The appearance of stripes being entirely removed, the cloth becomes of inconceivable fineness, and extremely regular in texture. This operation must in cotton fabrics be performed before the cloth goes to the bleach-ground.

Silk goods, on being taken out of the loom, must be wet and well rubbed, as in the common mode of washing, and then stretched backwards and forwards, in the manner above directed for cotton goods.

In silk goods the warp and weft may be both alike; in cotton goods the weft may be softer, but of the same fineness.

Fine linen cambrics may be made on this plan, much supesior to any hitherto made in France.

Though there are three threads within each dent or split of the reed, whilst the cloth is weaving, yet the headles or yealds lift up the threads alternately throughout the whole breadth of the cloth, and there are about 250 shoots in an inch.

By this improvement, cotton, linen, and silk goods, can be made much sooner and finer, than by any method yet discovered. The Inventor of it made a piece of plain silk cloth, from hand-thrown silk in the gum, that contained the amazing quantity of 65,536 meshes in one square inch.

It is impossible to make a reed half so fine as to weave such cloth upon the present principles of weaving; and even if that could be done, no weaver could make use of it: but upon the above plan, which the Inventor asserts he can teach in two minutes, as fine cloth may be woven in a twelve hundred reed, as by the old mode in a reed of twenty-four hundred, and with less rather than more trouble.

Of the Management of Fir-trees.

The Duke of Bedford having given orders to have proofs collected, with respect to the advantage of pruning and managing his fir-plantations, in the neighbourhood of Woburn, the result of the examination very clearly evidenced the advantage of early and close pruning, and the impropriety of leaving timber to the course of nature.

It will not be questioned, that fir-timber is more valuable in proportion as it is fine and straight-grained, and sound; but when the tree has been left to the course of nature, the branches of the trunk occasion frequent interruptions of straightness of grain, and often decaying early, the mischief commencing almost at the centre, is continued to the circumference of the tree, however long it may stand. Nor is the defect of grain, or merely a knot, the whole of the evil, but a projecting dead branch lets in wet to the heart of the tree, and the part of it which is inclosed by the growth of the tree, produces what workmen call a dead knot. But when the branches that can be dispensed with are cut off close to the trunk, they are inclosed while living, and the knot is small, at the same time that the wood is perfectly sound.

From every authority or observation, there can be no doubt that all firs should be planted thick; not more than four or five feet apart.

Where firs of the same kind are planted together, there is less loss of plants from one sort overgrowing and destroying the others; consequently it appears advisable to plant all the different sorts by themselves. If any admixture be admitted, the Scotch and larch may best succeed: but this is not certain, and they will certainly be best separate on two accounts; first, because they are not so likely to injure each other; and secondly, the larch may be put into the ground best suited to it, and the Scotch the same.

In making plantations of any particular sort, it may be right to have a few spruce, or other sorts, on the outside to prevent mischief from sudden gusts of wind; but if the situation is not subject to such gusts, the spruce had better be omitted, being mechanical agents only, and by excluding the sun and air they act against the operation of nature.

In these hints, ornament is not considered; if such be wanted, and profit also, then the spruce, larch, silver, and some other, may be combined.

From some years' observations on pruning and the effects thereof, it appears certain that fir-trees, at a certain age, should be pruned to a certain height; and to regulate this operation, the following rule is recommended: The pruning to commence when the trees are six years old, or when there is discernable five tier of boughs and the shoot; the three lower tier of boughs are then to be taken off. After this first pruning, the trees to be let alone for four or five years, and then, and at every succeeding four or five years, the pruning to be repeated, till the stem of the tree be clear to forty feet high; after which, as to pruning, it may be left to nature. The rule for the height of pruning, after the first time, to be half the extreme height of the tree, till it attains twenty years' growth; and after that time, half the height of the tree, and as many feet more as it is inches in diameter at four feet from the ground. This pruning is known, from repeated observations, not to be excessive, and the rule is calculated to check the too tapering top, and strengthen the slender bottom, by carrying the pruning to a greater proportionate degree, in a ratio compounded of the height and bottom bulk; and by this rule, it may be observed, that the trees will be at top clothed with somewhat less than half their branches. The proper time for pruning is between September and April; and the tool to be used, the saw.

Orderly thinning the trees at certain periods is the next essential to pruning; and for this purpose observations have been made on the most orderly and thriving plantations; and the following simple rule is recommended: Keep the distance of the trees from each other equal to one-fifth of their height. In the application of this rule for thinning, it is evident that each individual tree can never be made to comply; for the original distance (even if planted in the most regular order) will allow only of certain modifications, by taking out every other tree, and so on; but even if the obtaining of such equal distance were practicable, experience would show that another way should be preferred, of which the eye must be the judge, by taking out such trees as are least thriving, stand nearest another good tree, &c. &c.; at the same time keeping in view the rule prescribed. By measuring a chain square, or any quantity of land, and counting the trees thereon; then trying the height of two or three trees in that quarter, and taking one-fifth of such distance, it would be readily seen how many trees should be contained in the piece measured: or the practice may more simply be regulated, by taking the distance of eight or ten trees added together, the average of which should be equal to a fifth of the height of the trees.

The Author has for years known the expense, and produce from trimming only, and finds that in Bedfordshire the produce doubly repays the expense; and though some experimentists may differ from him, or time may shew some reason for deviating from his rule, yet it is presumed that all will agree that some simple system is advisable, instead of having plantations and woods mismanaged, to the great loss of the community and the proprietors.

In the common course of gardening, it is understood that pruning invigorates the tree; that trimming off the side branches makes the upright ones shoot the stronger; and by cutting out the dead and decayed wood, the tree is kept alive. Some of this doctrine will certainly apply to the tribe of the firs; it will certainly substitute clean wood for knots, and of all this treatment, from their particular uses, they of all other trees stand most in need, and will be most improved by it. And should it be admitted that like treatment would on the fir, as well as other trees, produce the like effect, it would lead to a well-grounded expectation that, as well as producing clearness from knots, straightness and length, the same operation would advance the quality nearer to that of foreign fir: for it may be traced, that where trees are tall, and clear of boughs or knots, the whole substance of the wood is better and of finer grain. The reason may probably be inferred from the sap having farther to rise and descend, and having no boughs to divert or delay it, the circulation must be more fine and rapid, most increase be left in the neighbourhood of the boughs at the top of the tree, and least on the sides at the lower part; consequently adding to the length of the bead, and rendering more fine each annual increase to the body; thereby producing a close-grained, clean, long, and regular, easy-tapering piece of timber; instead of a coarse-grained, short, sudden-tapering trunk, with a quantity of boughs and knots.

The foregoing observations and rules are meant to apply to fir-timber only, but to a certain degree they may be applied to other timber; though by no means to the same extent or age. But if applied as far as the first fourteen years of their growth, and then the pruning altogether omitted, and the thinning out very much increased, any plantation would be rendered much more valuable than if left entirely to nature.

Machine for cutting Roots for Cattle, Articles for Dyers' Use, or for culinary Purposes.

In this machine there are five knives, which are let in an iron plate, and the latter is screwed to the working bar.

The knives are fastened by bolts passing through them, close under and above the iron plate.

The sliding plate is for the purpose of preventing the meat from being scattered; and to this plate are added scrapers, which are screwed underneath, for the purpose of clearing the knives at every stroke.

A spring raises the knives, and enables any person to chop at least twenty times as much meat in the same time as can be done by the common mode.

The length of the knives being equal to the breadth of the trough, no meat can possibly escape the knives, nor will the meat require so much turning as is usually wanted. When it does require turning, it is easily done by alternately pressing the knives at either end of the trough, sliding them towards the middle.

When the meat is sufficiently chopped, the bar to which the knives are fixed may be lifted entirely free from the sliding plate, by taking the pin out of the guide. Indeed the whole of the moving apparatus may be turned in any direction as occasion may require.

This machine is particularly well calculated for chopping sausage-meat; and though its value in this respect may appear inconsiderable, yet the great demand in most towns for that article, and the many hands it requires to make the meat fit for use, is not generally known. Many of the sausage-makers employ four or five men constantly in this business, and frequently three or four hundred-weight of meat is cut up by one house in a day.

The machine is also applicable for cutting fat, suet, &c. previous to rendering them into tallow; likewise to chopping madder and other roots for calico-printers, or as used in their recent state for dyers; and for dividing potatoes, carrots, and other esculent roots, for farmers in feeding cattle.

That this machine is simple, and that the expense of constructing it will be moderate, will be admitted on examining it as represented in plate XCV, fig. 1. The meat is put into a wooden trough AA, which is a segment of a circle; its form is more clearly shown detached at fig. 2. This trough is fixed upon a triangular frame, supported by four legs, about the height of a common work-bench.

A short axis, *a*, is fitted to the angle of the frame, and is the centre from which the circle of the trough is struck; it is made forked at the top, to form a joint for the end of the lever B, shown separately at fig. 3,) having the five knives, *b*, for chopping the meat, fixed to it.

At D are two pieces of wood, through one end of which the centre pin of the lever B passes, and thus connects them with the axis *a* at the other end; they carry a piece of iron plate F, which has five narrow openings made through it to receive the five knives fixed on the lever B. This iron plate always rests upon the edge of the trough A, and acts so as to scrape off the meat, &c. which would otherwise adhere to the knives.

The knives are prevented from rising, so as to be quite lifted out of the openings in the plate F, by the wire-pin C, put through the small pieces of wood fixed to the pieces of wood D.

A spring *l* is fixed to the axis *a*, and presses on the under side of the lever B, to raise it up, that the chopping may be performed the more speedily, as the hand has only to force down, the knives being raised by the spring. The knives are worked by the lever continually backwards and forwards, so that the article contained in the trough is in every part exposed to their action.

When the knives require grinding, any one may be taken out by removing two iron pins. Each knife has two tenons, as shown at X, fig. 4, passing through corresponding mortises made in a piece of wood fixed under the lever B. The two pins pass through those tenons, and thus hold the knives in their places. The bottom of the trough A is held in by screws, so that it can be taken out and planed flat when worn by the action of the knives.

The perforated plate F, is shown separately in figs. 5 and 6.

A Machine for Washing Potatoes, and other esculent Roots, for feeding Cattle.

This machine is shown in plate XCV, fig. 7. The potatoes are put into a cylinder or lantern AA, formed of two circular boards, and a number of staves connecting them. Six of these staves are connected at the ends of two pieces of wood, so that they can be opened as a door, to put in or take out the potatoes. The cylinder turns round in a trough BB, filled with water, and supported on four legs. On the end of the axis of the cylinder, two pulleys, one of which is shown separately at D, are loosely fitted; these are intended for the cylinder to move upon when full of potatoes; they run upon a swinging frame EE, which rests on centres at FF. When the long ends of the frame are pulled down, the other end is raised up; lifting the cylinder out of the trough BB; when the long end of the frame becomes the lowest, the cylinder rolls down on its wheels D, till it is over the hopper or wooden funnel G, under which is placed a wheelbarrow or basket to receive the clean potatoes. The door of the cylinder is now opened, and the contents turned out through the hopper into the vessel beneath it. When the frame is in this situation, the iron rods H, which are jointed to the short ends of the levers, form stops to the farther descent of the frame.

When fresh quantities of potatoes are to be washed, they are thrown in at the door of the cylinder, which is then shut up, and kept shut by two small bolts. The end of the frame E is then raised up, so as to make the short end the lowest, and the cylinder runs down on its wheels D over the trough B, till it is stopped by two iron prongs fixed on the end of the frame E; the cylinder is then suffered to fall down into the trough, and the potatoes, &c. are washed by turning it round by its handle K; *a* is a plug to let out the foul water.

Any person who has seen the laborious and imperfect mode of washing potatoes in a tub, as practised in London, will be convinced of the utility of this machine, not only for expedition, but for preserving the potatoes from being injured by bruises, and from being water-soaked and spoiled, by too long an immersion in water.

With one of these machines, a man, and a boy ten years old, will wash, with great facility, twenty bushels of potatoes in an hour, or a man alone will do half the quantity. If the soil should be particularly adhesive, the heads of a couple of old heath or birch brooms, put into the cylinder, will effectually disengage it from the eyes of the potatoes; and as the dirt separates, it falls to the bottom of the water in the vessel under the cylinder.

Method of preventing Doors from dragging on Carpets.

By means of this invention, the current of cold air which enters under doors that are not close to the carpets underneath them, may be effectually prevented, at the same time that the door, when opened, will pass over the carpet with ease; the necessity for screw-rising hinges is obviated, and less expense incurred than for other contrivances to effect the same purpose. A slip of well-seasoned beech-wood, equal in length to the width of the door, one inch and a quarter wide, and half an inch thick, is covered with green cloth on the inside, and hung to the bottom of the door with three small brass hinges; it is drawn up by a concealed spring as the door opens, and is forced down when the door shuts, by one end of it, which is semicircular, pressing upon a concave semicircular piece of hard beech-wood, fastened at the bottom of the door-case, and which holds it down close to the floor or carpet, so as to exclude the air from entering under it.

The door to which this invention is to be applied, must be cut away, so that it may be about an inch and a quarter above the floor; this allows sufficient room for the door to open over any carpet. *a b d e*, figs. 2 and 3, plate XCVII, exhibit a section of the slip of wood, by which the opening thus made under the door is to be closed.

Fig. 1, is a perspective view of the bottom of the door, with the invention annexed to it.

Fig. 2, is a section across the door when closed.

Fig. 3, is a view of the edge of the door when open.

Fig. 4, is a section supposed to be made by cutting the door in two parts, edgeways.

The hinges on which the slip turns are fixed to the edge. In figs. 2 and 3, from *a* to *b* is exactly one inch and a quarter, so that when the ruler is turned down upon the hinges, it reaches the floor AA, as in fig. 2; in the other direction, *a d*, it is much less, being only half an inch, so that when it is turned up under the door, as in fig. 3, it leaves three quarters of an inch clear of the floor.

It now remains to show how the ruler is turned up or down. It has always a tendency to rise up into the state of fig. 3, by the action of a steel wire-spring, shown in figs 2 and 4, which is concealed in a rebate cut in the bottom of the door. One end of the wire is screwed fast to the door at *f*, the other is inserted into an eye fastened into the slip at *g*, to throw it down into the position of figs. 2 and 4. The end *h*, fig. 4, of the slip farthest from the hinges of the door, is cut into a semicircle, as seen in fig. 3. When the door is just closed, this semicircle is received into a fixed concave semicircle *k*, fig. 3, cut in the end of a piece of wood *k l*, made fast to the door-case; the end *m l*, fig. 3, represents the plane of the door when shut, and *p p*, part of the door seen edgeways. As the door in shutting moves from *p* to *m*, the semicircular end of the slip *a b d e*, presses against the end of the piece *k l;* and as the door proceeds, it turns down as in fig. 2, so that by the time the door is shut, the slip is turned quite down. The edge *e b* of the slip is cut into a segment of a circle struck from the hinges on which it turns.

The perspective view in fig. 1, shows that this contrivance, applied to any door, will not offend the eye, as it can scarcely be distinguished from an ordinary door. In fig. 1, *k* shows the concave semicircle of the piece of wood fastened to the door-case, in which the semicircular end of the slip *a* is to be received.

An Instrument called a Trocar and Canula, for discharging the Air from the Stomachs of Cattle that have been overfed with moist Clover-grass.

When cattle have been overfed upon moist clover-grass, their stomachs become distended by the air extricated from the grass they have taken, and in this state they are said to be gorged or hoven; and where speedy relief is not administered, great numbers of them perish. The instrument for performing the operation by which this complaint may be removed, is an adaptation of the trocar or canula used by surgeons, and in every instance in which it has been tried, it has proved a safe, easy, and effectual remedy.

The method of using the trocar, is to penetrate with it, through the hide of the beast, to the paunch on the near side, about six inches from the backbone, at an equal distance from the last rib and from the hip bone: then to withdraw the trocar, and to leave the canula in the wound, until the air which the paunch contained has escaped. The canula may then be taken out, and the wound covered witn a plaster of common pitch, spread on brown paper, about the size of a crown piece. All the danger incidental to the common mode of stabbing with the knife is effectually prevented, by the canula being left in the incision when the trocar is withdrawn. A feeding ox will thrive as well after the operation as if it had never been affected by the disorder. Cows in calf are in no danger from its use; and it has been found particularly beneficial in preserving rearing calves, and young cattle, when afflicted with this disorder, which has heretofore been fatal to great numbers of them.

The small expense of the instrument, its portability, the ease with which it can be used by an individual, its safety and efficacy in use, will doubtless recommend it to general adoption. It is represented in plate XCVII. figs. 5 to 8.

Fig. 5 shows the instrument complete. The blade of the trocar, *a a*, fig. 8, is of steel, fixed in a wooden handle *b b*. The shape of the blade of the trocar is elliptical, as shown in the end view of the canula, fig. 7. The canula, or sheath *e e*, figs. 5 and 6, is an elliptical tube, which exactly fits the blade of the trocar; *f f* is a concave circular plate, fixed at the end of the canula, forming a hilt, to prevent the instrument from giving too deep a wound when used: the end *g* of the canula is formed with a sharp edge, that it may not obstruct the passage of the instrument. The figures are on a scale of one inch to two inches and a half; in figs. 5 and 6 the trocar and canula are shown edgeways, or in the shortest diameter of the ellipse; in fig. 8, the trocar is shown flat, or presents to the eye its longest transverse diameter.

A swivel-headed Churn-Staff, to facilitate the making of Butter.

The improved churn diminishes the labour of churning in a much greater degree than could be supposed, from a slight view of its simplicity and apparently inconsiderable deviation from the common churn-staff; but it passes with much more ease through the cream, and must be worked more slowly than the common churn-staff, or it will be found to churn the cream too fast.

Fisher's swivel-headed churn.

Fig. 11, plate XCVII, is a section of the churn in a position for working, and figs. 9 and 10 are enlarged views of the head of the churn-staff.

In fig. 11, FG is the lid of the churn, KL, the staff, and HI the wings or beaters. It is only the part HI which differs from the common churn; it consists of four wings or vanes, MNOP, fig. 9, firmly fixed together; and turning freely on a pin driven into the end of the churn-staff. The flat part of each vane is cut, so as to be inclined to the plane on which all four lie, in the same manner as the sails of a windmill, and which is fully shown by figs. 9 and 10. When the beater is moved up and down through the cream, its action upon the oblique vane causes it to turn round upon the pin above mentioned as a centre.

In fig. 11, *a* is a small bolt sliding in a groove made in the churn-staff KL; its end enters a hole *b*, fig. 9, made in one of the vanes; when this bolt is pushed down, it prevents the vanes from turning round, for the purpose of collecting the butter together at the top of the butter-milk, when the churning is finished.

The Inventor tried the effects of the beaters in a variety of forms: with six wings the labour was less relieved; and the same effect followed the giving of less bevel to the ends of the wings; with more bevel, the wings passed through the cream without producing the proper effect. Experience evinced that it is best to have four wings from six to seven inches in length from the centre, according to the size of the churn, from two and a half to three inches in breadth, made plane in the centre or middle, about the fourth part of their length, and then regularly bevelled off, so that the extreme point shall form an angle of about 45 degrees with the plane of the middle. The plane part acts with its usual force upon the middle of the body of the milk; and the points turning rapidly round, give a compound alternating motion to the whole, without in the least splashing or throwing over the cream as in the common mode.

The small bolt *a*, fig. 11, which is used to prevent the vanes from turning round, whilst the butter is collected from the milk, may be made of wood.

Method of preserving Fruit without Sugar.

The utility of preserving the fruit produced by our gardens and orchards, is well known and acknowledged; but the expense of sugar, purchased and used at the same time as the fruit, is so considerable as to prevent many families from availing themselves of this provision for the less bountiful season of the year, to the extent they could wish; and in plentiful years, much fruit is on this account almost thrown away. The following successful method of preserving fruit without sugar, and so as to preserve the natural flavours of the different kinds, will, it is therefore presumed, be extensively adopted in proportion as it becomes known.

PROCESS.

The bottles to be used for small fruit, such as gooseberries, currants, cherries, and raspberries, may be selected from the widest necked of those used for wine or porter, as bottles of this description may be procured at a much cheaper rate than what are generally called gooseberry bottles. Having in the first place had them properly cleaned, and the fruit, which should not be too ripe, being ready picked, fill with the fruit as many of them as are to be done at the same time, till they will hold no more, allowing for the depth to which the cork will reach; and in filling, the bottles should frequently be shaken, to make the fruit lie close. When filled, put a cork into each bottle, but only with a light pressure, and then proceed to scald the fruit. This operation may be performed over a slow fire, either in a copper, or large kettle, or saucepan, first putting a coarse cloth of any sort at the bottom of the vessel used, to prevent the heat of the fire from cracking the bottles. The copper must be filled with cold water to such a depth as will nearly cover the bottles, which must be put into the water rather in a slanting direction till they reach the bottom, in order to expel the air that might otherwise lodge in the cavity at the bottom of them.

The bottles should not touch the bottom or sides of the copper, as that circumstance might occasion their bursting. The heat of the fire should be such as gradually to raise the water in the copper to the temperature of 160 or 170 degrees by a brewing thermometer, in the course of about three quarters of an hour. For want of an instrument of this kind, the proper temperature may be determined by a finger, to which it will feel very hot, but will not scald. If the water in the copper should become too hot, a little cold water must be added to it; and when it has acquired the proper degree of heat, it must be kept at it as steadily as possible, for about an hour, but not longer, as a greater heat, or a longer time, is liable to crack the fruit.

As soon as the fruit is properly scalded, take the bottles, one at a time, out of the copper, and fill them up, to within an inch of the place to which the cork will reach, with boiling water, kept in readiness for the purpose, and which may be very conveniently poured into them from a tea-kettle. Cork them immediately, pressing the corks down gradually, but making them very tight. In driving the corks, the bottles must not be shaken, as that might cause the hot water to break them.

When the bottles are corked, lay them on their side, which will cause the corks to swell, and prevent the air from escaping. When cold, they may be removed to any convenient place, always observing to let them lie on their side, until required for use. During the first month or two, it is necessary to turn the bottles a little round once or twice a week, to prevent the fermentation that will arise in some fruits from forming into a crust; the turning of the bottles keeps the fruit moist with water, and no mould will ever take place. After the first two months, it will be quite sufficient to turn the bottles a little round once or twice a month.

In getting out the fruit, the inconvenience which is apt to attend the use of narrow-necked bottles may be obviated, by employing a bent wire, or small iron meat-skewer, the liquor being first poured out into a basin. As this liquor is strongly impregnated with the virtues of the fruit, it is very suitable for putting into pies, tarts, or puddings, instead of water, and when boiled up with a little sugar, it forms a very rich and agreeable syrup.

There is reason to believe, that fruit thus prepared might with great advantage be rendered an article of store for shipping and exportation; if this should be attempted, it would be easy to increase the facility of preparing large quantities, and probably the best method of heating great numbers of bottles at once, would be by means of steam

Machine for raising large Stones out of the Earth.

The clearing of land from large stones generally proves a very expensive undertaking, from the time required to remove the earth surrounding them, and the number of men who must be in readiness to raise them as soon as this is accomplished, unless blasting be resorted to, which requires fewer hands, but is not on the whole less expensive. By the machine described in this article, no digging away of the earth is required, no blasting is employed, and two men will take as many stones out of the ground in one day, as would require twelve men, in the ordinary modes of procedure; and when the stones are from two to four tons each in weight, two men will raise as many as twenty in the usual way. Stones of four tons weight or upwards may be raised out of the earth in the space of five or ten minutes, by two men, without any previous digging or removal of the soil.

The machine, in its general construction, resembles those used by masons, for raising the stones used in building, and the tackle is similar to theirs, for exerting the necessary power. But the means by which the tackle is fastened, is the simplest and most easily applied that can be imagined, consisting merely of a cylindrical iron plug, which is driven into a hole made in the stone to be raised.

In fig. 1, plate XCVIII, K shows the upper part of a stone nearly buried in the earth, having a hole made in it three inches and a half deep, and one inch in diameter, by means of a miner's jumper: the cylindrical tail of the plug *a*, (figs. 2, 3, and 4,) which is of the same size, is driven fast into it, by means of a hammer applied upon the head of the plug at G. This plug, in its whole length, is nine inches, and has a hole made in its broad part H, through which the oval iron ring B passes easily, and on which the plug can move backwards and forwards, when the ring is hung upon the hook of the lower pulley of the lifting tackle.

CCCC, represents the four legs or framework of the quadrangle; D, a five-fold tackle, with blocks ten inches in diameter; E, a roller seven inches in diameter, turned by two long iron levers *b b*.

The handle I is used as a safeguard, and to assist in regulating the power of the levers.

In fig. 1, the plug A is shown fixed in a stone K, ready to draw it out of the ground, by means of the lifting tackle.

The hinder legs of the quadrangle are made to close in between the fore-legs, for the convenience of carriage.

J. C. Curwen, M. P. bears ample testimony to the ease with which the largest stones are lifted up by this machine, with which he had seen four men lift a stone of five tons. There is no difficulty in cutting the stone to receive the plug; the only care is not to make the hole too large. It is not easy to explain the theory of the action of the plug; the least stroke laterally disengages the stone. In many situations the machine is likely to be of great use, not only in drawing stones out of the ground, but in making weirs and embankments, where the stones are only to be lifted a moderate height. He exhibited it to numbers of persons, who could not believe its power till they saw it tried. One of his farmers in Westmoreland had made great use of one, and spoke of it in high terms. He is convinced of its power to raise any stone not exceeding five tons in weight, and it is generally of importance to preserve large stones entire. Adding wheels to the machine, or having it upon a sledge, would materially save time and trouble in removing it. He purposed the following summer to employ it in lifting the large stones for making an embankment against the sea. He does not consider it advisable to employ the plug of this machine for soft stones, nor to raise the stones employed in buildings, because of its being so easily disengaged by any lateral blow.

Robert Wright, of Rose Gill Hall, near Shap, Westmoreland, having been requested to give his opinion of the utility of the plan of raising stones by this machine, stated, that the plug he used was about six inches long, and one inch and a quarter in diameter; it required a hole of its own size, only two inches deep. The plug is to be driven in a little short of the bottom, and will raise a stone of six or eight tons, with the assistance, of three men, in the course of ten minutes after the hole is prepared. He believed that three men, with this machine, would clear the ground of large stones in less time, and more effectually, then twelve men by any other method within his knowledge. The plug should be made of good beaten iron. The simplicity and cheapness of the whole apparatus was a great object, as a good plug of the size used by him, will only cost two shillings and sixpence.

The possessor of a machine, of the above description, may occasionally wish to extend its use to the raising of stones considerably above the level of the ground, without incurring the risk of accidents which might dislodge the stones from the simple plug: he may also wish to raise large stones of a soft texture, such as most descriptions of sandstone, in which the simple plug could not be wedged sufficiently tight. In these cases, the compound plug, fig. 5, may be employed, and will be found effectually to answer the purpose intended. It consists of three bars of iron, *a b c*, joined together by a bolt *d*, passing through them. The stone to be raised must have a hole made in it, nearly of a dove-tail shape, and correspondent to that of the lower part of the three bars when united. To get these bars into the situation cut for them in the stone, they must be separated by unscrewing the nut *e*, and taking out the bolt *d*, the two outside bars *a b* must then be put into the hole, after which the middle one, *c*, may be thrust down between them; the bolt *d* being put through them, and the nut *e* screwed on, they have all the effect of one bar, dovetailed into the stone, the lifting of which is thus rendered perfectly certain and secure. In ordinary cases it is not requisite to use the nut on the end of the bolt, which, when in its place and in use, is not liable to be disengaged.

Improved Tram-plates, for Carriages on Rail Roads.

The method of laying rails or tram-plates, described in this essay, has received the entire approbation of professional men, experienced in the practice it is designed to improve. Rail-roads are daily increasing, from the great advantage they afford to those manufactories connected with mines and minerals, particularly to collieries. They also promote agriculture, by occasioning lime to be brought from places almost inaccessible by any other means, or from whence it could not be otherwise brought on moderate terms. If ever any one mode of conveyance supersede all others, it seems most likely to be effected by the perfection of the rail-road system, a system which is already so valuable, that every invention directly tending to advance it is of national importance.

The new tram-plates, represented by figs. 6 and 7, plate XCVII, are fastened by means of a tenon and mortise AB, each having a correspondent bevel, just sufficient to keep the end from rising up, so that the head of one plate confines the end of the other; by this means, the workmen are obliged to form their road in right lines, and maintain perfect levels, as the mortise and tenon confines them to the exactness required for a perfect road. Curves, or any given segment, may be formed with the same nicety, by having two bevel rails or plates made for such purposes.

Fig. 7. a side view or longitudinal section of the two plates placed on their stone blocks or sleepers EFG, showing three plugs in dotted lines, two bevelled, the other perpendicular, cast in the stop rail or plate, which is so called as it prevents the other from moving, and when taken up releases all those between the stop plates: twenty-five yards of rail-road, made with these plates, may be taken up and replaced within ten minutes. The plugs in dotted lines are shown in their proper positions within the sleepers EFG.

The usual length of a tram-plate is three feet; the flanch or outside edge H, about one inch and a half high; the sole or bed I, from three inches and a half to four inches broad, and three-fourths of an inch thick; but these dimensions may be varied according to circumstances. The most approved weight has been 14 pounds to the foot, or 42 pounds to the plate. The ends from which the plugs project, and to which the tenons and mortises fasten, should be one-fourth of an inch thicker than the other part of the plate.

Fig. 8, AB show the under part of the tenon and mortise, and the form of one of the sloping or bevel plugs.

The diameter of the plug near the shoulder is one inch and three quarters, reducing to one inch; its length two inches and a half, forming an angle of eight degrees; the plate from which it projects is countersunk, so that the shoulder of the plug may not receive any sharp pressure, or prevent the plate from having a perfect bearing. There is a small groove in the whole length of the exterior of each plug, to admit a wire to pass to its extremity, to draw the plug out, if broken by any accident; also to admit the expansion of water, in case of severe frost.

The blocks or sleepers EFG, on which the tram-plates are placed, should by no means be less than 120 pounds each in weight, but should be heavier on some kinds of ground: the depth of the hole for the plug should be three inches, and worked according to the inclination of the plug, for which purpose the stone-mason should have a standard cast-iron gauge; there should be projections, K, cast with the flanch or outside edge of the tram-plate, as shown at fig. 6, to make the plates lie firmly on their sleepers.

Fig. 9, is the section of one of the ends of a tram-plate, in which H shows the flanch or upright edge; I the flat part or sole on which the wheels of the waggons run; D one of the plugs; K the projection behind the flanch to make the plate lie firmly on the blocks.

The advantage of laying plates on the above principle is obvious: the blocks, once put in their places, never sink below their intended level, the act of driving either nail or plug (which requires a considerable degree of force, and frequently destroys the level of the road) being here unnecessary. In the common mode of making rail-roads, from the irregularity of nails, particularly in forming their heads, few can be driven exactly even with the plate; and if this be not done, they are perpetually obstructing the passage of the waggon; the workmen frequently not proportioning their holes and plugs to the hole in the block, also occasions considerable breakage; the exertion necessary to fix a rail or plate completely, is great, and numbers of plates, particularly when the iron is short or brittle, are broken near the mortises by missing the stroke of the hammer.

ADVANTAGE GAINED IN LAYING THE NEW TRAM-PLATES, IN COMPARISON WITH OTHER MODES.

	£.	s.	d.
Nails used in a mile, 3520 of 3 in the pound, at 4d. per lb.	19	11	0
Nails lost or defective, computed at per mile....	1	0	0
Plugs with their loss..........................	6	5	0
Breakage of rails, average from experience....	7	10	0
Lessened labour of block-laying, calculated at only 2d. per yard	14	13	4
Breakage of blocks..........................	1	0	0
Saving in the first cost per mile..	£49	19	4

This calculation does not take in the annual loss of nails, by theft or otherwise, and breaking of blocks, or the saving of the new plan would appear still more considerable.

In laying down a rail-road, a stop rail, having a perpendicular plug, as H, fig. 9, should be placed at every thirty yards, in which distance repairs may be made in ten minutes, that in the common way frequently require twice that time, exclusive of disturbing in some measure the line of road. All the new tram-plates have a certain degree of play, which is absolutely necessary, to obviate the breakage that occurs when they are fixed with nails and plugs.

It may be proper to remark, that the improved tram-plates are cast with as much facility as any other which have hitherto been used.

The Mole-plough for the temporary Draining of Land.

It frequently happens that lands are too wet except at particular times of the year, or when to be applied for particular purposes, or in seasons unusually rainy. Such lands are almost of equal value with those most favourably situated, if when found too wet, they are drained expeditiously, cheaply, and without materially breaking the surface; and this may be done very effectually by means of the plough described in this article.

This machine receives the name of mole-plough, because it hollows the earth, with scarcely any perceptible trace upon the surface.

A, plate XCVIII, fig. 10, the handle, for only one is used, mortised into the beam at *b*.

CC, the beam.

D, the coulter, held fast, in the usual manner, by wedges.

E, the cone or mole, of cast iron, having an upright piece of bar iron fastened to it, which passing through the beam at *f*, is tightened by wedges; and the pin *g* being put through one of the holes in the upright bar, serves to regulate the depth of the cavity below the surface of the land.

H, the copse, by which the cattle draw.

Previous to this plough being shown to the Society of Arts, &c. it had been used for three years in Sutton Park, for John Webbe Weston, esq. and had been found to answer every purpose of underground draining, without breaking the surface any further than by drawing along a thin coulter, the mark of which disappears in a few days. A man and a boy, with four horses, may drain thirty acres in a day, provided there is an open grip or ditch cut at the lower side of the ground to be thus drained, in order to receive the water from those small cavities which the plough forms in the ground, at the depth of twelve inches or more. The method of using it is, to go down and up, at the distance of fifteen, twenty, or thirty feet, as the land may require. This applies equally to grass land, to turnip ground where it is too wet for the sheep to be fed off, and to land that is too wet to sow; it remedies the evil in a very short time, provided there is some declivity in the ground. The best time for the operation, in grass land, is in October or November, when the land has received moisture enough for the plough to work, and not so much as to injure the land, or render it soft.

J. W. Weston, of Sutton Place, in a letter to the Society of Arts, &c. observes, that too much cannot be said in commendation of the mole-plough, for the purpose of temporary draining, where that operation is useful, as is the case with great part of his grass land, which is on a declivity, and is too wet only in the autumn and winter, after great falls of rain and snow. Being free from land springs, he conceived it improper to be underdrained in the usual way, as thereby the moisture necessary for its producing a crop of grass would be carried off equally at all seasons. The soil is very light, but not sandy, to the depth of from nine to eighteen inches, or more; and underneath is a strong clay, which renders the ground absolutely poachy in winter: but, from the use of this instrument, the ground on which a man could not walk, will, in the course of forty-eight hours, be enabled to carry any cattle. From ten to twenty acres may easily be drained in one day, by a single team, which makes the expense trifling, though it should be required every year. The drains made by the plough should be in direct lines, at from ten to twenty feet apart, and all vent themselves into an open furrow or grip, at the bottom. The price of the plough, complete, is about two guineas.

Edmund Boehm, of Burwood Park, remarks, that the mole-plough is so contrived, that it makes the drains at the depth of one foot to eighteen inches; the bore, two inches and a half in diameter. Upon a stiff clay soil, he used six horses, but thought, from the ease with which they worked it, that four would be fully sufficient. He afterwards found, that on light land, and the drain fourteen inches deep, he had no difficulty in working the plough with two oxen and three horses; but on strong clays, he found the work sufficient for four horses and two oxen, although the depth was reduced two inches. The drains he had drawn on low wet lands and clay, ran instantly after the plough; on these lands he generally made the drains about twenty feet asunder, which he found to produce great firmness and dryness.

Except in very heavy land, four oxen would be sufficient, and fully equal to two oxen and three horses, as oxen stop, and draw much better by themselves.

Machine to secure Persons attempting Depredations, without affecting their Limbs; with an Earth Screw, for fastening it to the Ground, for supporting a Surveying Staff, &c.

To those who live in the country, it is needless to explain the frequency of petty depredations committed on gardens, orchards, &c. and which are sometimes very vexatious. Few persons would like to endanger the life or limb of the depredator by setting the common steel man-trap, yet it is presumed that there are but very few who would not wish to detect the offender. The instrument described in this paper is for the purpose of catching and holding the person without injury.* At the Agricultural Meeting at Woburn, in the summer of the year 1808, an ingenious invention for a similar purpose was produced by Sir Theophilus Biddulph; it consisted of a wooden box, containing two springs in iron barrels, and two chains passing over and round them; when this was set, the chains were withdrawn from round the barrels, and extended to a certain distance. A trigger kept the trap from closing; the whole was covered over with thin iron plates, and if a person set his foot on those plates, his leg dropped into the box, and the chains closed round it, and held his leg; but as the box was about three feet square and a foot deep, it was requisite that it should, at setting, be let into the ground, which would be a work of considerable labour, and when done, it would be difficult to dispose of the stuff from the hole, or to conceal the trap; and as the whole

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* An instrument of this nature is entitled to particular attention, as some recent decisions of courts of justice, together with the opinion of eminent counsel, tend to establish the opinion, that it is unlawful for a person to set, even on his own ground, any instrument or machine which may endanger the life or limb of another. For an injury sustained by a boy, from the discharge of a spring gun, £120 damages were awarded by the jury at the Warwick Assizes, under the direction of the presiding judge.

apparatus was cumbersome and expensive, it was more useful in design than applicable to practice. It is mentioned here, as having suggested the idea of attaining the same object by simpler means, and to show the difference between it and the invention described below.

To set the man-trap, represented in plate XCIX, it is only necessary that the two keys be withdrawn, and that it be covered with a few leaves or mould. A piece of a chain, and a screw to be screwed into the ground, are attached to the trap, to prevent its being carried away; but against any person who may be caught, such a precaution is scarcely necessary, as the jaws of the trap close so fast on the leg, that no person who may be caught can drag the trap far without great pain, and will consequently be glad to stand still and call out for relief.

In plate XCIX, fig. 1, is a perspective view of the machine. ABC is a frame of wrought iron, about 18 inches square; it has an eye projecting from it to receive a short chain, the other end of which is fastened to an iron screw, shown separately at D, screwed into the earth by the key or handle E; this screw is about fourteen inches long, and when screwed into hard ground, will hold so firmly, that there is no danger of its being drawn out, even by two or three men, and having a small square end, it cannot be turned without the key or handle E, so that an offender would find it extremely difficult to remove the trap.

e e f g, Are two iron frames moving on centres in the frame ABC; these frames have a constant tendency to close together, by means of two springs *p p*, fixed in the frame AB, and acting against pins projecting from the upright sides of the moveable frame *e e*.

k k, Are two small iron rods jointed to the upper rod of the moveable frame *g*, and passing through small locks *l l*, fixed to the other frame *f*. These locks contain clicks, which are pressed by springs into the teeth upon the rods *k k*, so as to prevent the two bars of *g* from being drawn asunder when they have been closed by means of the springs *p p*. The internal mechanism of the locks is shown on a larger scale at LM, figures 2, 3; one side of the lock is supposed to be removed, to exhibit its interior parts; *k* represents the rack, or that part of the rod which is cut into teeth; *r* is the click, which engages the teeth of the rack, and prevents its being drawn through the lock. The click is pressed against the teeth of the rack by a spring, which is plainly seen in fig. 2. The locks are attached to the ends of the bar *f*, of the moveable frame, by the bar passing through the locks, and when the lids are riveted placed in the brackets beneath, and which also serve to strengthen the arms at their junction with the post.

Hand-posts of this description would not be expensive, if an iron-founder were to establish a manufactory of them; for then the patterns to cast them from might easily be made up from loose letters, and fixed in a frame of suitable dimensions Two or three alphabets would be sufficient for forming hand posts for any place which could be required. A single alpha bet would be to cut out, in wood, in the first instance; but as wood would be liable to warp, or be broken by accident in the course of frequent use, a sufficient number of iron alphabets would be immediately cast from it, and these, when nicely dressed, would be reserved to form the future patterns. Where it was supposed the hand-post might be liable to be injured by mischievous persons, strength might be gained, not by rendering the letters clumsy or unshapely in front, but by making them deep.

The durability of the hand-posts thus constructed, independent of any of their other advantage, should forcibly recommended them to the trustees of turnpike roads. They have already been adopted in several parts of the west of England. The expense of them has been found to be only about a shilling per letter: a sum altogether insignificant, in comparison with their utility to the public.

On the Extraction of Potash from Potato-Tops.

One of the most important discoveries of the present day is that of a druggist of Amiens, which promises to free Europe from the heavy tribute she pays to América for the article of potash. The author of the discovery has in a truly patriotic manner made it known, after ascertaining by a series of experiments the truth of his conclusions. The French Society of Agriculture, and the Society in that country for the Encouragement of National Industry, have both named Commissioners to frame official reports; in the mean time we give an account of the process, in the hope that, even in the present season, it may be turned to account—as it interests landlords, tenants, merchants, and manufacturers.

It is necessary to cut off the potàto-tops the moment that the flowers begin to fall, as that is the period of their greatest vigour; they must be cut off at four or five inches from the ground, with a very sharp knife. Fresh sprouts spring, which not only answer all the purposes of conducting the roots to maturity, but tend to the increase of their volume, as the sprouts demand less nourishment than the old tops. The tops may be suffered to remain on the ground where cut; in eight or ten days they are sufficiently dry without turning, and may either be carted home or to a corner of the field, where a hole is to be dug in the earth, about five feet square and two feet deep: the combustion would be too rapid, and the ashes cool too quickly, and thereby diminish the quantity of alkali, were they burnt in the open air. The ashes must be kept red hot as long as possible; when the fire is strong, tops that are only imperfectly dried may be thrown in, and even green ones will then burn well enough.

The ashes taken out of the hole must be put in a vessel, and boiling water be poured upon them, and then the water must be evaporated; for these two operations, potato-tops are to be used as the only fuel of the furnace, and the ashes thus produced must in their turn be lixiviated like the rest. There remains after the evaporation, a dry saline reddish substance, known in commerce under the name of *salin;* the more the ashes are boiled, the greyer and the more valuable the *salin* becomes.

The *salin* must be calcined in a very hot oven, until the whole mass presents a uniform reddish brown. In cooling it remains dry, and in fragments bluish within, and white on the surface; in which state it takes the name of potash.

The ashes exhausted of their alkaline principle, afford excellent manure for land intended to be planted with potatoes.

The following is a table of the results obtained in France

The number of potato plants on an acre is..	40,000
Each of these 40,000 plants yield, on an average, 3lb. of green tops	120,000 lb.
By drying, the weight of these tops is reduced to	40,000 lb.
This quantity produces of ashes	7,500 lb.
The evaporation gives of ashes, exhausted of alkali	5,000 lb.
Salin	2,500 lb.
The salin loses 10 to 15 per cent in calcination, which gives of potash..........	2,200 lb

By these estimates it appears that upwards of 2000 lb. of potash may be obtained, in addition to an increased crop, from every acre of potatoes, or a value far exceeding that of the crop itself. The expense of preparing the potash, as above described, is about six guineas per acre.

In Ireland 350,000 acres are annually employed in the cultivation of potatoes, and although the tops, converted into potash, might fall much below the result above stated to have been obtained in France, yet as the consumption of the United Kingdom amounts only to eight or ten thousand tons, the supply from that part of the Empire alone, could scarcely fail to be such as to leave an important surplus for exportation.

Instruments for the use of Persons who have lost their Hands.

The Inventor of the implements described in this article, had the misfortune to lose both his hands, and was from necessity induced to contrive such instruments as might supply the deficiency as far as possible. He has been very successful in his undertaking, being now able to perform a great variety of the most useful operations of hands, without difficulty to himself, or requiring assistance from others. It will perhaps appear surprising that a person thus situated should be able to write with great facility, in a hand not larger than is often used for the common occurrences of business, and in a style exhibiting a great degree of freedom. The Inventor has also made, by means of the use of his instruments, several neat drawings, (now in the possession of the Society for the Encouragement of Arts, &c.) to explain the construction of a great variety of instruments which he has made at various times, and from among which those now to be referred to, were selected, as being some of the most ingenious and useful in their application.

AA, fig. 1, plate C, is a tube or socket, formed of a strong leather, to receive the stump of the arm; it is open at one side next the open end, and has several holes to lace it on tight; but to prevent any danger of its coming off, it is connected with a band B, encompassing the arm above the elbow by two rings, one of which is marked *a;* the band is fastened by two double straps with a clasp. At the other end of the tube A, a piece of wood is fitted in, and faced with a circular iron plate; in the centre of this is a socket to receive various implements, one of which, DD, is represented as affixed to the tube; it terminates in an iron-hook D, useful for lifting any article, as a chair, &c. or drawing on boots. The other part of the instrument is made hollow, to receive a button-hook E, and pen, or pencil holder F, either of which can be turned out for use, and are retained in the positions of either shut or open, by springs similar to that of a knife; behind these, a knife G is placed, and can be opened out in a line with the instrument for use, or shut up within the instrument; *b* is a hook to open the knife by. The dotted lines H, show the manner in which a pen, or any similar instrument, can be held, the springs of the button-hook and pen-holder being sufficiently strong to hold such articles.

The instrument fig. 1, is adapted to the right arm; the left is provided with a similar leather socket, into which the instrument fig. 2, is fitted; it contains the button-hook I, and the fork K, either of which can be opened out for use; *e* is the spring by which they are held; L is a pair of spring tongs, which slide through a socket *i*, and are by that closed up; they have two pair of jaws, one at the end *f*, the other by the side at *g*; *k* is a small hook, by which the tongs can be opened by the button-hook of the other hand. The whole of the instrument, fig, 2, bends at a joint M, just where it joins the stump, and the end of the spring *e* catches in notches in the joint to hold it sufficiently firm at any particular point where it is set, by pressing the instrument on the knee, a table, or other fixture.

N is the pin which enters the stump; it has a notch all round it at the end, into which a wedge in the stump is received to hold it in; this wedge comes to the outside of the leather at *x*, fig 1, and has a hook by which it can be pulled by the button-hook of the other hand, so as to release the instrument. This wedge does not, however, prevent the whole instrument from turning round in the stump; but by means of holes in the circular plate *n*, and a spring-catch at *m*, fig. 1, which enters any of them, the instrument can be fixed in any position; the catch *m* is relieved by pressing it upon the table, &c. the instrument can then be turned round, but becomes fixed when the catch is at liberty.

Besides the socket in the centre of the stump, a smaller one is situated in the end thereof, provided with its catch; it is used to hold several small instruments, some of which are represented. Fig. 3, is a hook to take up a glass, or for hooking up light articles. Fig. 4, is a pair of tongs, which are opened and shut by a double-inclined plane A, which moves on a centre by means of the button-hook introduced through the ring *a;* when this is moved, it opens or shuts the tails *b* of the tongs, and produces a corresponding motion of the jaws *c*, to grasp any small articles ; these are very convenient, for by pressing the lower part *d*, of the inclined plane, on the table, the tongs are closed without the assistance of the other hand, and by striking the ring *a* under the table, they are opened again.

Fig. 4, is a small vice, its spring A acting to close it; it is opened by the hook *a*, and any article being put between the teeth, is held lightly by the spring, then by turning the screw *d* by its handle, the work is pinched fast: to turn this handle, the hook, fig. 6, is put into the socket of the opposite stump, and the pin *e* of the vice being entered into the hole *f*, a rotatory motion can be given to the screw; the hook *l*, is used to open the vice, and to move the work which is to be held therein. In this vice, may be held a file, or other tool, to operate upon any piece of work secured in the bench-vice, the handle of which may be moved by the knee. The Inventor also uses a socket, in which he can place a hammer or any other tool; this socket is inserted into the small socket of the stump.

Fig. 7, is a fork, which is preferable to that in the instrument, fig. 2, in its appearance, as it can be fitted into the small socket of the stump at the same time that an artificial hand is fixed in the centre socket, the fork having a joint *a*, with a spring *b* to hold it; it can be bent as necessary, and the fingers of the artificial hand being brought to touch the shank of the fork, will have a natural appearance. One of the artificial hands is provided with a money-box in the wrist, with a sliding cover.

Fig. 8, is a pen-holder fixed to a clasp A, which embraces the arm above the elbow, and is held on by a strap and hook-clasp *a;* to this a tape *b* is sewed, to take hold with the button-hook and clasp it; by this means the Inventor can fasten this apparatus (as also fig. 1,) upon his arm without assistance; he prefers this pen-holder to that in fig. 1, and uses it in all cases, except for signatures, &c. which would not be worth the trouble of fitting on the instrument fig. 8. The pen in fig. 4, comes directly before the person using it, and is turned round when necessary in its holder B by the teeth, the sliding-ring C being drawn up tight to fasten it by the hook of the other hand. The manipulation of putting on this pen-holder is not easily described ; the stem of B is held between the knees, whilst the clasp A is hooked as above-mentioned, by drawing the tape *b* tight over the arm; the ring C being slidden back, the pen is held in the mouth to place it in the holder B, where it is fixed by the other hand, the inventor uses a high table to write at, and the left hand is employed to hold the paper.

To pick up a pin or other small article, the tongs of fig. 2, are used; if it is lying upon a table, the jaws *f*, of these tongs, are placed on each side of the pin; and by pressing on the stump, the socket *i* slides towards them, and closes the tongs around the pin. In some cases, the side jaws, *g*, are more convenient; the tongs must then be moved by applying the button-hook of the other hand to the hook *k*.

A Committee of the Society for the Encouragement of Arts, &c. was appointed to consider the above, and other implements accompanying them. The Inventor personally attended this Committee: he had lost both his hands, and the lower parts of both arms, a little below the elbow, while loading a great gun, to fire a salute on the King's birth-day, in the Cove of Cork.

He produced to the Committee drawings of a great variety of instruments of his invention; and stated, that these drawings, with the written explanations which accompanied them, were wholly executed by himself.

He explained to the Committee the nature and uses of the several instruments which he brought with him; he unbuttoned and took off his coat and waistcoat in the presence of the Committee, and put them on again, and buttoned them without any assistance, and said he could entirely dress and undress himself, except the tying on of his neckcloth.

He showed one method of writing by his fixing a pen below his elbow, and a superior method by writing with a pen which he placed above his elbow; in both cases the writing was very fair and clear, and executed with considerable facility.

He took up a glass and drank out of it, and used a knife and fork for carving and eating without any person assisting him.

He showed his method of receiving or paying money, as occasion might require, and how to put the money into or take it out of a purse he had contrived for the purpose; and how to take up a small piece of money from the floor.

He can mend a pen by means of the instruments he has contrived, and can wash his face with a sponge placed and managed by himself.

He can use a punch and hammer for making holes in metal, and can work with a file.

He opened and shut the door of the Committee-room of the Society of Arts, &c. and introduced to the Committee a person named Charles Tool, who had lost both his hands, and one arm above the elbow joint; this man bore testimony to the comforts and advantages which he had derived from the Instruments, and which answered better than those for which he had paid other persons double and treble the price.

The Inventor stated that a good set of his instruments would cost 10*l.*; and that he manufactured them for sale.

Description of a Machine for clearing Roads from Mud.

The principal parts of this machine are, the frame, the scraper, the chain, the sledge, and the pole.

The *frame*, fig. 1, plate CI, consists of two pieces of timber, AA, which at one extremity are formed into a pair of shafts BB, and are strongly united by three transverse pieces CDE.

The *scraper*, F, is placed under this frame-work, in an oblique direction, at an angle of 30 degrees, between two of the transverse pieces, CD, and consequently forms an angle of 150 degrees with the line of draught. By this position of the scraper, the machine, when used, actually clears itself from the mud as fast as it is collected, and removes it into a heap on one side, after the manner of the plough

The *chain*, G, is connected with a piece of iron-work, H, which projects from the lower end of the scraper; for here additional power is required, as the whole body of mud, which has been collected, must pass off by this extremity. Some advantage is also gained by making this end of the scraper shorter than the other.

The *sledge*, II, is constructed upon the upper part of the frame, that by inverting the machine it can be transported without injury to the scraper, over the most rough and stony roads, or pavements, to those places where its use is particularly required.

The *pole*, K, which is moveable, serves the purpose of a rudder, that when the machine happens to be forced by any great weight of mud, or solid body of earth, &c. from its proper direction, it can be easily restored to its former position: and it may also be observed, that the moderate pressure of the hand upon the pole tends to make the machine steady, and therefore causes it to work to more advantage. The plates in front of the scraper, and upon the sledge, are made of cast-iron.

For the operation of the machine, two men and four horses are required; one man to drive the horses, and another to take the management of the pole and the direction of the labour to be performed. The horses are to be worked double, as commonly practised, two being employed to draw by the shafts, and two by the chain above described. But the manner of using the machine will be best understood by the following sketch.

Fig. 3. The first progress of the machine, marked No. 1. commencing from the arrow-mark, will remove the mud in a line to the right; the first return, No. 2, will remove another part of it to the left. The second progress, No. 3, will take up what was left by No. 1, besides the quantity which is upon the space now to be passed over, and will remove it all to the right. The second return, No. 4, will operate in a similar manner with regard to No. 2, and remove that to the left. Thus, by four lengths, more than twenty feet wide of a road can be cleared; and this has been frequently performed in the presence of several persons. The number of lengths may be increased at pleasure, according to the width of the road.

In the neighbourhood of London, where there is incessant travelling, it would be advisable to use two machines at the same time, one immediately following the other, as No. 1 and 3, which will leave a space sufficiently wide for the largest carriage to pass, without disturbing the mud already scraped up.

There is one advantage in the operation of this machine worthy of being noticed, which is, that by the use of it the road is made more even and smooth, the small holes being filled up by the more solid parts of the mud, whereas, when roads are scraped in the usual way, by hand, all the irregularities are increased, and become the future deposits of water; and it is universally known that these puddles, as they are called, are the chief cause of the destruction of roads.

It has been observed, that stones are sometimes forced up by the machine; but it appears to be those only which project in such a degree as to be dangerous to the traveller, and which require to be broken for the more effectual mending of the road.

If it should be objected, that the machine is too large, and that a smaller one, which might pass over half the space of ground that this does, and might be worked by two horses, would be better; it may be remarked, that there would in this change be a probability of devoting much labour to little purpose; because this machine, which passes over a space of about six feet and a half, will not in some places, when the roads are very wet and very deep, leave more than three feet clear, the mud on each side falling in and filling up, to a considerable extent, the space already passed over: it must therefore be obvious, that, under similar circumstances, the track of a smaller one would almost instantly be obliterated.

Some estimates may be required of the probable saving to be expected from the use of this machine. In the early trials made with it, no measured extent of ground was gone over; but the general effects were such, that several persons of great experience in the management of roads, rated the daily work of one machine only as equal to the labour of fifty to seventy men; fifty being the lowest estimate ever named. Afterwards, when some work had been done by measure, it was found, that one machine would clear three miles in a day, twenty feet wide, (consisting of four lengths, and making the day's work twelve miles,) which is considerably more than 120 men can do in a day.

120 men, at 2*s*. per day..............	£12	0	0
4 horses and two men, to work the machine, per day..............	1	5	0
Difference, a saving per day by using the machine	£10	15	0

In those parts, where carriages run principally in the centre of the road, the chief business in the management of it consists in keeping the sides clear and open. One machine may therefore be occasionally employed in the outside work only; that is, may go six miles and return, (making twelve miles, as just mentioned) with the saving already given.

In another trial, in the presence of four trustees of the road and others, two miles by measure on the road to Reading, were cleared from mud, to the extent of eighteen or twenty feet wide, by two machines, in the space of two hours and a half; and the work was judged to be equal to the labour of more than eighty men in a day. The success of this experiment was so satisfactory, that the trustees directed seven miles more of the same road to be cleared, the whole of which was done, by two machines, in one day. In the opinion of an experienced surveyor, this day's labour could not have been performed in one day by 400 men.

Those who are inclined to make trial of a machine of this sort, should be careful whom they employ in the construction of it. It is not sufficient merely to attend to the form represented in the plate; it is absolutely necessary that the different parts, and especially the two braces behind, should be firmly put together, otherwise it will be impossible for it to withstand the force that must sometimes be exerted upon it by four, or perhaps by six horses. The scraper may be made of beech or elm, &c. but the other parts ought to be made of ash, and the whole of the wood should be well seasoned.

The following summary of the description will probably be acceptable:

Fig. 1. AA, two pieces of ash timber, forming at one extremity a pair of shafts, BB.

CDE, three transverse braces, to secure firmly the timbers AA.

F, the iron plate, or front of the scraper, fixed within the braces CD, at an angle of 30 degrees, extending on the further side two feet, and on the nearer side one foot and a half beyond the timbers.

G, an iron chain, one end of which is fastened to the outside of the timber A: the other end of the chain may be moved nearer to, or further from that end of the scraper which deposits the mud, by means of notches in the iron muzzle H, fixed to the scraper, and which regulates the draught of the horses attached to the ring at G.

K, the pole or handle, to be made fifteen feet long, which passes through strong holdfasts in the braces CD. This pole acts as a lever, as the scraper may be raised or sunk by it at pleasure. The person who holds it, may direct the scraper in its proper line, and assist it in overcoming any obstacles it may meet with in its way, or in giving it additional pressure when requisite.

II shew the two parts of the machine which form the feet or sledge on which it slides when reversed, and which facilitate its removal from place to place, when the scraper is not in use. These feet are strongly fixed to the timbers AA, and strengthened by a transverse brace between them.

L is the iron chain or back-band, which lies upon the cart-saddle of the horse in the shafts, and which supports the shafts.

Fig. 2, shews on an enlarged scale, the iron-work fixed on the outside of the shafts, to which the chain and horse are attached.

Fig. 3, shews, in a small extent, the track usually made by the scraper in four rows, commencing at the arrow-mark in the track No. 1, as already described.

A New Packing Press.

This press is an improvement on Bramah's water-press; it produces a uniform action by means of a body of air, which is always above the water in the cylinder A, and which cannot escape, as the water occupies the lower part, next the leather collar. This compound action of air and water gives the press a considerable degree of elasticity, and causes the moveable part to descend uniformly, instead of descending by jerks, as when impelled by water only. This elasticity causes the press to exert an active pressure for a considerable time after the working of the pumps has been discontinued, and the degree of pressure is not materially affected by a small escape of water, an accident which occasionally occurs, and which is always fatal to the press when worked by water alone.

In the form given to this press, convenience has been particularly studied, and as the moving part of the press descends, the goods to be pressed are, as in the common screw press, nearly on the level with the floor, an arrangement which facilitates their being taken out to be made into bales.

This press is represented in plate CI, fig. 4.

A is a cylinder which receives the ram C.

B, the top of the press containing two chain wheels, with chains for returning the pressing part D.

EE, the two chains attached to the pressing plate D; they pass over the wheels, and enter the hollow cylinders II, and they have weights at their extremities, sufficient to raise the part D, to the top of the press, when the press is to be opened, which, as usual, is done by simply turning a stopcock to return the water.

G is a cistern, with a double combined pump, wrought by the handles HH. The small pipe, connecting the pumps G with the lower end of the cylinder A, is not shown in the plate; it may be carried up against the wall of the building in which the press is placed, or in any direction that may be most convenient.

KK are the guides of the pressing plate D.

A contrivance to obtain a press with an elastic power, by W. Bowler, was, in 1803, rewarded by the Society for the Encouragement of Arts, &c. It consisted in adapting a helical spring to the common screw press, so that the spring caused the pressing board to descend, as the elasticity of the body in the press diminished: but any contrivance of this nature must necessarily be inconvenient, and feeble and imperfect in its operation, in comparison with the elastic pressure obtained in the manner above stated by means of air, the elasticity of which is always proportionate to the compressing force.

A cast-iron Double Jib Crane.

This crane is represented in plate CII; it is entirely constructed of metal, and is exceedingly useful in loading or discharging vessels, particularly when time is an object, as it permits the men to be discharging one parcel of goods, while they are preparing to raise, or actually raising another parcel. For greater convenience, there are two powers or sets of wheels to each jib: one of the pinions on each handle shaft has twenty-one cogs, working into a wheel on the barrel shaft with eighty cogs; the other pinion has thirty-four cogs working into a wheel of sixty-seven cogs. By sliding the handle shaft through the brass collars in which it works, either of these combinations of wheels may be used; and they are kept in their proper places by a catch or fall that fits between collars on the shaft. When the catch is between the middle collars, both sets of wheels are then out of gear, and goods may be lowered with facility and safety by means of the wrought iron brake (shewn on an enlarged scale in fig. 5) that acts in a groove turned in a part of the barrel which is enlarged for that purpose. By pressing upon the lever *e*, the wrought iron straps *ff* are brought into close contract with the barrel, and the friction, which can be varied at pleasure by the force with which the lever is pressed down, is more than sufficient to counterpoise the articles to be lowered, and to cause them to descend with any required degree of velocity. The straps *ff*, are coupled together by the joint *g*, to allow them to act more freely,

a, Is an upright hollow column, round which the crane turns; it has a large flanch at the bottom, by which it is bolted to a cross that is let into the stonework, and firmly bolted down. The bolts are made a little dove-tailed, in their whole length, on one side, and the holes to receive them in the stone are made in a similar form, but as much larger on the side opposite to the dove-tailed part of the bolt, as to allow an oak wedge to be driven tight in. By this means the bolts are firmly secured: but in case it be required to remove the machine, or to renew a broken bolt, the wooden wedge may be easily bored out with an auger, by which means the bolt is set at liberty. The column *a*, at the lower part, is turned, to make it smooth and cylindrical, and at the top it is bored to receive a brass step that supports the crane by a wrought iron bolt (shewn in figs. 3 and 4) which passes through the cap *b*, and serves as a centre or pivot for it to turn upon.

The jibs, *c c*, are secured by two bolts to the cap *b*, and likewise to the moveable ring *d*, (made to imitate a base moulding,) which is bored out that it may the more easily move round the column *a*.

The extremities of the jibs are connected together, at the top, by means of a strong rod of wrought iron, and the mutual support thus afforded, together with the property that the whole weight of each jib always forms a balance to that of the other, and that therefore there is not in the crane itself any strain beyond a vertical pressure upon the column *a*, render the machine peculiarly susceptible of a light and economical construction, comparatively with the load which it is adapted to raise.

Hydrostatic Press.

The Hydrostatic Press was first invented by the late Joseph Bramah, of London, but has since undergone several considerable improvements, and is much simplified in its construction. Presses of this description have, with respect to pressure and expedition, a most decided superiority over the large screw presses formerly used. We have been favoured with the annexed drawings of two, which were made for the Publishers of this Work, and which have been found to be excellently adapted to the use of printers and bookinders.

Figs. 1 and 2, plate CIII, represent a front elevation of the two hydrostatic presses.

Fig. 3, the forcing or injecting pump, (made of brass,) and fixed in a cast iron cistern.

Fig. 4, a side view of the injecting pump.

Fig. 5, a bird's-eye view of the injecting pump.

Fig. 6, a plan, or bird's-eye view of the press, fig. 1.

Fig. 7. a horizontal section of the press fig. 2, supposed to be separated at *f f*, and the upper parts removed.

AAA, the bottom frames, each consisting of a strong piece of cast iron united at each corner to the top frame B, by four wrought iron bolts CCCC, which serve also as pillars for supporting the top, and are made sufficiently strong to resist the whole power of the press.

The pressure is exerted between the under surface of the top B, and the upper surface of the follower or cast iron plate D, which is fitted to the ram or piston E.

The piston is moveable in the strong metallic cylinder F, and by its motion upwards, the pressure is communicated to the articles placed upon the plate or table D.

In fig. 1, the ram is represented at its greatest elevation, acting against the folded sheets of printed books, with boards placed between them at certain intervals.

Fig. 2, shews the press with the ram and follower plate at their lowest situation, ready to receive any articles to which the power is to be applied.

G, fig. 3, 4, and 5, is the forcing or injecting pump, placed in a cast iron cistern H, containing water, and fixed upon two iron standards, which raise it to a convenient height, and are firmly bolted to the floor. I, the iron bow or fulcrum frame, which is fixed on the cistern, and has a cross piece at the bottom with an opening in its centre, to admit the pump. The pump has a rod working in it, and attached to the lever K, by a connecting link, which allows for its vibration, and plays in an opening in an enlarged part of the rod at L, which also allows the lever to pass through.

The guide rod M, passes through a brass bush in the top of the fulcrum frame, which serves to keep the rod true with the barrel of the pump. A weight N, is applied to the lever as a counterbalance. There is a projection on the frame towards the centre of the rod, for the purpose of admitting an additional hole to give a greater power in working the pump, by reducing the distance from its centre to the fulcrum, which is done by bringing the lever to a horizontal position, and then introducing through the hole that is opposite to a similar one in the lever, a turned steel pin which exactly fits it, and removing the one before used as a fulcrum, from the hole at the greatest distance from the pump.

O, a weight hung on a graduated lever P, which lever is to shew the power of the press, as well as to keep shut, in the common course of working, a valve over which it acts; but if the pressure should at any time become so great as to endanger the bursting of the pipes or cylinders, the valve rises, and suffers the water to escape.

All the before-mentioned figures are drawn to a scale of half an inch to a foot, and the same letters refer to the same parts in each figure.

Fig. 8, represents a section of the cylinder F and the piston E, five inches diameter in its place, drawn to a scale of one inch to a foot, except in its length, which is shortened for want of room. Near the top of the cylinder, in the contracted part, which is bored out perfectly true, to steady the ram, is a recess Q, turned within it, to admit a collar leather R, fig. 9, which presents a thin edge both to the ram and to the cylinder, to render the junction between them water-tight, and to prevent the least escape of the water injected.

Fig. 9, is a section of this leather, half its real size, a great part of it being removed to save room. S shews the edge of a brass ring, cut into six segments, and introduced within the leather, to sustain it when the piston descends, and to prevent its edges from being injured against the bottom of the recess.

This simple mode of making the junction of the ram and cylinder water-tight, was invented by Benjamin Hick, of Bolton, several years ago, and is now generally practised. In the old method of fitting up this part, an enlargement of the cylinder was made at its mouth, in which the leather was placed, and then secured by a loose metal ring, called a collar-plate, placed over it, and as large in diameter as the head of the cylinder, to which it was attached by ten or twelve screws, which, from the unavoidable inequality of their bearing, were continually subject to accidents.

The collar leathers, upon the improved mode, are also rendered more durable in the proportion of at least five to one, which is a considerable saving of expense, as well as of time and trouble, in not having so frequently to replace them.

To keep the surface of the piston clean, and to remove any substance which might adhere to and injure it or the leather, there is a small hollow, T, fig. 8, made at the top of the cylinder, which is filled with hemp or tow, saturated with oil, and is kept in its place by a thin wrought iron plate V, laid over it, and fastened by four small screws.

In the side of the cylinder, and immediately under the collar leather at W, is a small circular opening, which admits the water from the forcing pump, and is conducted into the enlarged part of the cylinder, by a small groove cut downwards from the opening. X is the copper communicating pipe, which has a brass boss screwed upon its end, and is further fastened by soft solder; it is fixed into the cylinder by a perforated screwed nut Y, put on the pipe before the boss is secured, and the joint is made water-tight by introducing a leather washer against a square shoulder, at the bottom of the screwed opening in the side of the cylinder. The other end of the copper pipe is connected to the junction piece Z, fig. 10, in a similar way.

The junction piece is used when more than one press is connected wiih the same forcing pump, and consists, in this case, of a piece of brass with one opening to join the pump, and other two openings, one of which communicates by separate pipes with each press. These openings can be secured or opened at pleasure, as either press may be wanted to be used, by the screwed stopper, which has a conical end that fits into a similar shaped seat over the opening to each pipe, and when screwed down prevents the passage of the water to or from the press.

Fig. 10, is the section of the injecting pump, drawn to a scale of two inches to one foot. This pump answers the purpose of two pumps made in the usual way; it consists of a brass rod three-fourths of an inch in diameter, and another rod one inch and a quarter in diameter, which is hollow, and occasionally serves as the working barrel for the smaller rod.

As the goods, when first placed in the press, are very elastic, and occupy much room in comparison to their real solidity, it is desirable, in order to save time, to make use of the larger pump rod to raise the ram as expeditiously as possible, preparatory to using which, the small rod is forced down by the lever, until the small hole *a*, is opposite to a similar one in the nut *b*, that is screwed into the top of the larger pump rod, and the single end of the key, fig. 11, is put through both, and connects the larger rod with the lever, and is then ready for use with the fulcrum in the farthest hole from the centre of the pump.

When the resistance becomes greater than can be overcome by this power, a pin must be fixed in the inner hole, the other removed, and the action continued till the resistance can be no longer overcome. The small rod must then be used, which may be done by again pressing down the lever until the enlarged part of the larger rod (which has a groove turned in it) touches the bottom of the recess that is turned out in the upper part of the nut of the pump barrel, on each side of which is a small square hole, cut through to admit the forked end of the key, which being drawn out of the smaller rod, leaves it at liberty, and secures the larger rod to the pump; by these means making it the working barrel for the smaller rod. The fulcrum is again to be placed in the outer hole, and when the power is to be increased, it must be removed to the inner hole as before.

Fig. 12, is the bottom valve or clack, also shewn at *c*, in fig. 10, contained in a screwed nut *d*, which is screwed into the bottom of the injecting pump, and made tight by a leather washer, against a square shoulder. This nut has a tube *e*, screwed to the bottom part of it, with an enlarged end, that is covered by a plate, perforated with small holes, to strain the water from any foreign matter, which might get into the pump, and prevent the valves from shutting close.

Fig. 13, is an elevation, and fig. 14, an end view of the valve, which prevents the return of the water from the press cylinder to the injecting pump, shewn also in its place at *f*, fig. 10.

Fig. 15, and *g*, fig. 10, a small screw, screwed down to a conical shoulder, to prevent the valve *f* from rising too high; by the removal of this screw the valve can be examined at pleasure, and for the convenience of lifting it out, there is a small hole in its top to admit a screw pin for that purpose.

Fig. 16, the safety valve, (also shewn in its place at *h*, fig. 10,) to prevent the bursting of the copper tubes and cylinders. This valve is pressed down by the lever P, which is graduated on its upper surface, and has the weight O (fig. 4,) suspended from it, which can be moved at pleasure. The opening over which this valve is placed, is generally made one-eighth of an inch in diameter; supposing the weight O to be moved to the end of the lever, its distance from the fulcrum at its other extremity, will then be twelve times as great as that of the valve, and the weight being fourteen pounds and a half, the pressure acting on the top of the valve will then be equal to one hundred and seventy-four pounds, over an opening of only one-eighth of an inch, which is the sixty-fourth part of a circular inch, consequently every circular inch of the piston's area, will be acted upon by a force of 11,136 pounds, or very nearly five tons; therefore, by multiplying the area of the piston of any press by this weight, its power or pressure is readily ascertained; and it may be necessary to say, that the thickness of the sides of the cylinder capable of resisting this pressure, should be at least equal to one half the diameter of the piston.

Should the force of the water become greater than has been stated, the safety valve will instantly be lifted up, and the water will escape through a small aperture just above the conical seat on which the valve shuts.

When the injecting pump is worked by the power of a steam engine or water-wheel, the proper action of this valve then becomes of great consequence.

i, Fig. 10, the discharging valve, with a sliding handle through its upper parts; its lower extremity is conical, and fitted into a similar seat, over the opening leading from the pump to the cylinder. When this screw is loosened, the water returns from the cylinder into the cistern, and the ram descends by its weight.

Fig. 5, *k* and *l*, two similar valves fitted into the junction piece Z, to form or cut off the communication with either press. To make these valves more perfectly water-tight, a leather collar is placed a little above the opening, and secured by a screwed nut, through which the valves are passed.

Fig. 17, a section of the conducting water-pipe, which is made of sheet copper; great care is requisite in the making of these tubes, both in closing the edges, and then in securing the joint by spelter solder through the whole breadth of the overlap.

Fig. 18, is a section of the leathers and the brass ring between them, used to prevent the escape of water past the pump rods.

The price of these two presses, with the pump adapted to the working of both of them, is only about 180*l*.

A Magnetical Instrument for ascertaining the Longitude at Sea.

The following letter from a gentleman in Greenock, relates to a matter of so much moment, that our readers will regret the death of the person who contrived and executed the instrument alluded to. It is fortunate, however, that the apparatus is still in existence, as further experiments, and a more minute examination of its structure, may perhaps lead to a discovery o: its principles.

All that can be inferred at present is, that possibly a well-poised magnetic ball, though it may remain stationary (excepting the change occasioned by the magnetic variation,) while kept in the same place, may possess a property, which, on carrying it eastward or westward from that spot, may occasion a revolution on its axis proportioned to the distance. Should any thing like this turn out to be the fact, we may yet see that accomplished which has hitherto baffled every human effort.

But be that as it may, ingenious men will endeavour to profit by the hint which the following letter presents :—

Greenock, Aug. 2.

"An affair of so much consequence to mankind as the following, it were criminal in me to conceal; I therefore request of you to make it as public as possible among your seafaring and philosophical friends.

"Our mutual friend, before his departure last fall for Philadelphia, constructed a machine, apparently simple, but which is infinitely more valuable to navigation than the compass. It was brought to me, together with his log-book, by a fellow passenger homewards, who unluckily had paid no attention to the use of the apparatus, which was the more unfortunate, as our friend died within three leagues of land.

"It is a magnetic ball, floating in a basin of quicksilver. The ball is painted all over, to keep the quicksilver from penetrating the pores, which might embarrass the evolutions, which coating I dare not destroy to examine the materials of the ball; but from its weight it must be metallic, yet it floats high in the fluid. Since he took it from this place, I perceive he has marked it with lines of longitude and latitude, like a geographical sphere. This, I presume, he has done on his voyage outward, the journal of which is likely left in America. But this [journal] which I possess begins with the exact point of latitude and longitude of Philadelphia, and records the zenith of every day as accurately as if he had been all along on terra firma. In bed, he told the captain his distance from the coast of Ireland to a minute, by looking at his machine.

"The properties of magnetism are not yet sufficiently known, and they have heretofore been applied to use only in the form of the needle. But it appears to possess, besides its well known polarity, a propensity to retain its native relative position on the earth, that is to say, it turns upon an axis, like the earth, one point always pointing to the pole-star. Beyond the line, this point upon the ball is below the horizon; and on the shores of America the longitudinal line, which now is its meridian, was far down the side; so that if he had sailed round the earth, his little ball would have made a complete revolution upon its axis."

The preceding remarks, and the letter which accompanies them, are from the Philosophical Magazine for 1802.

Thus was announced to the public, probably for the first time, a property of the magnet not less curious and interesting than those of its dip and polarity. The subject appears not, for several years afterwards, to have excited general attention; it has lately, however, been revived, with sanguine hopes that the investigation of it will be attended with important results. Benjamin Wood, an optician, formerly of London, and now of Liverpool, attempted to realize the plan of discovering the longitude by means of a magnetic ball, floating in quicksilver. His experiments, for some time, appeared to throw little light upon the immediate object of his pursuit; but having observed that a flat unmagnetized bar of steel, which, when suspended by its centre, in the same manner as the compass needle, remained perfectly horizontal, did not, after being magnetized, remain horizontal either in the direction of its length, or in any given line of its breadth, he concluded that though the angle which the bar formed with the horizon, in the direction of its length, was evidently no other than the well-known phenomenon of the dipping needle, yet that the angle which it formed with the horizon in its transverse direction, must either be attributed to the action of the same power as that possessed by the magnetic ball, or to some other property of magnetism till then unknown. At length he found that a magetic cylinder afforded the best means of ascertaining whether this apparently new property of the magnet could be rendered available or not to purposes of utility, and after a variety of trials, both by sea and land, the method of suspending the cylinder represented by plate CIV, has been found the most convenient.

In fig. 1, AA is a cylinder of steel, as free from flaws as it can be obtained, turned perfectly true and smooth, and highly polished. At its two extremities, *b b*, it is reduced into the form of pivots, and each of these pivots is terminated by a fine conical point; these conical points turn in agate centres, fitted at *c c* into the pieces of brass FG, and the friction is so small, that the cylinder AA revolves with the greatest freedom.

BR is a light brass wheel, fitted upon the steel cylinder AA, and graduated on its circumference. If the magnetic cylinder AA, possess the property of turning a different point of its surface to the earth, with every variation of the longitude of the place of observation, it is evident that this wheel affords the means of increasing the scale upon which the variation is observed; and as the longitude east or west can never exceed half a circle, or 180 degrees, the circumference of this wheel, though divided into 360 degrees, is numbered twice from 1 to 180, commencing on each side of the zero.

The supports FG, of the cylinder AA, are attached to the plate or ring CC, within which the wheel BR turns. Upon the upper surface of the ring CC, are engraved the cardinal points with the usual divisions of the compass card, and across the diameter of it is fixed a bar *d d*, in the middle of which is an apparatus consisting of two pair of gimbals, with an agate cap *e*, in the centre. This agate cap is placed upon an upright rod of steel *f*, which terminates in a cone at the end that enters the agate cap. To the bar *d d* are riveted two brass wires *g g*, and the lower ends of these wires are riveted into a plate or ring *h h*, which circumscribes the unnecessary motion of the ring CC and cylinder AA, upon the point of the rod *f*, and serves as a support for these parts of the machine, when removed from their state of suspension on the rod *f*.

The circular hoop DD is suspended by gimbals at *i i*, in the frame EEE, and another frame *k k*, nearly like that of EEE, but smaller, is attached by gimbals at *l l*, to the hoop DD. The gimbals *i i*, and *l l*, are 90 degrees distant from each other. On the middle of the bar *k k*, is fixed a leaden weight *m m*, to give the hoop DD a quick and decided tendency to the horizontal position. Into the weight *m m*, is screwed the rod *f*, which supports the ring CC, carrying the cylinder AA.

When thus fitted up, the cylinder AA, in addition to a free motion on its axis, admits of every other motion that can be requisite: the ring CC will turn entirely round horizontally upon the extremity of the rod *f*, or any point of it, through the whole or a part of this revolution, may be directed above or below the horizon; while the gimbals *i i*, *l l*, and the other two pair of gimbals connected with the cap *e*, enable the whole machine readily to yield to and recover itself from the effects of any agitation which it may experience in a ship.

The support G slides in a dove-tailed groove, contained in the piece *n*, which is riveted or otherwise made immoveably fast to the ring CC; and when the nut *p* is unscrewed, it can be drawn out, and the cylinder AA removed. To the back of it is attached, by two screws, a plate of brass, *q*, by taking off which, the agate which receives one extremity of the cylinder, may, when it is worn, be removed, and another inserted. The agate in the support F may be removed in the same way, but this support does not slide in a groove like the other. If rubies were employed to receive the extremities of the cylinder, they would probably not require to be renewed; but agate wears considerably under constant friction from a hardened steel point; and the steel, if not hardened, loses its figure.

A slender piece of brass *t t*, which is fastened to the ring CC, passes over the circumference of the wheel BR, at the smallest distance that prevents it from touching the wheel, and constitutes the index, from which the motion of the wheel is estimated. A vernier is attached to the index, for more accurately reading off the divisions.

Fig. 2 is an enlarged view of one end of the cylinder AA, and fig, 3 is a plan, on an enlarged scale, of the gimbals connected with the cap *e*.

To prevent the injury which the machine might sustain from accidents, it is, when taken on shipboard, put into a box, to the bottom of which it is screwed by screws passing through the frame EEE, at *r r*, and the box itself is fastened down in any convenient situation. In the lid of the box may be fixed a pane of plate-glass, through which the machine may at any time be inspected. The glass may be protected by a sliding lid.

When this machine is taken westward, the cylinder AA, and consequently the wheel BR, moves in a direction from B to R; when it is taken eastward, the motion of the wheel is the reverse, that is, from R to B. A great number of trials which have been made, appear to evince that the number of degrees which the wheel moves in the passage from the place of departure to that of observation is the same as that of the difference of the longitude of the two places: consequently, if the point immediately under the index, where the wheel would rest at the place of departure, be made the zero of the graduated circumference, the longitude thence, of the place of observation, becomes immediately known by simple inspection.

If future experiments should prove that the machine possesses these properties, it will unquestionably become one of the most valuable inventions of the age. If such should not be the result of further investigation, and if every machine thus depending upon magnetism for its action, should be as far from showing the true longitude of a place, as the dipping needle is from showing the true latitude, still it will have established a singularly curious fact in natural philosophy, to account for which must enter into every theory of magnetism, and of which future ingenuity may make a valuable use.

The machine is now undergoing a complete trial, by direction of the Board of Longitude, and it has also been taken for trial on board many merchants' vessels.

The Marquis of Worcester's Scantling of Inventions.

FIRST PUBLISHED IN THE YEAR 1655.

This little tract having now become very scarce, and yet still continuing to be deemed a production of great curiosity, and exciting much interest among those who take pleasure in mechanical inquiries, we have concluded, that, as an addition to this work, our Readers will deem it equally suitable and acceptable. It will ever be memorable, for containing, in, the sixty-eighth article, the original hint to which we are indebted for the Steam-engine.

A Century of the Names and Scantlings of Inventions by me already practised.

I. *Seals abundantly significant.*

Several sorts of seals, some shewing by screws, others by gages fastening or unfastening all the marks at once; others by additional points and imaginary places, proportionable to ordinary escocheons and seals at arms, each way palpably and punctually setting down (yet private from all others but the owner and by his assent) the day of the month, the day of the week, the month of the year, the year of our Lord, the names of the witnesses, and the individual place where any thing was sealed, though in ten thousand several places, together with the very number of lines contained in a contract, whereby falsification may be discovered, and manifestly proved, being upon good grounds suspected.

Upon any of these seals a man may keep accounts of receipts and disbursements from one farthing to an hundred millions, punctually shewing each pound, shilling, penny, or farthing.

By these seals likewise, any letter, though written but in English, may be read and understood in eight several languages, and in English itself to clean contrary and different sense, unknown to any but the correspondent, and not to be read or understood by him neither, if opened before it arrive unto him; so that neither threats, nor hopes of reward, can make him reveal the secret, the letter having been intercepted and first opened by the enemy.

II. *Seals private and particular to each Owner.*

How ten thousand persons may use these seals to all and every of the purposes aforesaid, and yet keep their secrets from any but whom they please.

III. *A One-line Cipher.*

A cipher and character so contrived, that one line, without returns and circumflexes, stands for each and every of the twenty-four letters; and as ready to be made for the one letter as the other.

IV. *Reduced to a Point.*

This invention, refined and so abbreviated, that a point only sheweth distinctly and significantly any of the twenty-four letters; and these very points to be made with two pens, so that no time will be lost, but as one finger riseth the other may make the following letter, never clogging the memory with several figures for words and combination of letters; which with ease, and void of confusion, are thus speedily and punctually, letter for letter, set down by naked and not multiplied points. And nothing can be less than a point, the mathematical definition of it being *cujus pars nulla*. And of a motion no swifter imaginable than semiquavers or releshes, yet applicable to this manner of writing.

V. *Varied significantly to all the twenty-four Letters.*

A way by circular motion, either along a rule or ringwise, to vary any alphabet, even this of points, so that the selfsame point individually placed, without the least additional mark or variation of place, shall stand for all the twenty-four letters, and not for the same letter twice in ten sheets writing, yet as easily and certainly read and known, as if it stood but for one and the self-same letter constantly signified.

VI. *A mute and perfect Discourse by Colours.*

How at a window, as far as eye can discover black from white, a man may hold discourse with his correspondent, without noise made or notice taken; being, according to occasion given and means afforded, *ex re natâ,* and no need of provision beforehand; though much better if foreseen, and means prefaced for it, and a premeditated course taken by mutual consent of parties.

VII. *To hold the same by Night.*

A way to do it by night as well as by day, though as dark as pitch is black.

VIII. *To level Cannons by Night..*

A way how to level and shoot cannon by night as well as by day, and as directly; without a platform or measures taken by day, yet by a plain and infallible rule.

IX. *A Ship-destroying Engine.*

An engine, portable in one's pocket, which may be carried and fastened on the inside of the greatest ship *tanquam aliud agens,* and at any appointed minute, though a week after, either of day or night, it shall irrecoverably sink that ship.

X. *How to be fastened from aloof and under Water.*

A way from a mile off, to drive and fasten a like engine to any ship, so that it may punctually work the same effect either for time or execution.

XI. *How to prevent both.*

How to prevent and safeguard any ship from such an attempt by day or night.

XII. *An unsinkable Ship.*

A way to make a ship not possible to be sunk, though shot an hundred times betwixt wind and water by cannon, and should lose a whole plank, yet in half an hour's time should be made as fit to sail as before.

XIII. *False destroying Decks.*

How to make such false decks as in a moment should kill and take prisoners as many as should board the ship, without blowing the decks up, or destroying them from being reducible, and in a quarter of an hour's time should recover their former shape, and to be made fit for any employment without discovering the secret.

XIV. *Multiplied Strength in a little Room.*

How to bring up a force to weigh up an anchor, or to do any forcible exploit in the narrowest or lowest room in any ship, where few hands shall do the work of many; and many hands applicable to the same force, some standing, others sitting, and by virtue of their several helps, a great force augmented in little room, as effectual as if there were sufficient space to go about with an axle-tree, and work far from the centre.

XV. *A Boat driving against Wind and Tide.*

A way how to make a boat work itself against wind and tide, yea, both without the help of man or beast; yet so that the wind or tide, though directly opposite, shall force the ship or boat against itself, and in no point of the compass but it shall be as effectual as if the wind were in the pupp, or the stream actually with the course it is to steer, according to which the oars shall row, and necessary motions work and move towards the desired port or point of the compass.

XVI. *A Sea-sailing Fort.*

How to make a sea-castle or fortification cannon-proof, and capable of a thousand men, yet sailable at pleasure to defend a passage, or in an hour's time to divide itself into three ships as fit and trimmed to sail as before; and even while it is a fort or castle they shall be unanimously steered and effectually be driven by an indifferent strong wind.

XVII. *A pleasant floating Garden.*

How to make upon the Thames a floating garden of pleasure, with trees, flowers, banqueting houses, and fountains, stews for all kinds of fishes, a reserve for snow to keep wine in, delicate bathing-places, and the like; with music made with mills: and all in the midst of the stream, where it is most rapid.

XVIII. *An hour-glass Fountain.*

An artificial fountain to be turned like an hour-glass by a child, in the twinkling of an eye, it holding a great quantity of water, and of force sufficient to make snow, ice, and thunder, with a chirping and singing of birds, and showing of several shapes and effects usual to fountains of pleasure.

XIX. *A Coach-saving Engine.*

A little engine within a coach, whereby a child may stop it, and secure all persons within it, and the coachman himself, though the horses be never so unruly in a full career: a child being sufficiently capable to loosen them in what posture soever they should have put themselves, turning never so short; for a child can do it in the twinkling of an eye.

XX. *A Balance Water-work.*

How to bring up water balance-wise, so that as little weight or force as will turn a balance will be only needful, more than the weight of the water within the buckets, which counterpoised, empty themselves one into the other, the uppermost yielding its water (how great a quantity soever it holds) at the self-same time the lowest taketh it in, though it be an hundred fathom high.

XXI. *A Bucket Fountain*

How to raise water constantly, with two buckets only, day and night, without any other force than its own motion, using not so much as any force, wheel, or sucker, nor more pulleys than one on which the cord or chain rolleth with a bucket fastened at each end. This, I confess, I have seen and learned of the great mathematician Claudius his studies, at Rome, he having made a present thereof unto a cardinal; and I desire not to own any other men's inventions, but if I set down any, to nominate likewise the inventor.

XXII. *An ebbing and flowing River.*

To make a river in a garden to ebb and flow constantly, though twenty foot over, with a child's force, in some private place or room out of sight, and a competent distance from it,

XXIII. *An ebbing and flowing Castle-clock.*

To set a clock in a castle, the water filling the trenches about it; it shall shew, by ebbing and flowing, the hours, minutes, and seconds, and all the comprehensible motions of the heavens, and counter-libration of the earth, according to Copernicus.

XXIV *A Strength-increasing Spring.*

How to increase the strength of a spring to such an height as to shoot bumbasses, and bullets of a hundred pound weight, a steeple height, and a quarter of a mile off and more, stone-bow-wise, admirable for fire-works, and astonishing of besieged cities, when, without warning given by noise, they find themselves so forcibly and dangerously surprised.

XXV. *A double-drawing Engine for Weights.*

How to make a weight that cannot take up an hundred pound, and yet shall take up two hundred pound, and at the self-same distance from the centre; and so proportionably to millions of pounds.

XXVI. *A to-and-fro Lever.*

To raise a weight as well and as forcibly with the drawing back of the lever, as with the thrusting it forwards; and by that means to lose no time in motion or strength. This I saw in the arsenal at Venice.

XXVII. *A most easy Level Draught.*

way to remove to and fro huge weights, with a most inconsiderable strength, from place to place. For example, ten ton with ten pounds, and less; the said ten pounds not to fall lower than it makes the ten ton to advance or retreat upon a level.

XXVIII. *A portable Bridge.*

A bridge, portable in a cart with six horses, which in a few hours' time may be placed over a river half a mile broad, whereon with much expedition may be transported horse, foot, and cannon.

XXIX. *A moveable Fortification.*

A portable fortification, able to contain five hundred fighting men, and yet in six hours' time may be set up, and made cannon proof, upon the side of a river or pass, with cannon mounted upon it, and as complete as a regular fortification, with half-moons and counterscarps.

XXX *A rising Bulwark.*

A way in one night's time to raise a bulwark twenty or thirty foot high, cannon proof, and cannon mounted upon it, with men to overlook, command, and batter a town; for, though it contain but four pieces, they shall be able to discharge two hundred bullets each hour.

XXXI. *An approaching Blind.*

A way how safely and speedily to make an approach to a castle or town-wall, and over the very ditch, at noon-day.

XXXII *An universal Character.*

How to compose an universal character, methodical and easy to be written, yet intelligible in any language; so that if an Englishman write it in English, a Frenchman, Italian, Spaniard, Irish, Welsh, being scholars, yea, Grecian or Hebrean, shall as perfectly understand it in their own tongue as if they were perfect English, distinguishing the verbs from the nouns, the numbers, tenses, and cases, as properly expressed in their own language as it was written in English.

I *A Needle Alphabet.*

To write with a needle and thread, white, or any colour upon white, or any other colour, so that one stitch shall significantly shew any letter, and as readily and as easily shew the one letter as the other, and fit for any language.

XXXIV. *A knotted String Alphabet.*

To write by a knotted silk string, so that every knot shall signify any letter, with comma, full point, or interrogation, and as legible as with pen and ink upon white paper.

XXXV. *A Fringe Alphabet.*

The like by the fringe of gloves.

XXXVI. *A Bracelet Alphabet.*

By stringing of bracelets

XXXVII. *A pincked Glove Alphabet.*

By pincked gloves.

XXXVIII. *A Sieve Alphabet.*

By holes in the bottom of a sieve.

XXXIX. *A Lantern Alphabet.*

By a lattin or plate lantern.

XL. *An Alphabet by the Smell.*—XLI. *Taste.*—XLII. *Touch.*

By the smell—by the taste—by the touch.—By these three senses as perfectly, distinctly, and unconfusedly, yea, as readily, as by the sight.

XLIII. *A Variation of all and each of these.*

How to vary each of these, so that ten thousand may know them, and yet keep the understanding part from any but their correspondent.

XLIV. *A Key-pistol.*

To make a key of a chamber door, which to your sight hath its wards and rose-pipe but paper thick, and yet at pleasure, in a minute of an hour, shall become a perfect pistol, capable to shoot through a breast-plate, commonly of carabine-proof, with prime, powder, and firelock, undiscoverable in a stranger's hand.

XLV. *A most conceited Tinder-box.*

How to light a fire and a candle at what hour fo eht night one awaketh, without rising or putting one's hand out of the bed. And the same thing becomes a serviceable pistol at pleasure; yet by a stranger, not knowing the secret, seemeth but a dextrous tinder-box

XLVI *An artificial Bird*

How to make an artificial bird to fly which way and as long as one pleaseth, by or against the wind, sometimes chirping, other times hovering, still tending the way it is designed for.

XLVII. *An Hour Water-ball.*

To make a ball of any metal, which, thrown into a pool or pail of water, shall presently rise from the bottom, and constantly shew, by the superficies of the water, the hour of the day or night, never rising more out of the water than just to the minute it sheweth of each quarter of the hour; and if by force kept under water, yet the time is not lost, but recovered as soon as it is permitted to rise to the superficies of the water

XLVIII. *A screwed Ascent of Stairs.*

A screwed ascent, instead of stairs, with fit landing places to the best chambers of each story, with back stairs within the well of it, convenient for servants to pass up and down to the inward rooms of them unseen and private.

XLIX. *A Tobacco-tongs Engine.*

A portable engine, in way of a tobacco-tongs, whereby a man may get over a wall, or get up again being come down, finding the coast proving unsecure to him.

L. *A Pocket Ladder.*

A complete light portable ladder, which taken out of one's pocket, may be by himself fastened an hundred foot high to get up by from the ground.

LI. *A Rule of Gradation.*

A rule of gradation, which with ease and method reduceth all things to a private correspondence, most useful for secret intelligence.

LII. *A mystical Jangling of Bells.*

How to signify words and a perfect discourse by jangling of bells of any parish church, or by any musical instrument within hearing, in a seeming way of turning it; or of an unskilful beginner.

LIII. *An hollowing of a Water-screw.*

A way how to make hollow and cover a water-screw as big and as long as one pleaseth, in an easy and cheap way.

LIV. *A transparent Water-screw.*

How to make a water-screw tight and yet transparent, and free from breaking; but so clear, that one may palpably see the water, or any heavy thing, how and why it is mounted by turning.

LV. *A double Water-screw.*

A double water-screw, the innermost to mount the water, and the outermost for it to descend more in number of threads, and consequently in quantity of water, though much shorter than the innermost screw by which the water ascendeth; a most extraordinary help for the turning of the screw to make the water rise.

LVI. *An advantageous Change of Centres.*

To provide and make that all the weights of the descending side of a wheel shall be perpetually further from the centre, than those of the mounting side, and yet equal in number and heft to the one side as the other. A most incredible thing, if not seen, but tried before the late king (of blessed memory) in the Tower, by my directions, two extraordinary ambassadors accompanying his majesty, and the duke of Richmond and duke Hamilton, with most of the court, attending him. The wheel was fourteen foot over, and forty weights of fifty pounds apiece. Sir William Balfour, then lieutenant of the Tower, can justify it with several others. They all saw that, no sooner these great weights passed the diameter-line of the lower side, but they hung a foot further from the centre, nor no sooner passed the diameter-line of the upper side, but they hung a foot nearer. Be pleased to judge the consequence.

LVII. *A constant Water-flowing and ebbing Motion.*

An ebbing and flowing water-work in two vessels, into either of which, the water standing at a level, if a globe be cast in, instead of rising, it presently ebbeth, and so remaineth until a like globe be cast into the other vessel; which the water is no sooner sensible of, but that vessel presently ebbeth, and the other floweth, and so continueth ebbing and flowing until one or both of the globes be taken out, working some little effect besides its own motion, without the help of any man within sight or hearing; but if either of the globes be taken out, with ever so swift or easy a motion, at the very instant the ebbing and flowing ceaseth; for if during the ebbing you take out the globe, the water of that vessel presently returneth to flow, and never ebbeth after, until the globe be returned into it, and then the motion beginneth as before.

LVIII. *An often-discharging Pistol*

How to make a pistol to discharge a dozen times with one loading, and without so much as one new priming requisite, or to change it out of one hand into the other, or stop one's horse.

LIX. *An especial way for Carabines.*

Another way as fast and effectual, but more proper for carabines.

LX. *A Flask-charger.*

A way with a flask appropriated unto it, which will furnish either pistol or carabine with a dozen charges in three minutes' time, to do the whole execution of a dozen shots, as soon as one pleaseth, proportionably.

LXI. *A way for Muskets.*

A third way, and particular for muskets, without taking them from their rests to charge or prime, to a like execution, and as fast as the flask, the musket containing but one charge at a time.

LXII. *A way for a Harquebuss—a Crock.*

A way for a harquebuss, a crock, or ship-musket, six upon a carriage, shooting with such expedition, as without danger one may charge, level, and discharge them sixty times in a minute of an hour, two or three together

LXIII. *For Sakers and Minyons.*

A sixth way, most excellent for sakers, differing from the other, yet as swift.

LXIV. *For the biggest Cannon.*

A seventh, tried and approved before the late king (of ever blessed memory) and an hundred lords and commons, in a cannon of eight inches half-quarter, to shoot bullets of 64 lbs. weight, and 24 lbs. of powder, twenty times in six minutes, so clear from danger, that after all were discharged, a pound of butter did not melt being laid upon the cannon breach, nor the green oil discoloured that was first anointed and used between the barrel thereof and the engine, having never in it, nor within six foot, but one charge at a time.

LXV. *For a whole Side of Ship-muskets.*

A way that one man in the cabin may govern the whole side of ship-muskets, to the number (if need require) of two or three thousand shots.

LXVI. *For guarding several Advenues to a Town.*

A way that against several advenues to a fort or castle, one man may charge fifty cannons playing, and stopping when he pleaseth, though out of sight of the cannon.

LXVII. *For Musketoons on Horseback.*

A rare way likewise for musketoons fastened to the pommel of the saddle, so that a common trooper cannot miss to charge them with twenty or thirty bullets at a time, even in full career.

"When first I gave my thoughts to make guns shoot often, I thought there had been but one only exquisite [illegible] inventible, yet by several trials, and much charge, I have perfectly tried all these."

LXVIII. *A Fire Water-work.*

An admirable and most forcible way to drive up water by fire, not by drawing or sucking it upwards, for that must be, as the philosopher calleth it, *intra sphæram activitatis*, which is but at such a distance. But this way hath no bounder, if the vessels be strong enough; for I have taken a piece of a whole cannon, whereof the end was burst, and filled it three-quarters full of water, stopping and screwing up the broken end, as also the touch-hole; and making a constant fire under it, within twenty-four hours it burst and made a great crack: so that having a way to make my vessels so that they are strengthened by the force within them, and the one to fill after the other, have seen the water run like a constant fountain-stream forty foot high; one vessel of water, rarefied by fire, driveth up forty of cold water. And a man that tends the work is but to turn two cocks, that one vessel of water being consumed, another begins to force and re-fill with cold water, and so successively, the fire being tended and kept constant, which the self-same person may likewise abundantly perform in the interim between the necessity of turning the said cocks.

LXIX. *A triangle Key.*

A way how a little triangle screwed key, not weighing a shilling, shall be capable and strong enough to bolt and unbolt round about a great chest an hundred bolts through fifty staples, two in each, with a direct contrary motion, and as many more from both sides and ends, and at the self-same time shall fasten it to the place beyond a man's natural strength to take it away; and in one and the same turn both locketh and openeth it.

LXX. *A Rose Key.*

A key with a rose-turning pipe, and two roses pierced through endwise the bit thereof, with several handsomely contrived wards, which may likewise do the same effects.

LXXI. *A square Key with a turning Screw.*

A key perfectly square, with a screw turning within it, and more concealed than any of the rest, and no heavier than the triangle screwed key, and doth the same effects.

LXXII. *An Escocheon for all Locks.*

An escocheon to be placed before any of these locks with these properties.

1. The owner, though a woman, may with her delicate hand vary the ways of coming to open the lock ten millions of times, beyond the knowledge of the smith that made it, or of me who invented it.

2. If a stranger openeth it, it setteth an alarm a-going, which the stranger cannot stop from running out; and besides, though none should be within hearing, yet it catcheth his hand, as a trap doth a fox; and though far from maiming him, yet it leaveth such a mark behind it, as will discover him if suspected, the escocheon or lock plainly shewing what monies he hath taken out of the box to a farthing, and how many times opened since the owner had been in it.

LXXIII. *A transmittible Gallery.*

A transmittible gallery over any ditch or breach in a town wall, with a blind and parapet cannon-proof.

LXXIV. *A conceited Door.*

A door whereof the turning of a key, with the help and motion of the handle, makes the hinges to be of either side, and to open either inward or outward, as one is to enter or to go out, or to open in half.

LXXV. *A Discourse woven in Tape or Ribbon.*

How a tape or ribbon weaver may set down a whole discourse without knowing a letter, or interweaving any thing suspicious of other secret than a new-fashioned ribbon.

LXXVI. *To write in the Dark.*

How to write in the dark as straight as by day or candle light.

LXXVII. *A flying Man.*

How to make a man to fly, which I have tried with a little boy of ten years old in a barn, from one end to the other, on an hay-mow.

LXXVIII. *A continually going Watch*

A watch to go constantly, and yet needs no other winding from the first setting on the cord or chain, unless it be broken, requiring no other care from one, than to be now and then consulted with concerning the hour of the day or night, and if it be laid by a week together, it will not err much, but the oftener looked upon, the more exact it sheweth the time of the day or night.

LXXIX. *A total Locking of Cabinet Boxes.*

A way to lock all the boxes of a cabinet (though never so many) at one time, which were by particular keys appropriated to each lock opened severally, and independent the one of the other, as much as concerneth the opening of them, and by these means cannot be left opened unawares.

LXXX. *Light Pistol Barrels.*

How to make a pistol-barrel no thicker than a shilling, and yet able to endure a musket proof of powder and bullet.

LXXXI. *A Comb-conveyance for Letters.*

A comb-conveyance, carrying of letters without suspicion, the head being opened with a needle-screw drawing a spring towards them; the comb being made but after an usual form carried in one's pocket.

LXXXII. *A Knife, Spoon, or Fork Conveyance.*

A knife, spoon, or fork, in an usual portable case, may have the like conveyances in their handles.

LXXXIII. *A Rasping Mill.*

A rasping-mill for hartshorn, whereby a child may do the work of half a dozen men, commonly taken up with that work.

LXXXIV. *An Arithmetical Instrument.*

An instrument whereby persons ignorant in arithmetic may perfectly observe numerations and substractions of all sums and fractions.

LXXXV. *An untoothsome Pear.*

A little ball, made in the shape of plum or pear, being dextrously conveyed or forced into a body's mouth, shall presently shoot forth such and so many bolts of each side and at both ends, as without the owner's key can neither be opened or filed off, being made of tempered steel, and as effectually locked as an iron chest.

LXXXVI. *An imprisoning Chair.*

A chair made *à-la-mode,* and yet a stranger being persuaded to sit down in it, shall have immediately his arms and thighs locked up beyond his own power to loosen them.

LXXXVII. *A Candle-mould.*

A brass mould to cast candles, in which a man may make 500 dozen in a day, and add an ingredient to the tallow which will make it cheaper, and yet so that the candles shall look whiter and last longer.

LXXXVIII. *A Brazen Head.*

How to make a brazen or stone head in the midst of a great field or garden, so artificial and natural, that though a man speak never so softly, and even whispers into the ear thereof, it will presently open its mouth, and resolve the question in French, Latin, Welsh, Irish, or English, in good terms uttering it out of his mouth, and then shut it until the next question be asked.

LXXXIX. *Primero Gloves.*

White silk knotted in the fingers of a pair of white gloves, and so contrived without suspicion, that playing at primero cards, one may, without clogging his memory, keep reckoning of all sixes, sevens, and aces, which he hath discarded.

XC. *A dicing Box.*

A most dextrous dicing box, with holes transparent, after the usual fashion, with a device so dextrous, that with a knock of it against the table, the four good dice are fastened, and it looseneth four false dice made fit for his purpose.

XCI. *An artificial Ring-horse.*

An artificial ring-horse, with saddle and caparisons fit for running at the ring, on which a man being mounted, with his lance in his hand, he can at pleasure make him start, and swiftly to run his career, using the decent posture with bon grace, may take the ring as handsomely, and running as swiftly, as if he rode upon a barbe.

XCII. *A Gravel Engine.*

A screw made like a water-screw, but the bottom made of iron plate spadewise, which at the side of a boat emptieth the mud of a pond, or raiseth gravel.

XCIII. *A Ship-raising Engine.*

An engine whereby one man may take out of the water a ship of 500 tons, so that it may be caulked, trimmed, and repaired, without need of the usual way of stocks, and as easily let it down again.

XCIV. *A Pocket Engine to open any Door.*

A little engine, portable in one's pocket, which placed to any door, without any noise but one crack, openeth any door or gate.

XCV. *A double Cross-bow.*

A double cross-bow, neat, handsome, and strong, to shoot two arrows, either together or one after the other so immediately that a deer cannot run two steps, but, if he miss of one arrow, he may be reached with the other, whether the deer run forward, sideward, or start backward.

XCVI. *A Way for Sea-banks.*

A way to make a sea-bank so firm and geometrically strong, so that a stream can have no power over it; excellent likewise to save the pillar of a bridge, being far cheaper and stronger than stone-wall.

XCVII. *A perspective Instrument.*

An instrument whereby an ignorant person may take any thing in perspective as justly and more than the skilfullest painter can do by his eye.

XCVIII. *A semi-omnipotent Engine.*

An engine so contrived, that working the *primum mobile* forward or backward, upward or downward, circularly or corner-wise, to and fro, straight, upright or downright, yet the pretended operation continueth, and advanceth none of the motions above-mentioned, hindering, much less stopping the other; but unanimously, and with harmony, agreeing, they all augment and contribute strength unto the intended work and operation: and therefore I call this a *semi-omnipotent engine*, and do intend that a model thereof be buried with me.

XCIX. *A most admirable Way to raise Weights.*

How to make one pound weight to raise an hundred as high as one pound falleth, and yet the hundred pound descending, doth what nothing less than one hundred pounds can effect.

C. *A stupendous Water-work.*

Upon so potent a help as these two last-mentioned inventions, a water-work is, by many years' experience and labour, so advantageously by me contrived, that a child's force bringeth up, an hundred foot high, an incredible quantity of water, even two foot diameter, so naturally, that the work will not be heard even into the next room; and with so great ease and geometrical symmetry, that though it work day and night from one end of the year to the other, it will not require forty shillings reparation to the whole engine, nor hinder one's day-work, and I may boldly call it the most stupendous work in the whole world: not only with little charge to drain all sorts of mines, and furnish cities with water, though never so high seated, as to keep them sweet, running through several streets, and so performing the work of scavengers, as well as furnishing the inhabitants with sufficient water for their private occasions; but likewise supplying rivers with sufficient to maintain and make them portable from town to town, and for the bettering of lands all the way it runs; with many more advantageous and yet greater effects of profit, admiration, and consequence. So that deservedly I deem this invention to crown my labours, to reward my expenses, and make my thoughts acquiesce in way of further inventions; this making up the whole Century, and preventing any further trouble to the reader for the present, meaning to leave to posterity a book, wherein under each of these heads the means to put in execution and visible trial all and every of these inventions, with the shape and form of all things belonging to them, shall be printed by brass plates.

In bonum publicum, et majorem Dei gloriam.

APPENDIX.

Description of an improved Method of giving Motion to a Pendulum.[*]

THE application of the pendulum to clocks produced at once such an accurate mensuration of time, as to render that invention conspicuous amongst the most important modern discoveries; and the balance, which had for ages so imperfectly pre-occupied its place, is now almost consigned to oblivion.

Although the mode of communicating motion to the pendulum of a clock appears to be very complete; yet, on a strict examination, it will be found to have some defects, which render its further improvement very desirable.

Whatever may be the nature of the escapement, that contrivance may be reckoned the best, which transmits to the pendulum the impulse of the wheel, with the least lost of power; but, in practice, the wheel and pallets, and crutch-pin and pendulum-rod, cannot act in the same, but in parallel planes. The pendulum will therefore rather receive an oblique impulse from the crutch, by its bending at each stroke, and if the rod be made stiff and strong to prevent bending, whilst a part of the motion of the crutch promotes, another part absolutely opposes the motion of the pendulum; for, since the crutch-pin must pass through the slit in the pendulum-rod with some *shake*, which will be continually increasing by wear, and since it can only be in contact with one side of the rod at any moment of time, it will be alternately struck by either side of the crutch-pin leaping from one side of the pendulum-rod to the other; thus, during the ascent of the pendulum, the lower side of the rod is impelled by the ascending side of the crutch-pin, but when the pallet drops from the wheel, the crutch-pin will drop on the ascending side of the pendulum-rod, checking its progress, and opposing by its weight the arc of vibration. It is proved by experiment, that no inconsiderable part of the motive force is in this way dissipated; and it is the object of the present paper to show, that this double drop and weight, and bending of the crutch, may be entirely obviated.

It is proposed to fix the crutch to the axis of the verge, in the usual way; and in the suspension of the pendulum, the only change is, that the spring on which the pendulum is suspended, when included in the slit of the cock, should there be held fast. This is never well done by a pin, but may be effectually done by means of a screw, which both presses the surfaces together,

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[*] The Society for the Encouragement of Arts voted D. Ritchie, for this invention, their Gold Isis Medal and thirty guineas

and prevents separation. Let it further be supposed, that the front and back surfaces of the bar which forms the pendulum-rod, are formed into parallel planes, so that, when the axis of the verge is set truly level, and the pendulum suspended, those planes may cut the axis of the verge at right angles.

To the middle of the back of the pendulum-rod, and at the distance of the crutch from the line of suspension, is fastened a flat piece of rectangular steel, having a part at each end bent into planes at right angles to its surface; these ends must be equidistant, and parallel to a plane passing through the axis of the verge and the axis of the pendulum, and therefore parallel to each other. In the ends of this piece are cut rectangular notches parallel to the pendulum-rod, into which a hardened and tempered watch-chain is fixed, and this chain should be perfectly horizontal when the pendulum is at rest; it should also be just free of the front of the pendulum-rod. The steel piece has cylindric grooves cut on the outside of each end, at the extremities of the chain, which are parallel to the axis of the verge: the extreme links must be made double the thickness of the chain, by having a link riveted on each side, and the steel piece should be hardened and tempered. To put the chain in its place, press the two ends of the steel piece to approach each other, which the springing of the material will admit, and insert the chain, so that the last double outside links are found to snap into the cylindric grooves; this will secure it, and the elasticity of the piece will keep the chain in a constant state of tension; thus the whole apparatus is fixed to the pendulum, and becomes a part of it.

In the end of the crutch is fixed a rectangular prism, having a rectangular groove in it, but both the external and internal sides must be parallel to the axis of the verge. In this groove a piece of brass is made to slide backward and forward, and may be fastened in any position, by a finger screw on the lower side. The end of this piece, next the pendulum-rod, is at right angles to the horizontal sides of the groove, and forms a rectangle of 2-tenths by 5-tenths of an inch. This surface must be accurately parallel to the pendulum-rod, or, what is the same thing, perpendicular to the axis of the verge; a prismatic cover, of the same dimensions, is fitted to it by two steady pins. A finger-screw, the head of which is on the back of the pendulum-rod, passes freely through the cover, is screwed into the end of the slider, and its shoulder bears against the cover; a hole is cut through the pendulum-rod, to clear the screw and cover, and by this screw the two surfaces are brought into contact, and by unscrewing it, the cover is raised by the exertion of a spring inserted between the two surfaces; between these, the chain already described is to pass.

The spring by which the pendulum is suspended, should be of steel hardened and tempered, not more than half an inch in length, and about the same breadth; it should be pierced in the middle, and that part of it which bends, need not exceed the tenth of an inch in breadth. The axis of the verge, if produced, should pass through the plane of the spring, and should be set truly horizontal, by placing a spirit-level on the two ends of the arbour, these ends being previously made cylindrical and of equal diameters; and when the pendulum, with its chain passing between the sliding piece and cover, is suspended and at rest, the effect of gravity will give the rod a position at right angles to the horizon and to the axis of the verge, and parallel to the frame plate.

This being thus disposed, move the sliding piece until its end comes into contact with the chain, and by means of the finger-screw beneath the piece, fasten it in that position; and, lastly, the axis of the crutch being placed in the same plane as the axis of the pendulum-rod, which its gravity will nearly effect, turn the finger-screw at the back of the pendulum, and clip the chain fast between the end of the slider and its cover. By these means the pallets, crutch, and pendulum, are locked together, and the whole braced by a kind of rectangular framing, of which the crutch and pendulum-rod, and axis of the verge and sliding piece, are the opposite sides, the whole vibrating together with one uniform, uninterrupted motion. The double drop can no longer exist, nor the springing of the crutch, nor its weight on the pivots of the verge, for it is supported by the pendulum, of which the line of suspension is without friction. This line of suspension is but a continuation of the axis of the verge, or the same right line produced; and therefore any point taken either in the crutch or pendulum-rod, will describe concentric circles.

In plate CV, fig. 1, is a side view of the crutch-cock and part of the pendulum bar; *a a*, the clock plate; *b*, part of the verge; *c*, the crutch; *d*, the pendulum bar, having the part *e e*, in section as far as the dotted line *e e*, fig. 3; *f*, the slider and clip, serving instead of the crutch-pin; *g*, the slider screw; *h*, the clip screw; *i*, the grooved part of the crutch; *k*, the cover, into which the screw *g* and steady pins of the slider fasten, to fix it to the grooved piece of the crutch.

Fig. 2, shows the parts separated; *b*, the cover of the sliding lip; *m*, the spring which opens the cover when the screw *h* is oosened.

g. 3, the back view of the pendulum bar; *n n*, the steel spring which extends the chain; *o*, the opening in the pendulum bar, to make room for the slider clip and screw.

Fig. 4. a section of the pendulum bar above the spring *n*, showing a bird's eye view of the slider clip and spring *n*; *p p*, the chain extended by the spring *n n*, which the slider clip holds, and attaches the crutch to the pendulum; *q q*, figs. 1, 4, and 5, the slits in the spring *n*, which receive the chain *p*.

Fig. 5, *r r*, the cylindric groove at the bottom of the slit *q*, into which the thickened ends of the chain *p* snap, and are kept in their places.

Fig. 6, a front view of part of the pendulum bar, showing the spring *n n*, chain *p p*, and the opening.

Fig. 7, a bird's eye view of a section of the clock plate *a a*, and pendulum bar *d*, showing a slip of brass which is laid in the slits *q q* of the spring *n n*, by the workmen, to know whether the pendulum vibrates parallel to the clock plate, which is quite necessary; *t t*, two pins in another slip of brass *v v*, laid in notches *w w*. In the clock plate, these pins nearly touch the slip *s s*, to show the error, if any, of the pendulum's vibrations.

The same effect may be produced by the following means, if thought preferable.

Fig. 8. A represents a brass piece which is screwed to the pendulum rod, at a proper place, by two screws that pass through the holes *u u*.

x x, Represent two small steel cylinders, which slide in cylindrical holes, exactly in the same line as the two adjusting screws *y y*.

z, Represents the end of the crutch pin, held between the two cylinders *x x*, each of which is pressed firmly against the crutch pin by the screws *y y*.

Fig. 9, represents a section of fig. 8, by a plane passing through the screws *y y*, fig. 8, the same letters being applied to the same parts.

It is evident that the crutch pin may be shifted to the right or left, as occasion may require, by slackening one of the adjusting screws, and tightening the other. It may not be wholly superfluous to state, that this is the adjustment for setting the clock in beat.

The pendulum should be suffered to find its place of rest after the clock is fixed, that it may swing parallel to the clock plate, which it will do, if the clock is fixed in a perpendicular position. The adjusting screws may then be applied, to close the cylinders *x x* upon the crutch pin *z*, after which the clock may be brought to beat by using the adjusting screws as before described.

*Improved Pulley Blocks.**

The pulley is a machine of so much simplicity, portability, and power, a the use of it extends to cases of such frequent recurrence, that it might be expected to have long since reached the utmost limit of improvement in its construction. It is well known however, to practical mechanics, that the improvements of tackle blocks, which have hitherto been proposed, are of such doubtful excellence for general purposes as to be seldom employed; nor has the attempt to produce an unexceptionable construction been often made, a circumstance which in this case seems scarcely to be explained but by the apparent difficulty of the task. To elucidate more clearly the merits of the present invention, it may not be improper to advert to the difficulties which it was intended to obviate, and to the degree in which these difficulties have been overcome by the inventions of others.

The imperfections of common blocks are so well known to all persons who are in the habit of using them, and are in fact so obvious to the most cursory observer, that it would be superfluous to mention them, were it not necessary to state the evil for which a remedy is proposed. When there is more than one sheave in the same block, the fall or end of the rope to which the power is applied, comes last over the outside sheave; and that sheave, if the exertion of the power is in a line nearly parallel to the direction in which the load is drawn, always endeavours to get into a line with the point of suspension, and the place where the power is exerted; for the great friction to be overcome, preventing the equal transmission of the power throughout the combination; and the outside sheave having to sustain, not only the pressure of its own share of the load, but the additional strain sufficient to overcome the friction of all the other parts of the blocks, and the *vis inertiæ* of the entire load; it must, therefore, be considerably depressed, and in consequence of this oblique direction of the block, the lateral friction of the sheaves become so great, as in some cases nearly to equal the power.

Again, if the tackle-fall is drawn in a direction making a considerable angle with that of the load, the sheave it passes

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* The Society for the Encouragement of Arts, &c. voted their silver medal, for this invention, to James Jones, of High Holborn, London.

over tends very powerfully to get into a right line with the point of suspension and the power as before; but in this case the ill effects are of rather a different kind; for although the block is not so much depressed on one side as in the other case, it does not face the pull; that is, the axis of the sheaves does not stand at right angles with the fall, but is considerably twisted from it, and consequently the rope suffers violent friction and wear against the edge of the cheek of the block. The evils here pointed out are rapidly increased by the extension of the combination; it is, therefore, not surprising that the multiplication of pulleys, thus used, soon ceases to be advantageous.

The first attempt, of indisputable excellence, to remove the imperfections of the common method of combination, was that of the celebrated Smeaton, who brought the fall through the middle sheave by means of double tiers: but as his arrangement does not apply to any combination of less than twelve; as such great strains are not frequently required, and there is considerable loss of height, it is, though so perfect in itself, very seldom used.

The next improvement proposed, of any note, appears to have been that of Garnett, who obtained a patent for his method of avoiding friction by the introduction of friction rollers into each sheave; but this plan being expensive, soon out of repair, and not tending to remove the imperfections of lateral drag or twist by any change in the combination, did not come much into use. Then followed White's patent concentric pulleys, which, having the same tendency to drag on one side as the common blocks, laboured under the same difficulties, namely, great lateral friction and obliquity of draught; to which may be also added, a great increase of friction, arising from the speedy loss of the relative proportion of the diameters of the several grooves, occasioned by the stretch and wear of the rope. Thus, suppose we take a rope of an inch diameter, which being added to the several grooves in the top sheave, for instance, shall with its respective groove give the proportionate compound diameters of 2, 4, 6: that is, a 3-inch groove, with the semi-diameter of the rope on each side, is four inches; a 7-inch groove with its rope is eight inches, and a 11-inch groove with its rope is twelve inches. Now, supposing the rope to stretch and wear so much as to reduce it to 8-tenths of an inch, the proportion of the respective compound diameters will then be 2, 4.105, 6.210, being 3.8 inches, 7.8 inches, and 11.8 inches, whereas, to preserve the just proportion, they ought to be 3.8, 7.6, and 11.4 inches; that is, as 2:4::3.8:7.6; and as 2:6::3.8:11.4. Thus the proportion of the grooves is entirely lost, the second one being two-tenths of an inch, and the third being four-tenths of an inch too large; and consequently, in use, all the grooves except the largest, both in the top and bottom blocks, (for they are equally affected by the diminution of the diameter of the rope,) must revolve so much slower than the rope which passes over them, as to create an immense accession of friction, thereby adding greatly to the load, and very speedily wearing out both blocks and rope. These are imperfections of such magnitude, that no one can be surprised at the discontinuance of the use of pulleys thus constructed.

The latest improvement of tackle blocks is that of Lieut. Shuldham, and consists of White's pulley doubled, base to base, with two friction wheels in the cheeks of the block, for the axis of the compound sheave to revolve on.

Blocks constructed upon this principle are compact, and may in some cases be useful; but it is obvious, there must always apply to them the objections which have been above stated to those proposed by White himself; and as the diameters of the concentric pulleys must be understood as taken to the centre of the rope, the mere alteration of the figure of the rope by pressure, and before it has begun to wear, will be a source of friction, by destroying the relative proportion upon which its proper action depends. The friction wheel upon which each end of the axis of Lieut. Shuldham's compound pulley rests, is large, and well constructed to prevent its getting out of order; but it is chiefly efficient in a construction like his, that is, where many pulleys are formed upon the same piece of wood or metal, and fixed to the same axis: the use of friction rollers must be considered inapplicable, to each single sheave of a series turning separately but concentrically—a case in which they are most conveniently placed upon the same fixed axis.

Plate CVI, fig. I, exhibits a perspective view of a pair of iron blocks of seven sheaves, of which fig. 2 is a section, and fig. 3 is a front view of the top block.

It will be seen that the rope is fastened to one of the partition plates in the bottom block at A, whence it passes over the outside sheave at top, then under the outside sheave at bottom, whence it is transferred over to the other side by means of the cross sheave B, at top; it then descends to the outside sheave at bottom, turns up to and over the outside sheave at top, under the centre sheave at bottom, and thence comes out over the centre sheave at top, and consequently has no tendency to twist or to drag on one side.

Jones' improved pulley blocks.

A small rope or line C is attached to a bent wedge or gripe D, which lies on the fall in the centre sheave (as may be more distinctly seen in figs. 2 and 3,) for the purpose of retaining the load, if the fall is let go, either by accident or design. It is evident that on the return of the fall, the wedge D, if not held back by the rope C, will be carried in by the fall, and by taking its bearing against the collet E, will be jammed so fast against the sheave, as to retain it in opposition to any force tending to draw the fall through. The fall may be instantly released, and the load lowered, by drawing the fall just sufficient to liberate the wedge, which may then be held by the line C passing over the small roller F, and might be drawn entirely out of the block, but for the pin G, inserted into the wedge, and which stops against the collet E.

Fig. 4 is a front view of a pair of wooden blocks of four sheaves (being the lowest combination of which this method is susceptible,) and fig. 5 is a horizontal section of the lower block, showing the angular direction of the two sheaves, which in this case is requisite, to avoid the necessity of making the cross sheave so small as would be extremely detrimental to their action. The ellipse shown in the view of the lower block, and the indentation in the front of the section, show the situation and form of a groove cut in the wood for the sake of lightness.

The cross sheave in the top block is contained in a shell of metal, through which the strap passes, and thereby retains it in its proper situation, or the cross sheave may be contained in a mortise cut across the other, either at right angles or diagonally, in the same piece of wood.

The remaining figures in the plate, exhibit outlines of all combinations upon this plan, from five sheaves to twelve. In each figure the sheaves are numbered in their proper order, and the place of the ties is designated by a black dot.

It will be obvious to the experienced mechanic, that the improvement of tackle-blocks above described is not essentially different in principle from that of Smeaton; the fall in this method, as in his, passing immediately under the point of suspension, effectually preserves the perpendicularity of position; but with this important advantage, that the transfer from one side to the other is here effected by the intervention of only one sheave, instead of six, at least, employed for that purpose by Smeaton; and this increased simplicity of construction renders the present invention incomparably more applicable to general purposes.

LIST

OF

INVENTIONS, AND THEIR AUTHORS.

VOL. I.

Class I.—*Inventions relative to Manufactures and Trade.*

T. S. A. denotes *Transactions of the Society for the Encouragement of Arts, &c.*
Rew. *reward:* gs. *guineas:* the rewards are those given by the above Society
Com. *Communication:* dat. *dated:* v. *volume.*
Phil. Mag. *Philosophical Magazine*, by Alexander Tilloch.
R. A. *Repertory of Arts*, &c.
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On the refining of Lead, with remarks on the inconvenience of Ash Cupels, and the description of a new and economical Method of constructing Cupels or refining Vessels. Read in the French National Institute. By C. Duhamel, member of the Institute, and Inspector of Mines. Journal des Mines, No. 64. Phil. Mag. v. 14. 184

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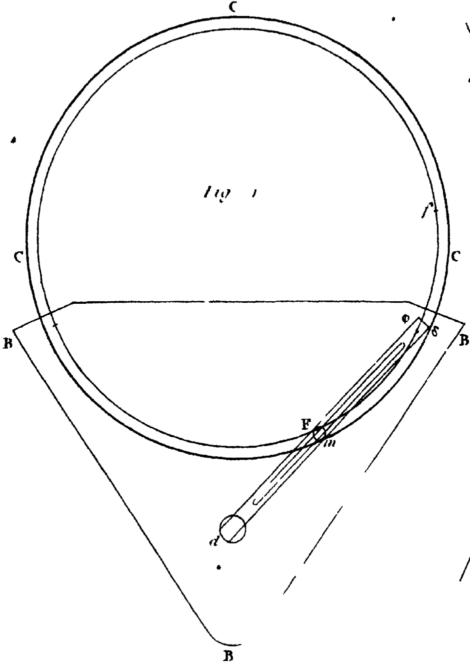
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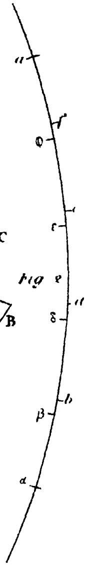
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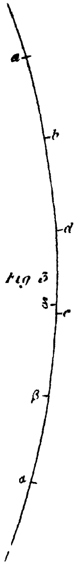
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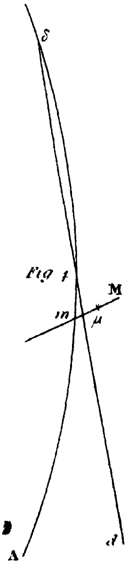
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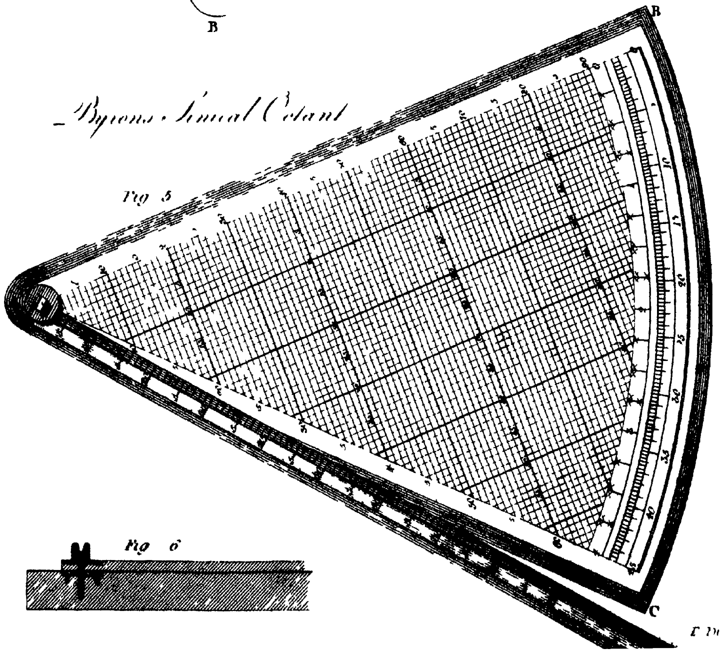
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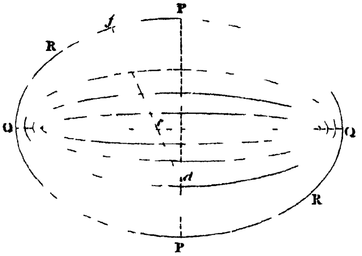

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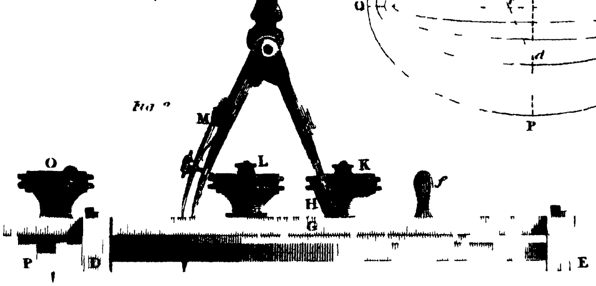
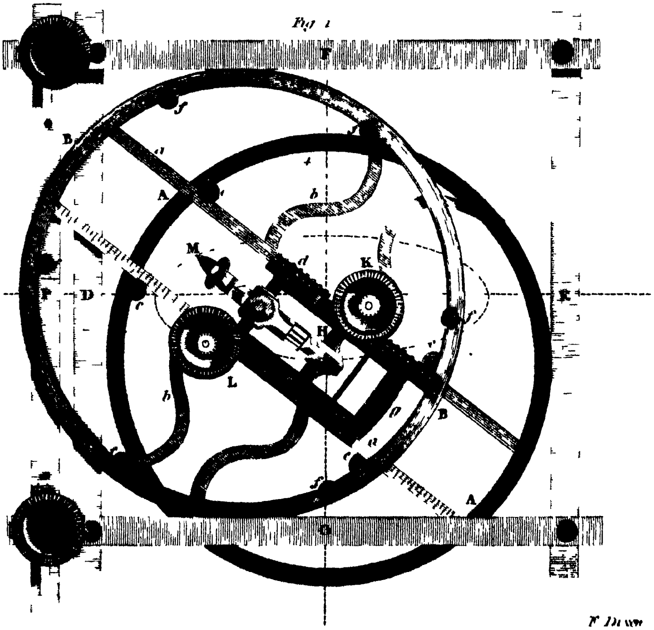


Fig. 1

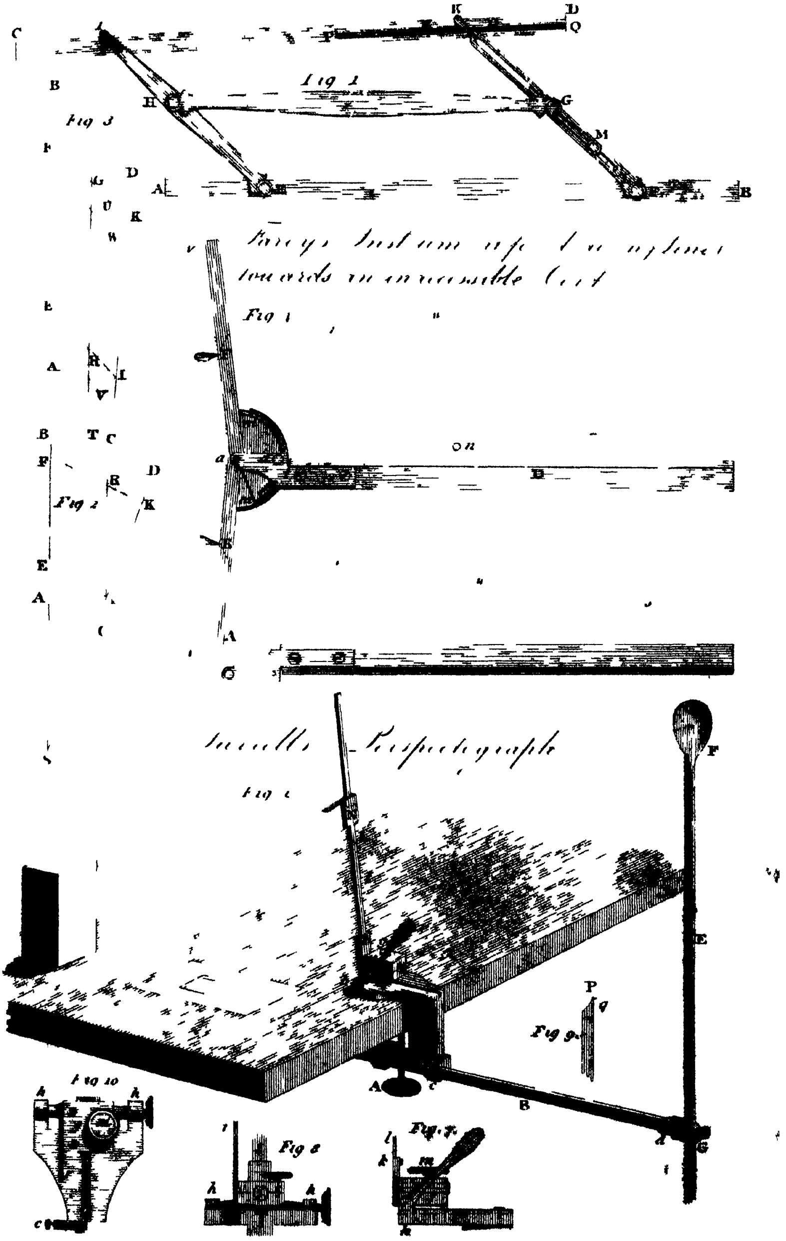


F Dunn

Nicholson's Centrolinead

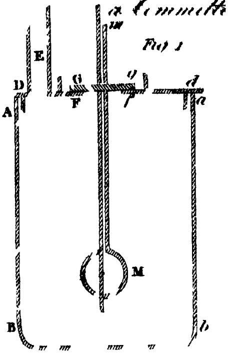
Farey's Instrument for drawing lines towards an inaccessible Point

[illegible] Perspectograph



Method of adjusting the fixed Points of Thermometers proposed by a Committee of the Royal Society

Fig 1



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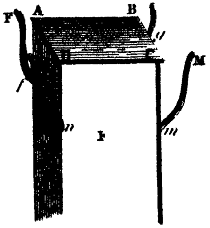

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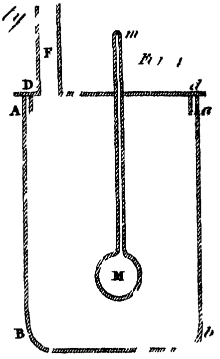

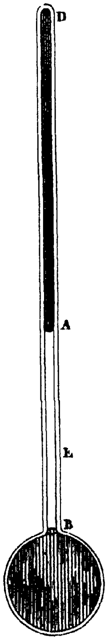

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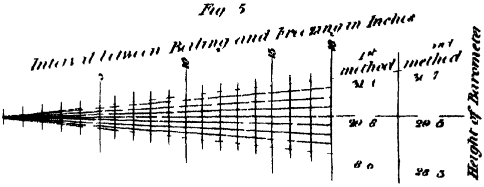

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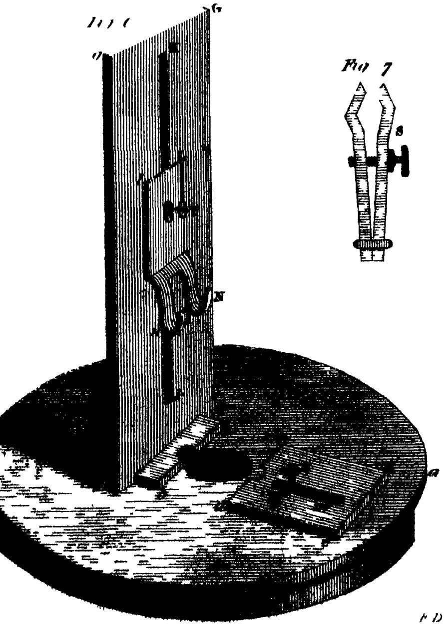

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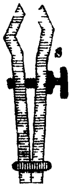

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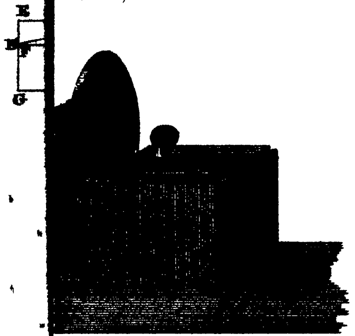

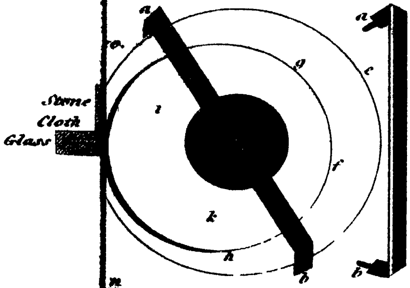

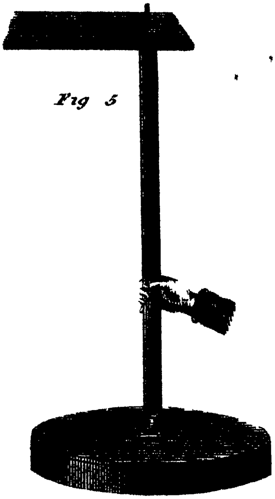
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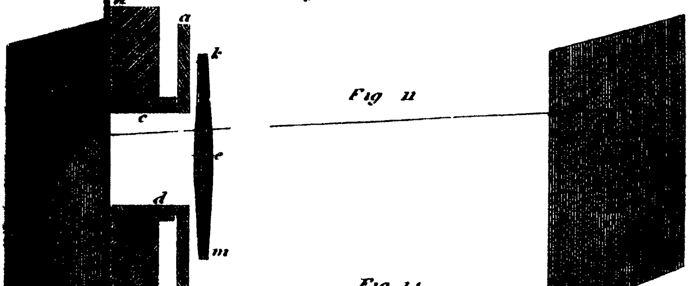
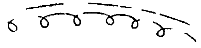


Fig 11

Fig 14


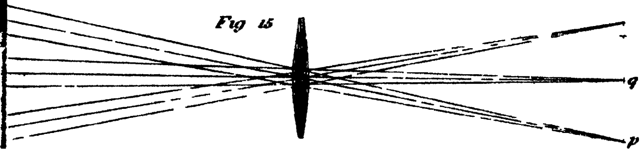
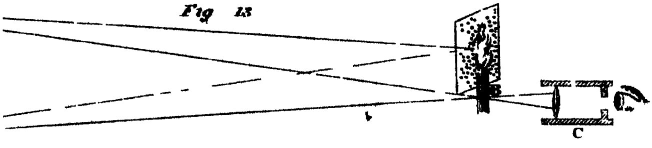
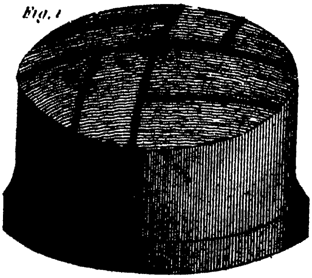


Fig 15

Fig 13


Mudge's method of forming the Specula for reflecting Telescopes.

Fig. 1



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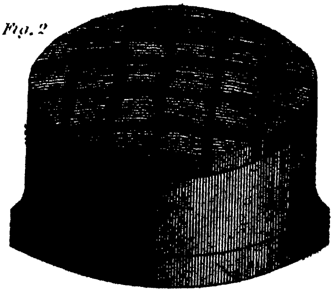

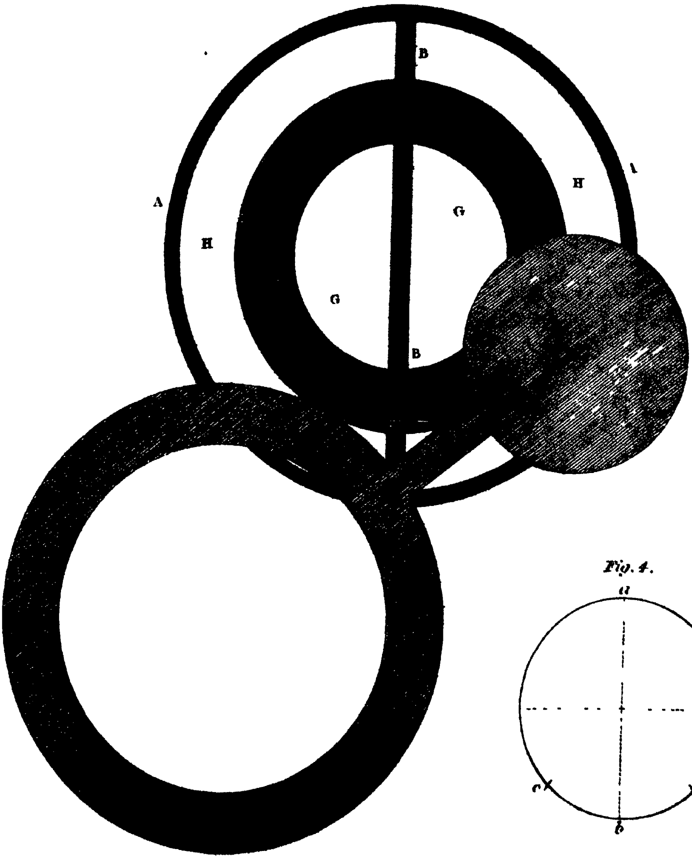

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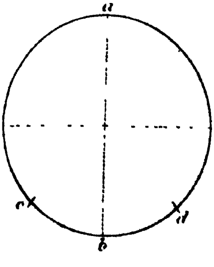
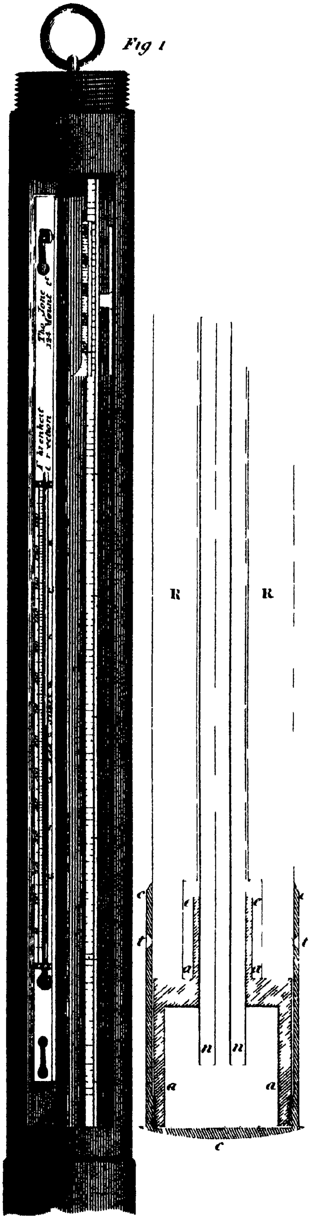
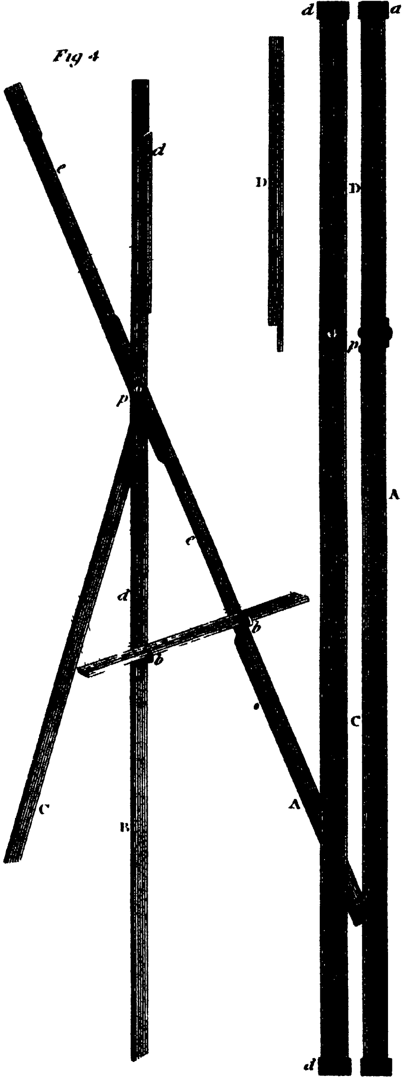


Sir H. C. Englefield's Mountain Barometer

Williams's Portable Easel





ircles & other Instruments

Fig 1

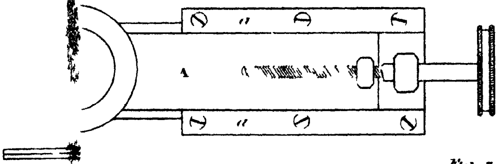


Fig 10

Fig 8

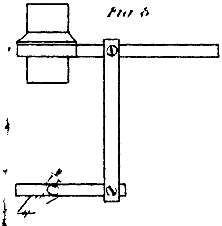


Fig 7

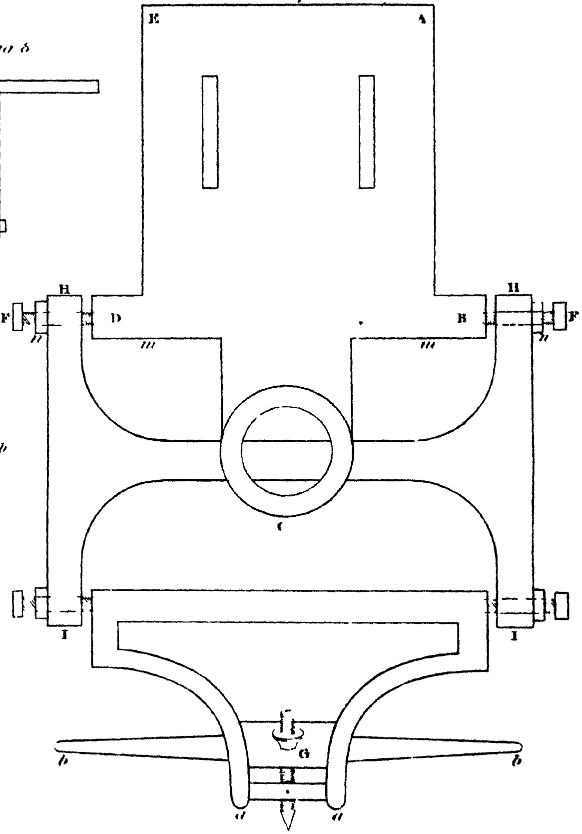
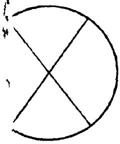


Fig 6



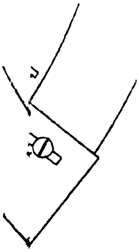
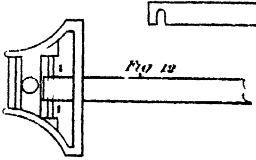


Fig 13

Fig 12



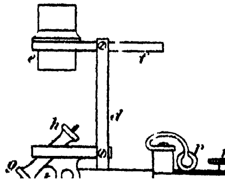
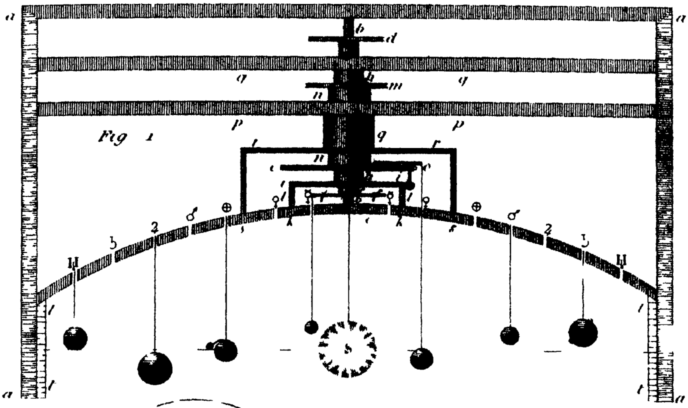


Fig 11

Allison's Pendant Planetarium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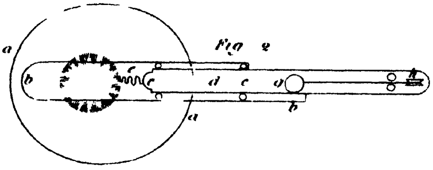


Fig 2

Dr Wollaston's reflective Gon

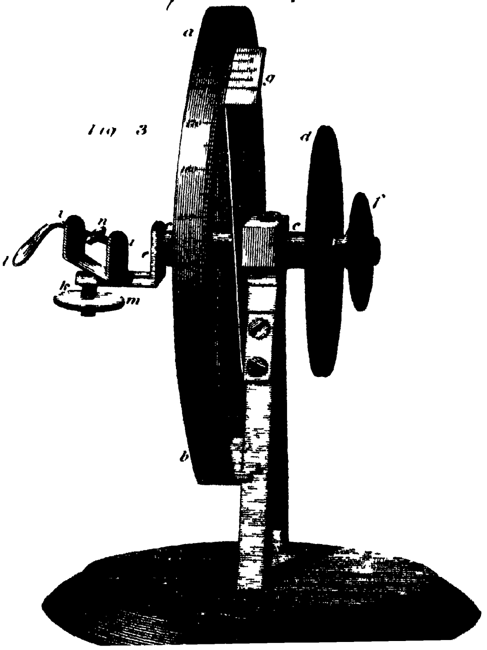
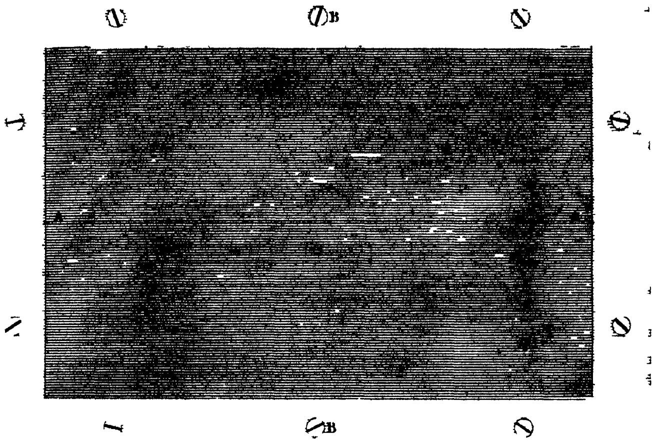


Fig 3

J D ×

Turrell's improved Drawing Board & T-square

Fig 1



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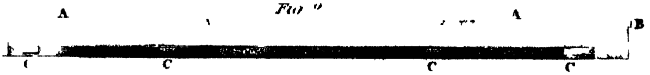


Fig 3

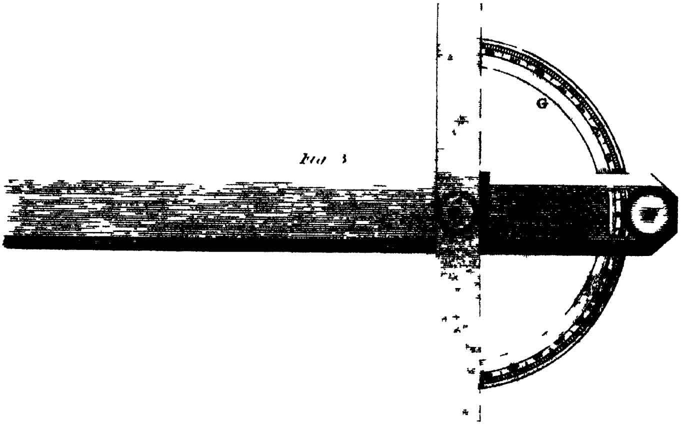


Fig. 4.

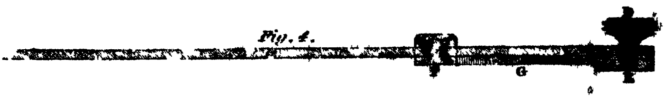
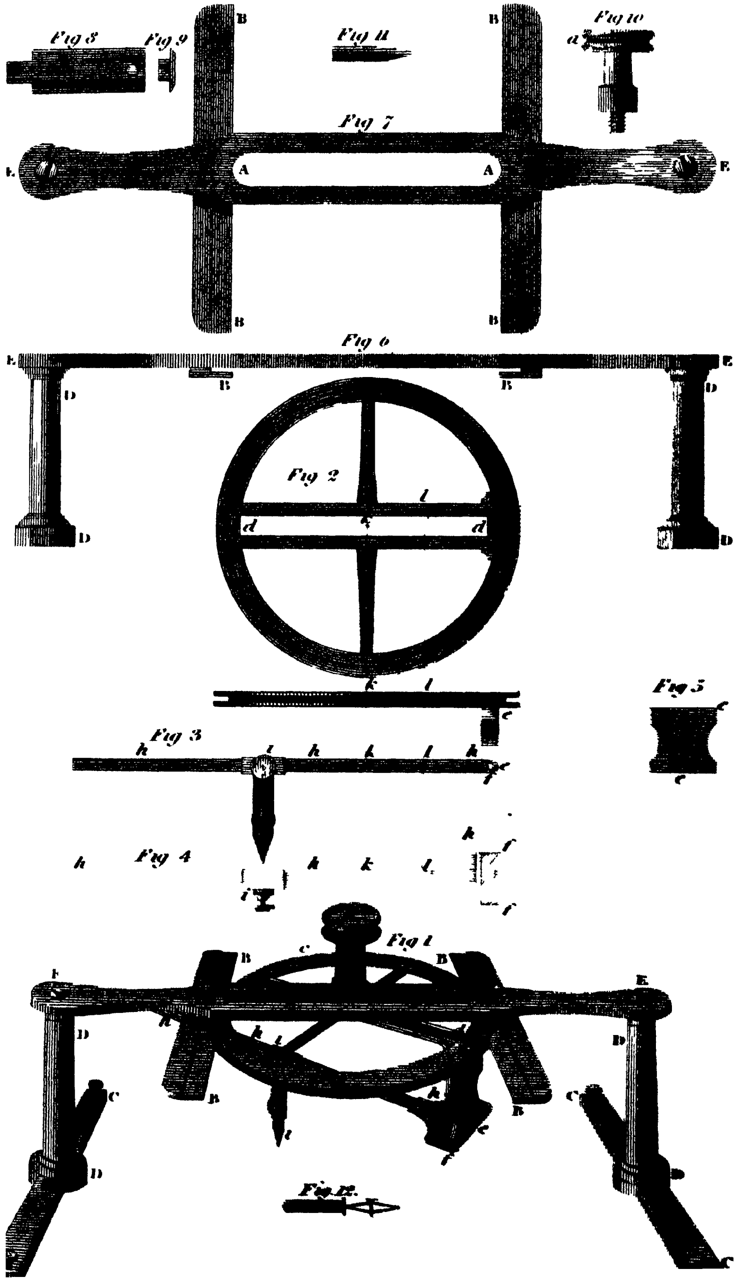


Fig. 5.

Cubitt's Instrument for drawing Ellipses



Barber's Angulometer.

Fig 1

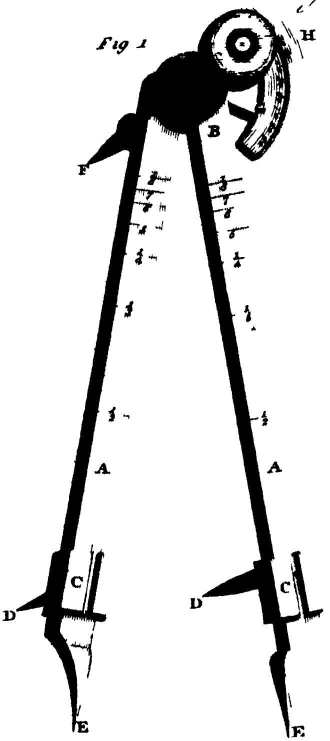


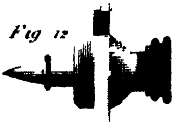
Fig 7

Fig 8

Fig 9

Fig 6

Fig 12



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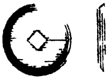

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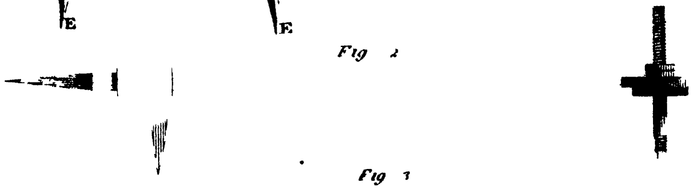
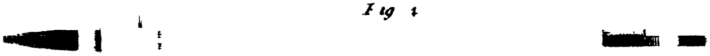


Fig 3

Fig 4



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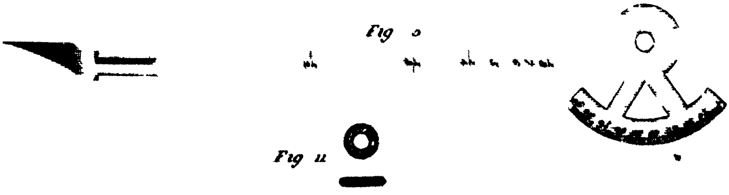

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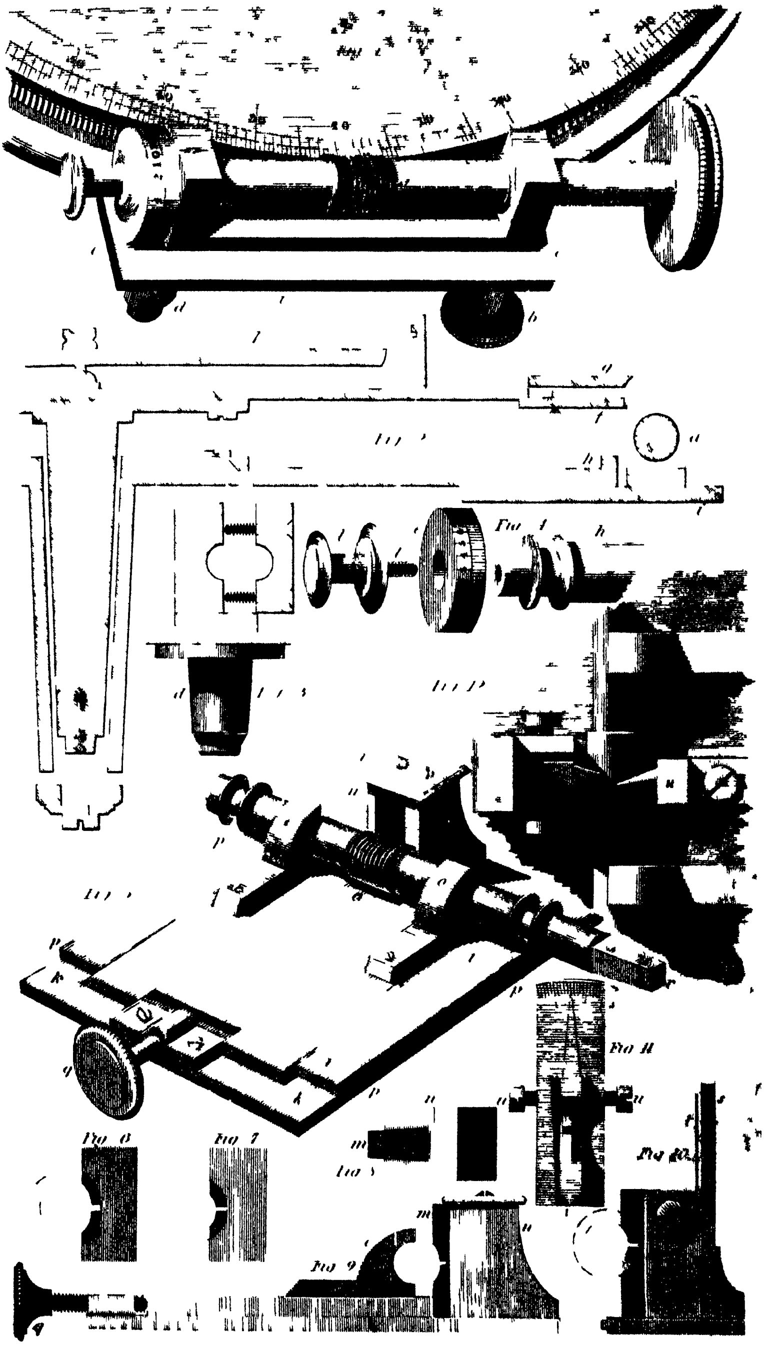
Fig 4
Fig 5
Fig 6
Fig 7
Fig 9
Fig 10
Fig 11
a
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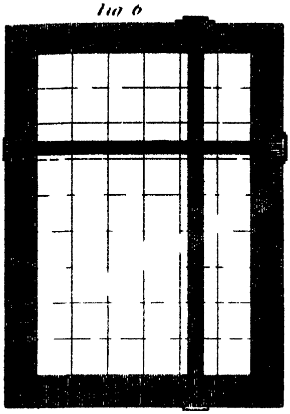
q

Mason's Perspectograph

Fig 6



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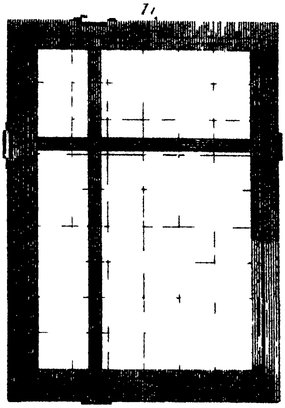
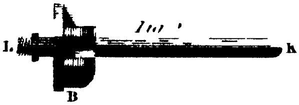


Fig 4

Fig 3

Fig 2



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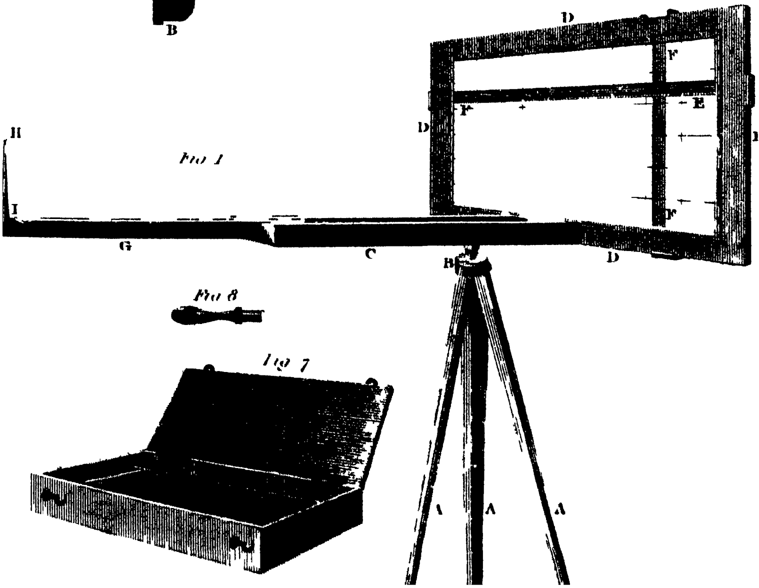
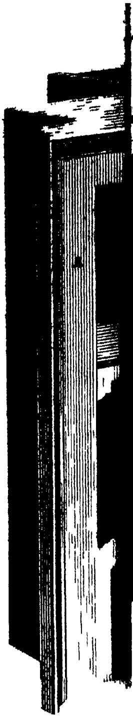


Fig 8

Fig 7

Floor

Youngs Ladder Fire Escap



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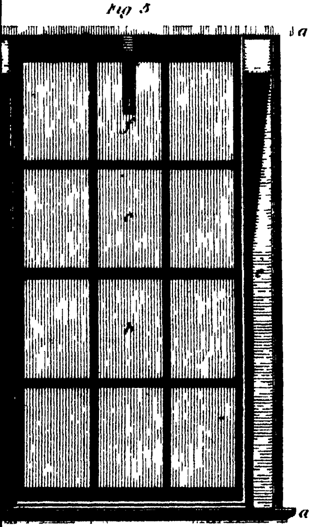
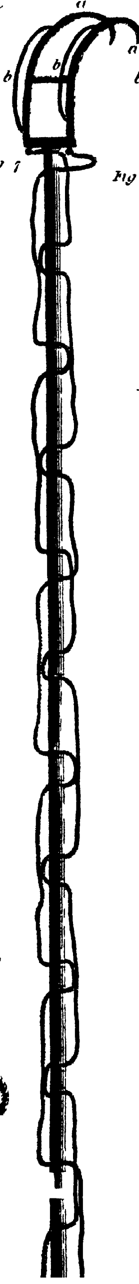


Fig 6

Fig 7



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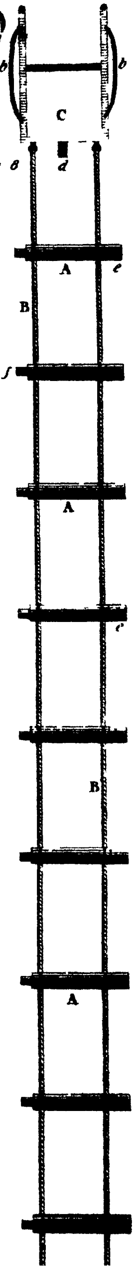
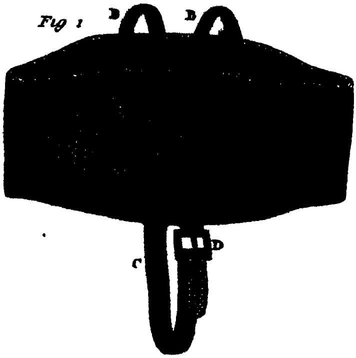


Fig 9

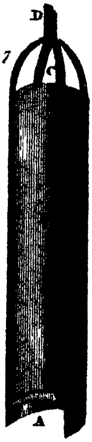
Daniel's Life Preserver

Fig 1



Eccleston. Peat Bore

Fig 7



Kneebones Drag for two-wheeled Carriages

Fig 2

Rapson's Drag for Carriages

Fig 3

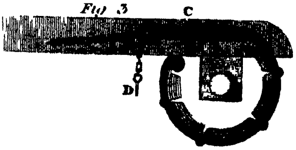


Fig 4

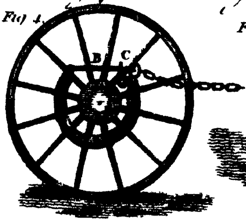


Fig 5

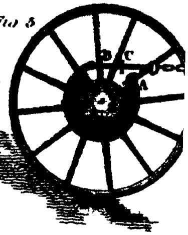
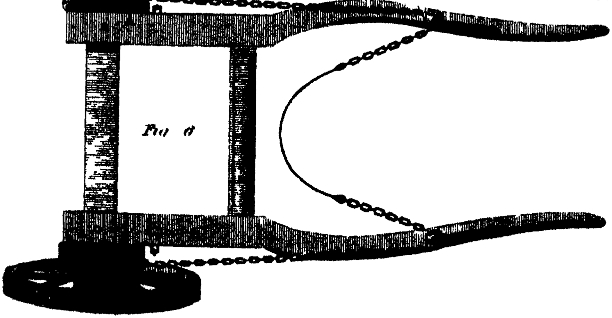


Fig 6



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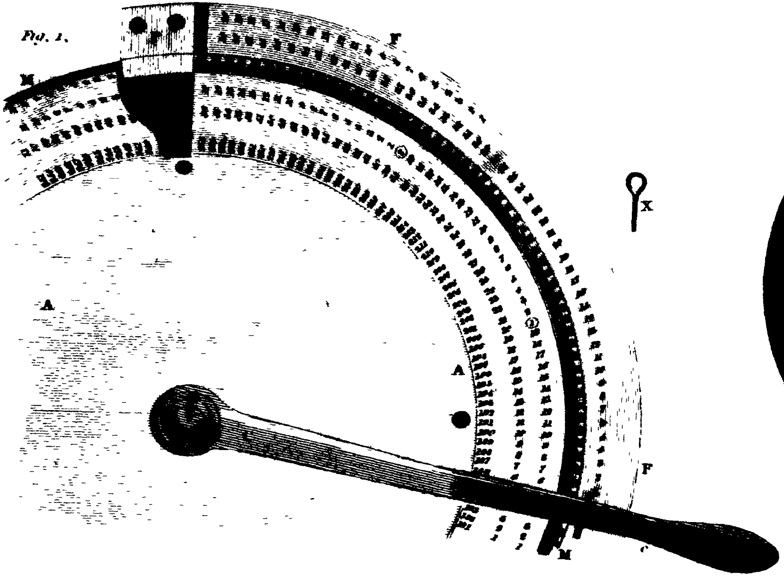

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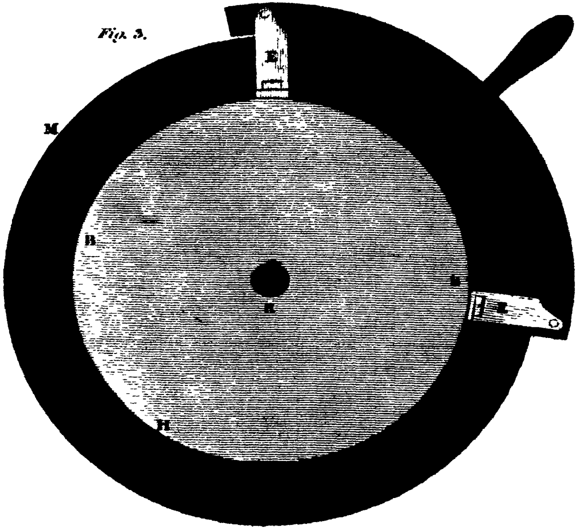

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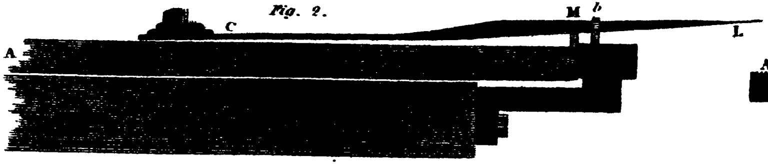

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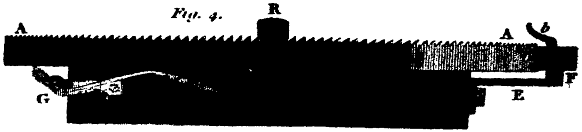
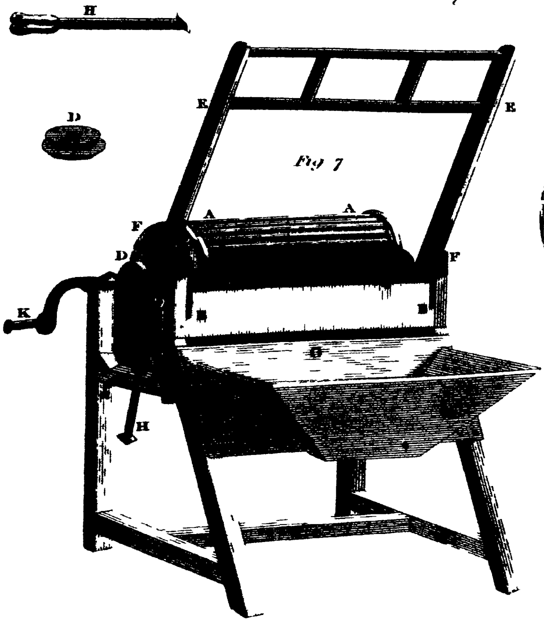
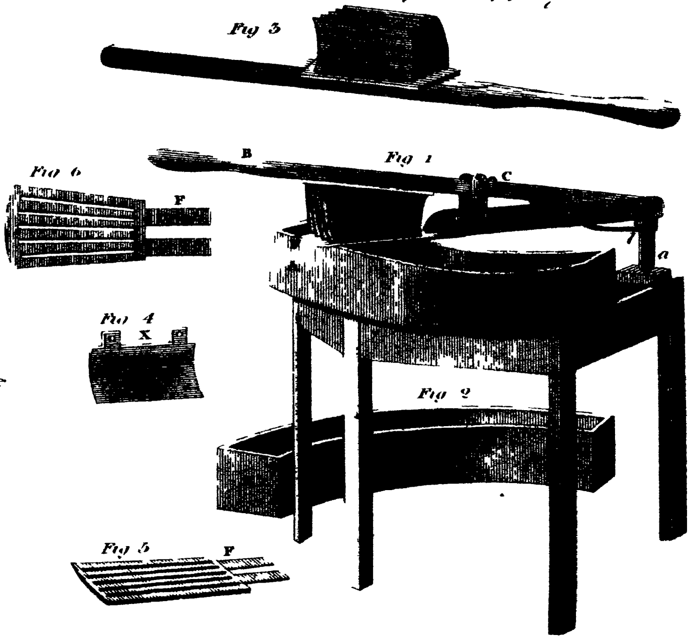


F Dixon sc

Lester's Machine for Washing Potatoes, and other esculent Roots for feeding Cattle.



Newton's Machine for chopping Roots.



Published by Henry Fisher Caxton London 1823

Lee's Thrashing Machine

Fig 1.

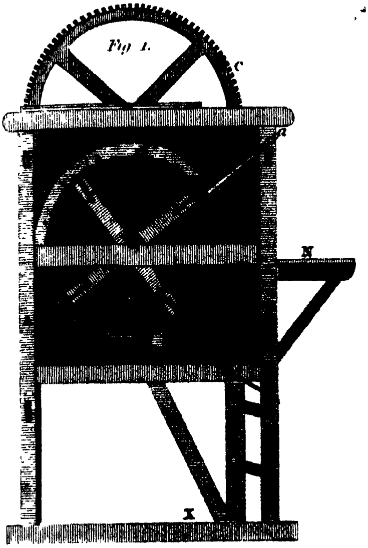
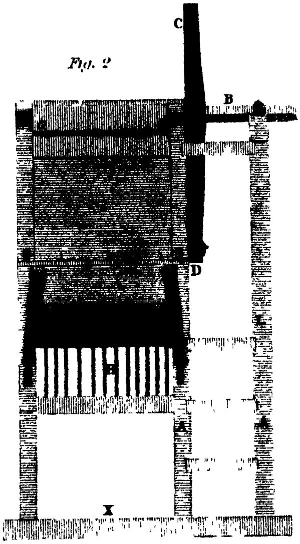
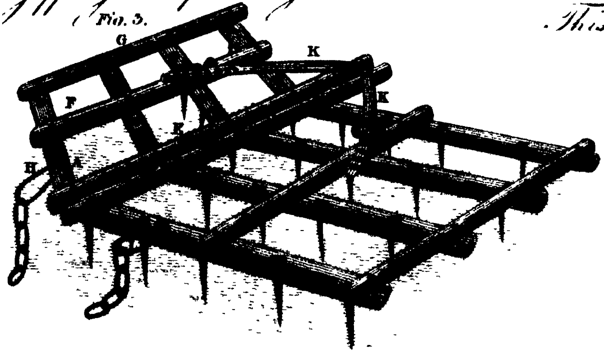


Fig. 2



Jeffery's Expanding Harrow

Fig. 3.

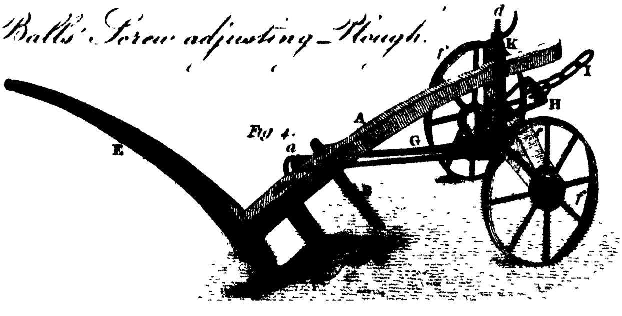


Baker's
Thistle Extirpato

Fig 5

Ball's Screw adjusting Plough.

Fig 4.



Trocar & Canula for relieving Hoven Cattle

Fig 7


Front view of the canula

Fig 6

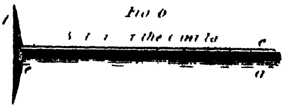
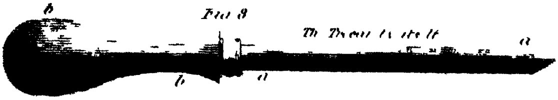

Side view of the canula

Fig 8


The Trocar by itself

Fisher's Iron headed Churn staff

Fig 11

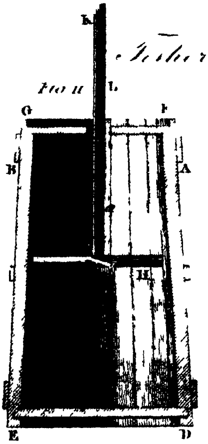


Fig 9

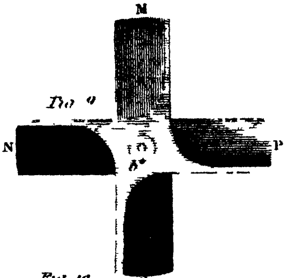


Fig 10

Tad's method of preventing Doors from dragging on Carpets

Fig 1

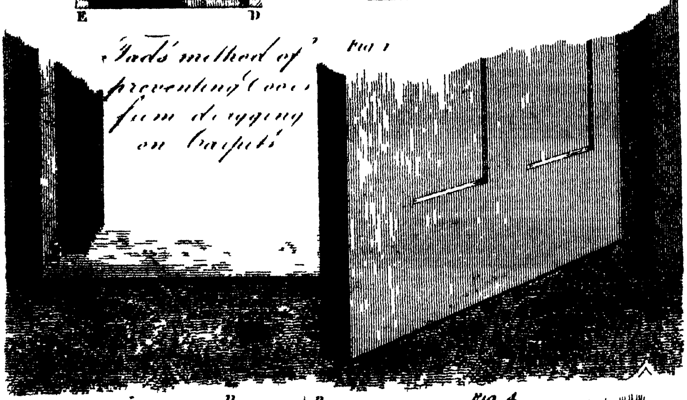


Fig 2

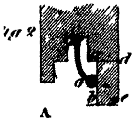


Fig 3

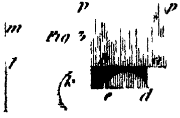
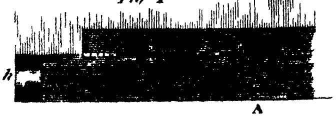
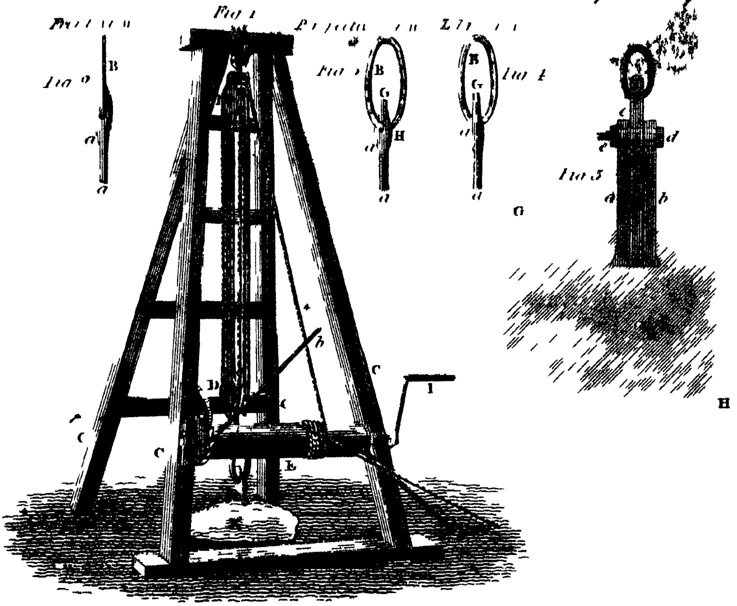


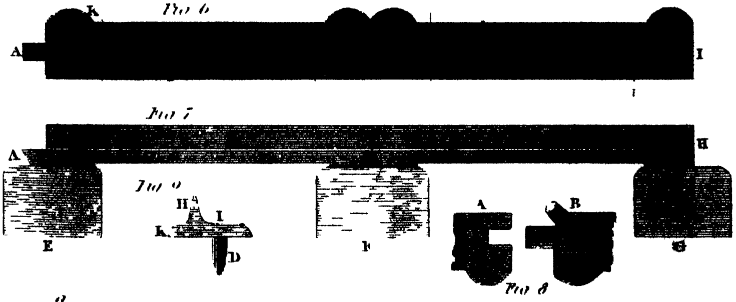
Fig 4



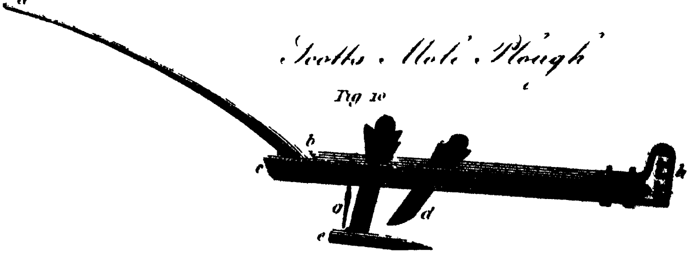
Richardson's method of raising large Stones out of the Earth



McCanns Improved Tram plates

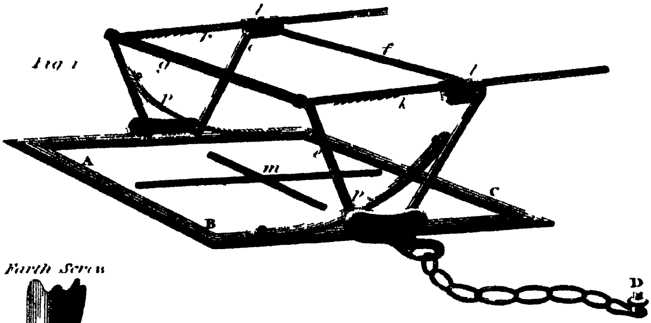


Scotts Mole Plough



Salmons Man Trap & Earth Screw

Fig 1



Earth Screw

Fig 2

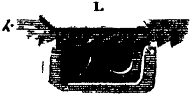
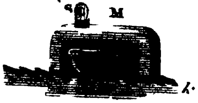
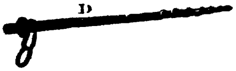


Fig 3





Greaves method of constructing Guide Posts

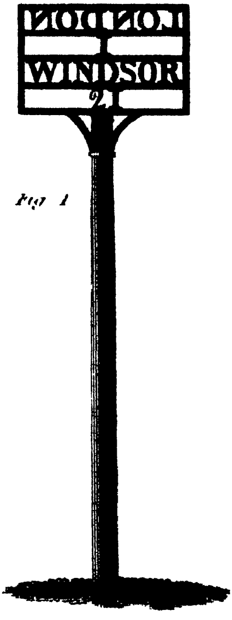


Fig 4

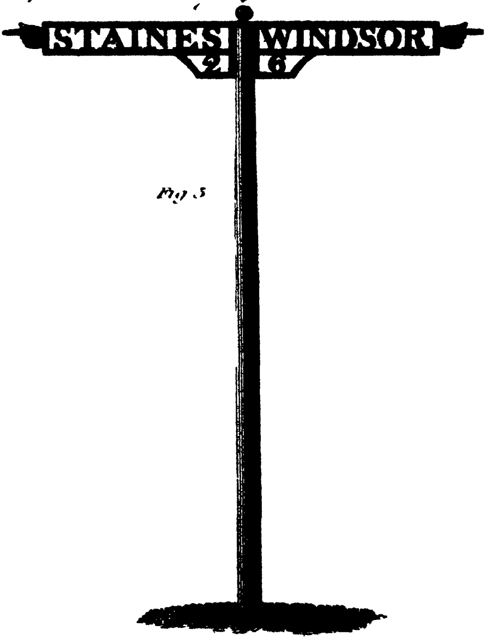
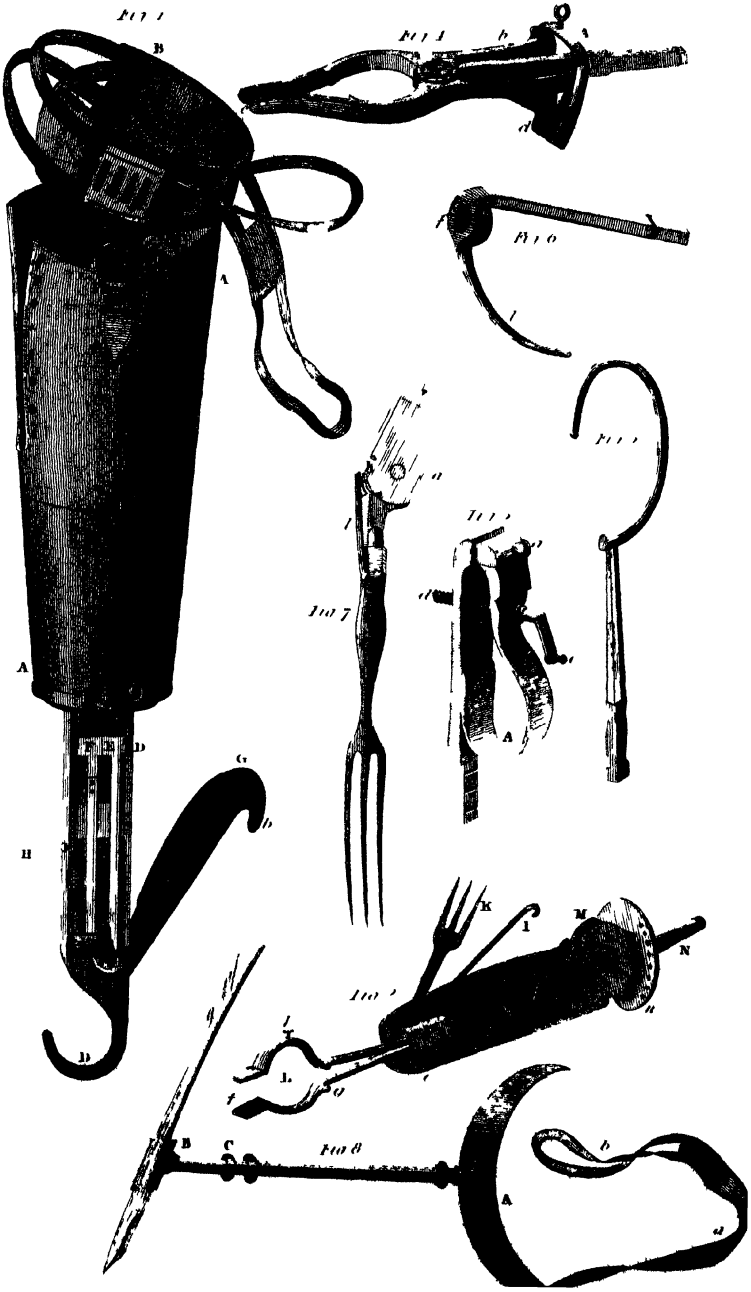
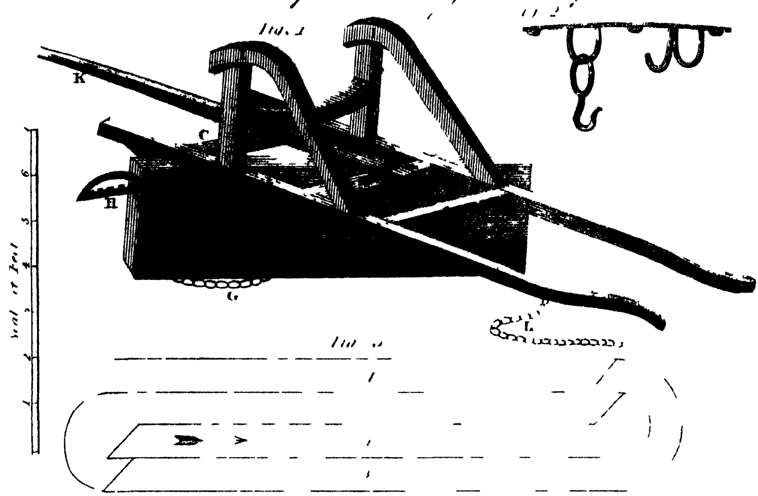


Fig 5

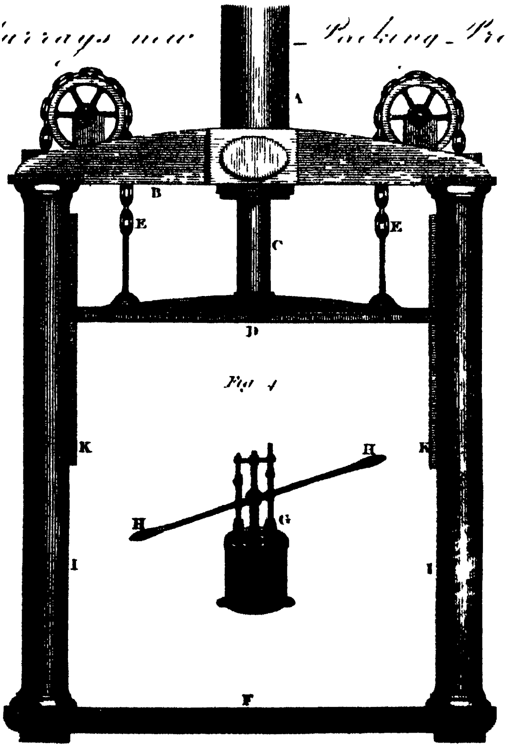
[illegible] Instruments for Persons who have lost their [illegible]



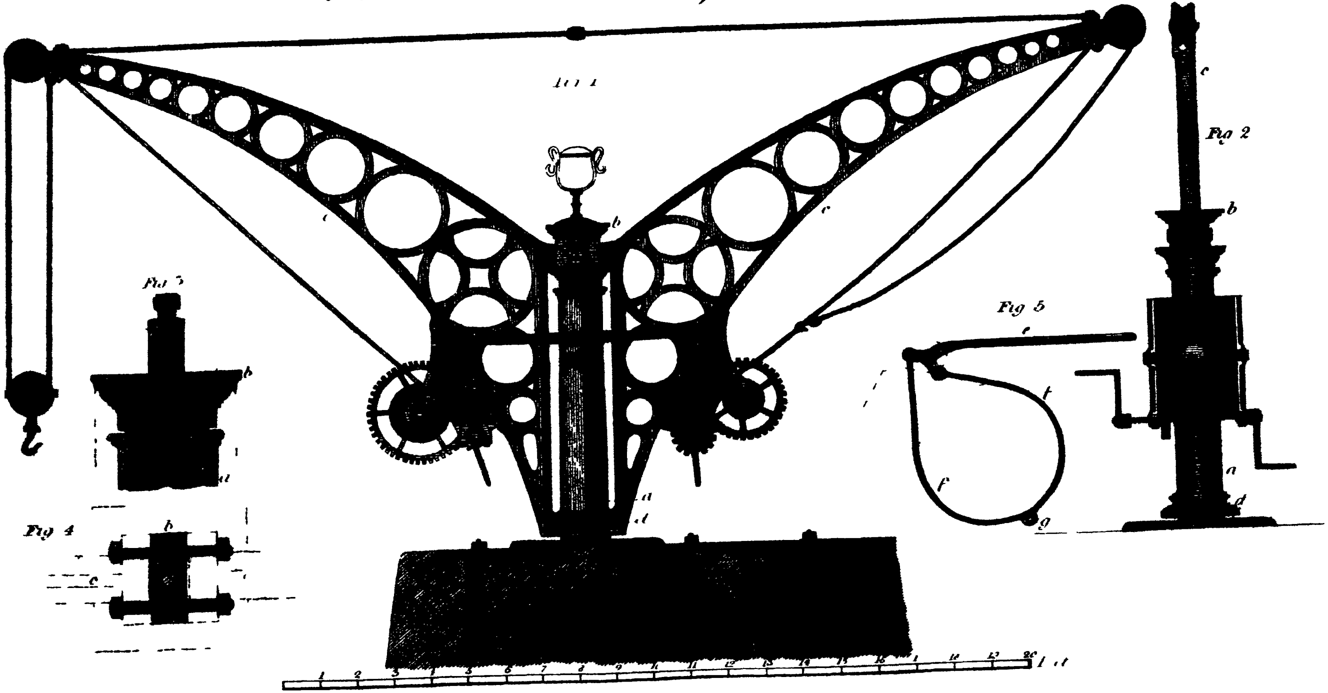
interbottom's Machine for cleaning Roads from Mud



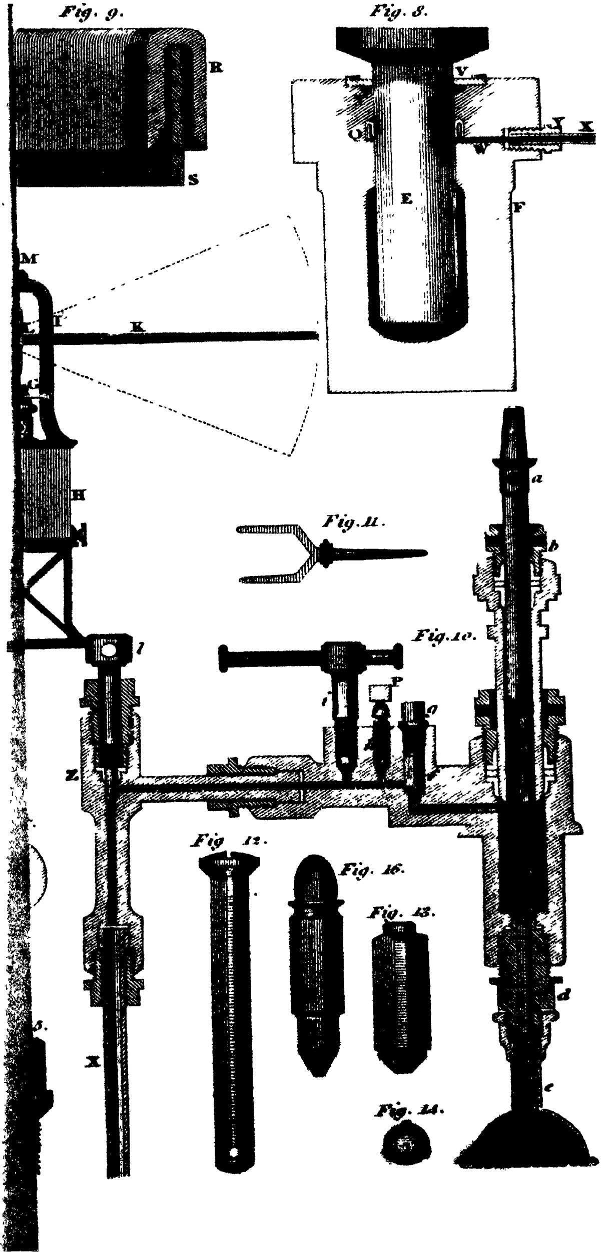
urray's new Packing-Press



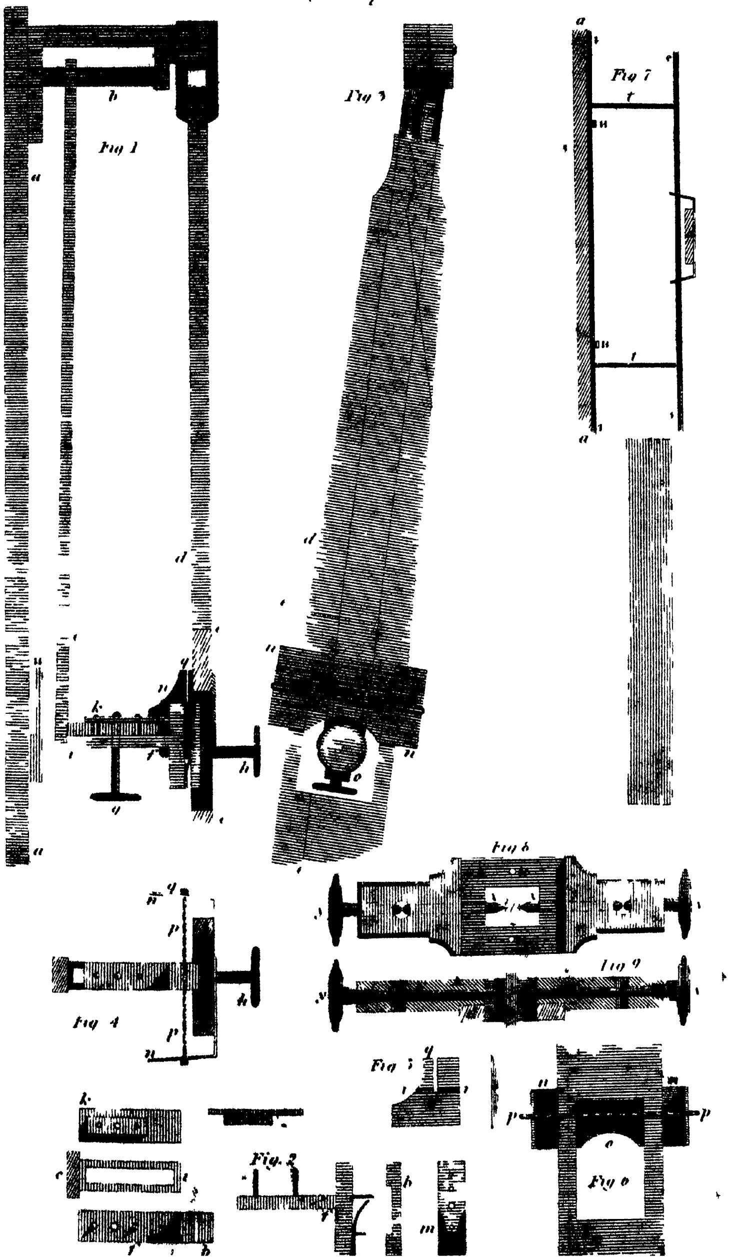
Hick's Cast Iron Double Jib Crane



Engineers, Bolton, Lancashire.



Ritchie's improved method of giving Motion to a Pendulum.



[illegible] C. 2

Benjn Wood's magnetical Instrument for ascertaining the Longitude at Sea

Fig 3

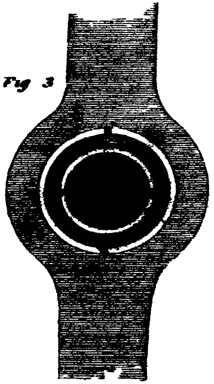
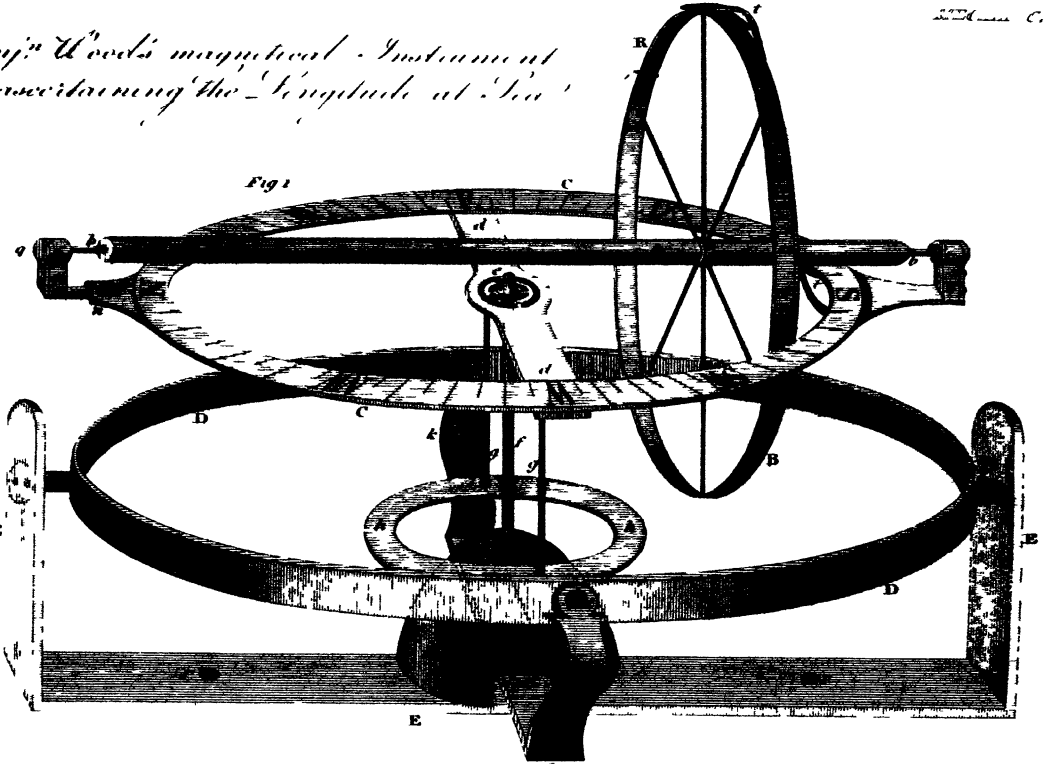


Fig 2

Fig 1



Jones's improved Pulley Blocks

Fig 1

Fig 2

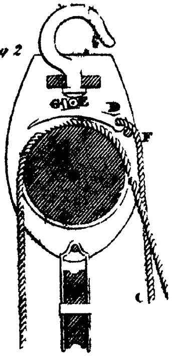
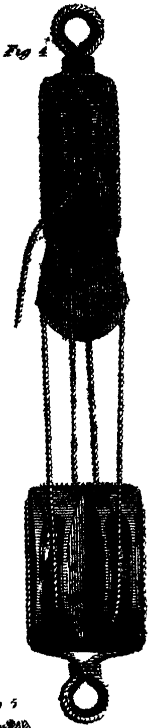


Fig 4



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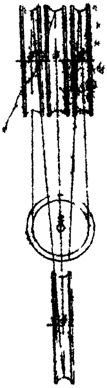
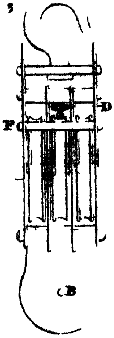


Fig 3



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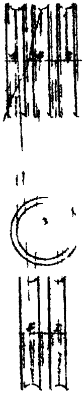

Fig 5

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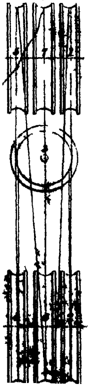

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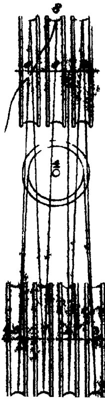

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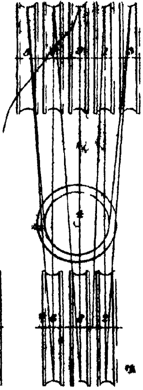

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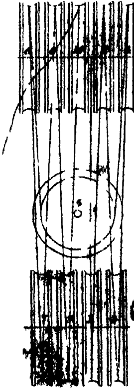

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