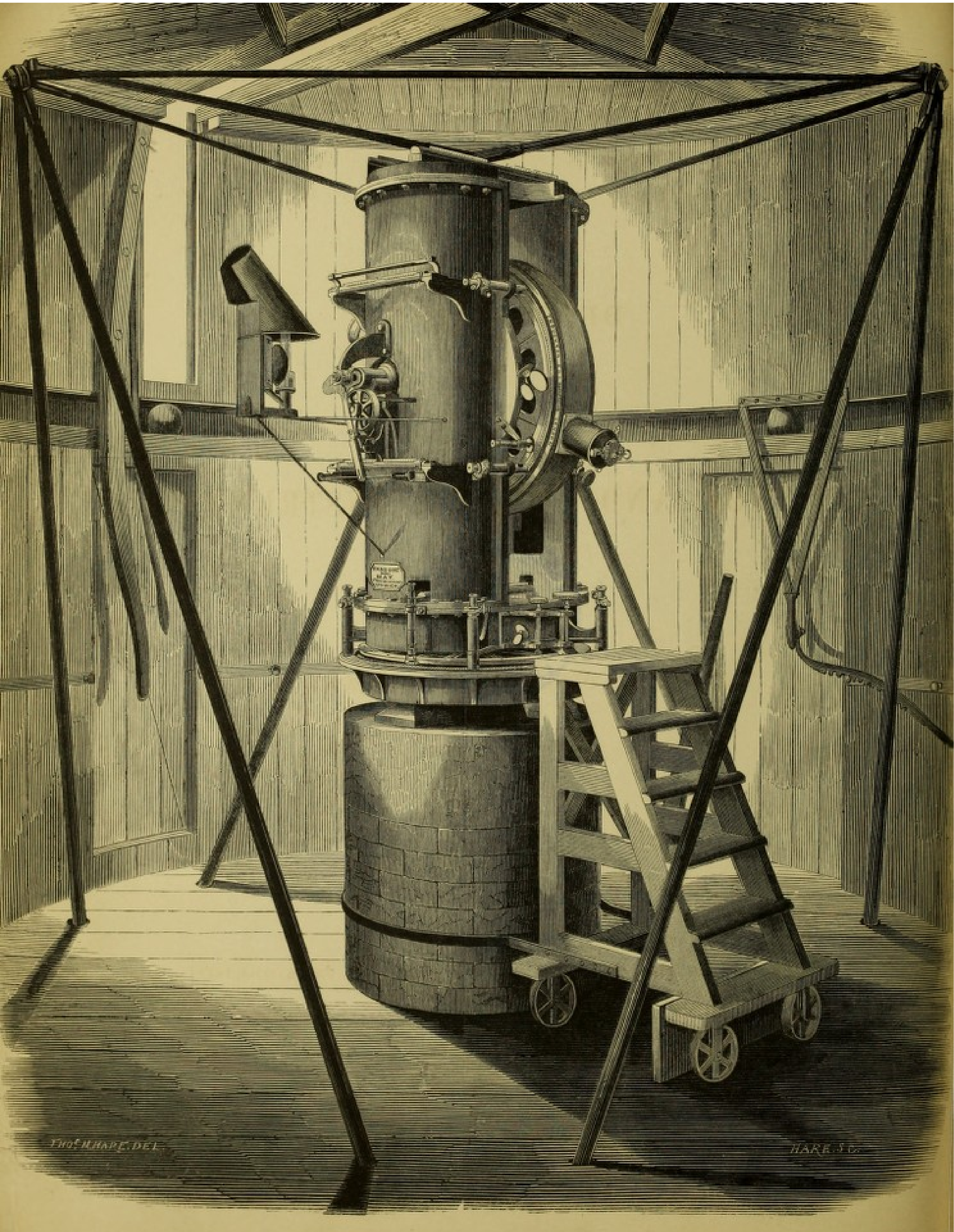

A PERSPECTIVE VIEW OF THE ALTITUDE AND AZIMUTH INSTRUMENT,

RECENTLY ERECTED AT THE ROYAL OBSERVATORY, GREENWICH.

FROM THE "ILLUSTRATED LONDON NEWS," SEPTEMBER 1847.

DESCRIPTION

OF THE

ALTITUDE AND AZIMUTH INSTRUMENT,

ERECTED AT

THE ROYAL OBSERVATORY, GREENWICH,

IN THE YEAR 1847.

[Extracted from the Introduction to the Greenwich Astronomical Observations, 1847.]

DESCRIPTION

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At the commencement of this Description is given a general perspective view of the instrument, to which the reader is referred for an understanding of the aspect of the instrument and the relation of its principal parts. The details are contained in Plates I., II., III., IV., to which the following explanations refer in every point.

It is proper to premise that the foundation of the instrument is a three-rayed pier of brickwork, unconnected with the surrounding building, &c.: that upon the three rays of this pier are laid the radial arms of the iron triangle which is the basis of the support of the upper pivot of the instrument, and that upon its center is placed a smaller pier that supports the fixed circle in which turns the lower part of the instrument: that the remaining parts of the frame supporting the upper pivot are in triangular arrangement, and possess very great firmness: and that in all the moving parts of the instrument the fundamental principles of construction have been:—to form as many parts as possible in one cast of metal,—to use no small screws in the union of parts,—and to leave no power of adjustment in any part; it being intended that the observations shall be so arranged that every instrumental error shall be deduced from the ordinary observations, and that numerical corrections shall be applied in the reduction of the observations.

In every part of the diagrams the same letters refer to the same parts.

Figure 1, Plate I., is a horizontal plan of the brick pier and the iron basis of the support of the upper pivot.

A is the central part of the pier, which is triangular.

B, B, B, the three rays of the pier. These are covered by blocks of Portland stone 4½ inches thick, which are continued inwards till they meet at the center. The height of the surface of this stone above the foundation is about 26 feet. The stones are channelled, and the radial arms D of the lower iron triangle are laid in the channels.

C, the upper cylindrical pier, covering the center of A, and covering also the center of the iron radial arms. Its top is a block of Portland stone, 1 foot thick. C is the support of the lower fixed circle of the instrument.

D, D, D, the radial arms of the lower iron triangle, $1\frac{1}{4}$ inch square, resting in the stone channels.

E, E, E, the three sides of the lower iron triangle, $1\frac{1}{4}$ inch square. They are welded to the radial arms D; and they have no support except at their extremities.

F, F, &c., the places of attachment of the rising bars of the side-triangles. Screw-bolts project horizontally from the sides of E E E, being welded to E E E; and upon these the eyes at the bottoms of the rising bars are forced by powerful nuts. The radial arms D, the sides E of the triangle, and the screw-bolts at F, form, by welding, one piece of metal.

G, G, &c., portions of the rising arms of the side-triangles, as projected on the horizontal plan. The lower triangle is entirely below the floor and floor-joists of the observing-room.

Figure 2 is an elevation of one of the three side-triangles.

F, the attachment of the eye at the bottom of the rising bar G, shewn more clearly in figure 2*a*.

G, G, the rising bars, which are round, $1\frac{1}{4}$ inch in diameter. They are welded together at the top, and at the place of their meeting a hole is pierced for the passage of the screw-bolt which is welded to the upper triangle.

H (see also figure 2*b*), a screw-bolt welded to the upper triangle, passing through the hole at the union of the arms G, where the screw H is drawn by a powerful nut.

I, I, portions of the sides of the upper triangle, which are round iron bars, $1\frac{1}{4}$ inch in diameter.

K, a fork, welded to the upper triangle, in which one of the upper radial bars rests.

L, a nut upon the end of the radial bar, which is cut with a screw.

The arms G G pass through holes in the floor of the room without touching it.

Figure 3 is the horizontal plan of the upper triangle with its radial bars and the upper Y for the rotation in azimuth.

G, G, &c., are portions of the rising bars, as projected on the horizontal plan.

H, H, H, the screws on the arms which project horizontally from and are welded with the angles of the upper triangle, passing through holes at the unions of the bars G G, &c., and drawn by powerful nuts.

I, I, I, the three sides of the triangle, welded in one piece.

K (see figure 3*a*), a fork which projects upwards from, and is welded with, each angle of the upper triangle. The sides I, the screws H, and the forks K, form, by welding, one piece of metal.

M, M, M, the three radial bars of the upper triangle, which are round, and 1 inch in diameter. They are welded together at the center, where they meet, and their ends are cut into screws. Each of these ends rests in a fork K, and carries two nuts, L, L, one exterior to K and one interior to it. By these nuts the fork K is firmly embraced, and the rod is prevented from sliding endways in it.

N is the upper Y, in which the upper pivot of the azimuthal motion turns. The triangular part of N is welded to M; the pivot is forced horizontally into the triangular part by a vertical plate which is screwed by bolts and nuts, and in which the spring of metal insures a firm and constant contact with the upper pivot. The three bars M and the triangular part N of the Y form, by welding, one piece of metal.

The Y was placed nearly in its proper position by the use of the pairs of nuts L L (every strain of these nuts producing a flexure of some part of the radial bars M), and then all the nuts L were made tight and the Y was left without further adjustment.

Figure 4 is a perspective view of all the parts described in figures 1, 2, 3; the floor being supposed to be removed, and no part of the instrument mounted except the lower fixed circle. The reader will remark that, in the perspective, the lower triangle is represented as viewed from above, and the upper triangle as viewed from below: and thus it will be seen that the sides of one of these triangles correspond to the angles of the other. The general arrangement of the rods represents the edges or arrêtes of a slightly irregular octahedron.

The azimuthal position of the triangles is not arbitrary. There was, however, only one reason to determine the selection of position, namely, that that position ought to be preferred in which the bars of the frame would least interrupt the telescope in the view of the Moon (the interruption of the view of a star being unimportant, as the observation might be deferred, or another star might be taken). The single bars offer no material interruption to the telescope; the only part which deserves consideration is the angle of the upper triangle, where five bars unite, and where there are also a fork, nuts, &c. Now it was obvious that, if the frame were so placed that one of these angles should be exactly South; then the two remaining angles would be in positions in which the Moon could never pass them; and the southern angle, though it would undoubtedly interrupt the sight of the Moon, would do so in a position of the Moon which is not favourable to observations with this instrument, and in which she would infallibly be observed with the meridional instruments. That position was therefore adopted for the frame; and every arrangement of the building, staircase, &c., was made in subordination to this choice.

The support for the upper pivot is exceedingly firm and steady; it requires no precise adjustment of the length of the bars (which would take perfectly firm bearing if the lengths of one or of several were erroneous, even to the amount of one or two feet), and is therefore made at small expense; and I would propose it for adoption in any other similar case. In the detail of workmanship I would propose as an improvement, that the three radial bars of the lower triangle should not be united at the center, or should be omitted entirely; and that the three angles of the lower triangle should be widened into broad thick plates, each admitting of a vertical hole in each side, through which the points of the rods G should pass: these points having screws cut upon them, and the rods G being drawn down by nuts below the horizontal triangle.

Figure *5* is a plan of the lower fixed circle, as viewed from above.

O, O, O, are the three cast-iron blocks, weighing 36 lbs. each, in which three spokes of of the circle rest. These are solid blocks, having projections below which enter into the stone capping of the central pier and are fixed there with plaster of Paris, and whose tops are cut each with a furrow to receive the spoke of the circle. A very little consideration will shew that there is but one position in which three given spokes can rest in three given furrows. These blocks have no adjustment whatever, and their furrows were cut to the proper depth by filing. The circle being dropped into them, the horizontality of its graduated limb was examined by means of a spirit level. When it was discovered which side was too high, the circle was raised, the furrows nearest to the high part were filed, and the circle was lowered and again examined in the same manner, till it was brought sufficiently near to horizontality.

P, P, P, are three of the spokes of the circle, resting in the furrows.

Q is the dove-tail furrow turned in the circle, for the insertion of the band of silver upon which the graduations are cut. The divisions are to every $5'$: the numeration of the divisions is in a continuous series from 0° to 360°, in the direction N., E., S., W., N.

The spokes, the cylindrical ring, and the flat circle, are of rather hard gun-metal, cast in one piece. The weight of this cast is 441 lbs.

R is a circle with interior toothed-wheel (in which act the pinions X X, figure 8, for slow motion in azimuth), screwed upon the solid cast circle. To avoid confusion, the teeth are not represented in figure *5*: but in figure *5 a* they are represented in full size.

Figure 6 is a plan of the lower fixed circle as seen from the lower side: it requires no explanation.

Figure 7 is a vertical section of the lower fixed circle. The teeth of the toothed wheel R are shewn in view; and two of the blocks O are also seen, one of which exhibits its furrow as viewed obliquely. The perforation at the center of the circle is for the bearing of the lower pivot of the revolving frame and for the counterpoise machinery, which will be explained in reference to figure 9.

In the case of constructing another instrument for the same purpose, it would be well to consider whether the graduated limb could not be carried by a circle entirely unconnected with those parts which carry the bearing of the pivot of the vertical axis and the toothed wheel for slow motion. When the instrument is turned by the toothed pinion X, there is no sensible tendency to turn the fixed circle: but when the instrument is turned by hand there is a tendency to turn the fixed circle and graduated limb, equivalent to the friction of the pivot upon its bearing. An arrangement such as I propose would perhaps be practically difficult.

Figure 8 is a horizontal plan of the lower part, or base-plate, of the frame revolving in azimuth, as viewed from below.

S, S, &c., are the vertical ribs, of cast-iron.

T, T, T, T, are the four micrometer-microscopes by which the graduations of the circle Q are read. The tubes of these microscopes are of iron, cast in the same flow of metal with the rest of the base-plate, and forming one piece of metal with it. They were cast solid and afterwards bored. The bored cylinders were bushed with brass (by a process which gives an almost metallic connexion with the iron), and in these brass linings were cut the screws for attachment of the object-glasses and the eye-tubes. The cases, &c., of the micrometers are attached by small screws in the usual way: but the piece which supports the pressure of the micrometer-screw, and upon which the accuracy of the micrometer depends, is cast in the same flow with the rest. The microscopes are marked **a**, **b**, **c**, **d**, in the order of the graduations of the lower fixed circle: **a** being at the observer's right hand when the graduated face of the vertical circle is Right.

V is the pointer-microscope, or microscope for reading the integer graduations of the circle Q. It is a plain microscope with cross-wires in its field of view: it is screwed to the edge of the base-plate. The only part of it seen in this view is its reflector.

W, W, are the two clamps (of which one only is used at a time) for taking hold of the projection of the circle to which R is screwed.

X, X, are the two toothed pinions (of which only one is used at a time, the other being withdrawn longitudinally) which act in the teeth of R, and by which a moderately-slow motion in azimuth is given to the instrument. It will be remarked, that there is no apparatus for very-slow motion, as by screws. The observations being made entirely by the observation of the time of transit over the wires in the field (whatever be the direction of the telescope, and whatever be the direction of the star's motion), no very-slow motion in azimuth is needed for an observation in azimuth; but a moderately-slow motion in azimuth is needed for an observation in zenith-distance, in order that the vertical transit may always be observed on the middle of the horizontal wires.

Y, Y, are reflectors, two on each side, by which the light of a lamp β in figure 22, which is thrown downwards by a reflector ϵ in figure 22, is turned horizontally to illuminate the reflectors of the microscopes T, T, T, T. In each system Y of reflectors, the two reflectors are inclined opposite ways, one to throw the light upon the right-hand microscope, the other to throw it on the left-hand microscope.

The weight of the base-plate, &c., is 340 lbs.

Figure 9 is a vertical section through the base-plate in its longest direction, and through the lower fixed circle, to shew the machinery of the counterpoise for relieving the vertical pressure of the lower pivot: and shewing also one of the levels parallel to the axis of the vertical circle.

Z is the counterpoise.

a, the lever on which it immediately acts.

b, the hook which serves as fulcrum for **a**.

c, the connecting rod, which is drawn upwards by **a**.

d, the hook which serves as fulcrum for **e**.

e, the lower lever by which the slider **f** is thrust upwards. This slider has a small hard steel cylinder at its top, acting against a similar cylinder inserted in the spherical pivot **g**: the ends of these cylinders where they are in contact are nearly flat, thus allowing the spherical pivot to remain in contact with the internal cone **h**. The slider **f** has a collar of leather to retain the oil.

g, the spherical pivot, of gun-metal, which takes bearing upwards in a socket in the base-plate, and downwards in a cone **h** of harder gun-metal in the lower fixed circle. It has a projection upwards to the top of the base-plate, for keeping it steady. The channel bored through it is for oiling the bearing of **g** upon **h**.

i, **i**, the flanges at the bottoms of the vertical cheeks. The dotted upright lines shew the section of the vertical cheeks (see figure 10), and other dotted lines shew the holes through which the ends of the level-bar pass (see z, figures 22 and 23).

j, **j**, the level-bar. This is a bar of cast-iron, one inch square, widened at one end in order to admit of two bearing-points (between which the screw passes), and having at the other end only one bearing-point, or rather narrow ring surrounding the screw. These points take bearing upon the flanges **i i** of the vertical cheeks; and the bar is held down by pretty strong screws. The support of the bar is made to depend on the external flanges of the vertical cheeks, because the level which it carries is intended to give information as to the position of the horizontal axis, whose bearings are on the external side of the vertical cheeks.

k, **k**, two brass Y's attached to the bar **j j**, in which the glass tube of the level rests, and into which it is pressed by light springs above.

l, **l**, two stops for preventing end-motion of the level: one of them is furnished with a spring.

m, the glass shade, covering the level and its scale. The numeration of the divisions of the level-scale proceeds in a continuous series of numbers from that end which is nearest the vertical cheek carrying the microscopes (figure 11) to that end which is nearest the vertical cheek carrying the clamping circle and toothed wheel (figure 12).

It must be remarked, that there are upon the base-plate two similar levels parallel to the axis of the vertical circle. The holes in the vertical cheeks through which they pass are seen at **z z** in figures 11, 12, and 23. No part of these levels or level-bars has any adjusting-screw, the adjustment having been effected by filing. The level which is nearest to the observer when the face of the vertical circle is right is marked **e**, **f**: the other **g**, **h**.

Figure 10 is a section, in the same direction as the section of figure 9, through one of the cast-iron vertical cheeks (namely, that which carries the microscopes).

n is the inner flat plate of the cheek, which is not continuous, very large parts being removed, as shewn in figures 11 and 12.

o is the exterior semi-cylindrical plate of the cheek, which is continuous, except that it is pierced with one hole for the pivot of the vertical circle, and with the holes for the level-bars **j j**.

p is the upper flange, by which the cheek is bolted to the upper plate.

q, **q**, are the brackets which carry the levels that are parallel to the plane of the vertical circle.

r is the bracket which carries the Y for the horizontal pivot. It appears here interrupted, the section passing through the large hole (see figure 14) through which the screw-bolt of the Y passes.

s is the Y for the horizontal pivot, of gun-metal, resting upon the bracket **r**, with a piece of lead between them. Its lower part passes through the hole of **r**, and is cut with a screw-thread, upon which is a powerful nut, by which **s** is drawn with great force into contact with **r**. There is no power of adjusting either of the Y's: they have been adjusted by filing.

t is the pivot of the vertical circle.

v, a counterpoise.

w, a lever, upon which **v** immediately acts.

x, a wheel-frame, supported by the other end of **w**.

y, a friction-wheel, turning in the frame **x** and supporting the pivot **t**.

Figure 11 is an elevation of the inner flat plate of that vertical cheek which carries the microscopes.

o, **o**, **o**, **o**, **o**, are portions of the external semi-cylindrical plate seen through the large openings of the inner plate.

z, **z**, are the holes through which the level bars **j j** pass.

a is the hole in the semi-cylindrical plate through which the pivot of the vertical circle passes.

b, *b*, *b*, *b*, are the four micrometer-microscopes. The description of T, T, T, T, figure 8, applies in every respect to *b*, *b*, *b*, *b*. The microscopes are marked A, B, C, D, in the order of the graduations of the Vertical Circle (see figure 18, below), A being the upper microscope which is nearest to the observer when the graduated face of the vertical circle is Right.

c is the pointer-microscope, for reading the integer divisions. Its reflector only is seen in this view: it is screwed upon the iron cheek.

The vertical cheek, the microscopes, the brackets which carry the levels, and the bracket which carries the Y for the pivot of the vertical axis, are all in one cast of metal. The weight of this cheek is 429 lbs.

Figure 12 is an elevation of the inner flat plate of the other vertical cheek.

d is the clamping-ring, for the clamp of the vertical circle.

e is a toothed wheel, in which acts the pinion *n* (figure 18), carried by the vertical circle.

d and *e* are upon a plate of gun-metal which is screwed to the iron plate.

The weight of this cheek is 421 lbs.

Figure 13 is a horizontal section, on a larger scale, through one side of the toothed wheel and clamping ring of figure 12, in the direction of a horizontal diameter of the toothed wheel. The ends of the teeth of the wheel *e* are seen in perspective here: their points or ridges being seen in figure 12.

Figure 14 is a horizontal section of the vertical cheek which carries the microscopes and the levels parallel to the plane of the vertical circle; with view (from above) of the lower pair of microscopes and lower level. The levels parallel to the plane of the vertical circle are of the ordinary English construction, the glass tube being fitted into a tube of thin brass by the insertion of plaster of Paris. The ends of the brass tube are connected with more solid pieces of brass, and these are screwed down to the brackets **q q**, the bearing being at one end upon two points between which the pressing-screw acts, and at the other end upon a thin ring surrounding the screw. There is no screw-adjustment; the adjustment was made by filing. The numeration of the level-scales is in a continuous series of numbers proceeding from right to left. The scale of the lower level (here shewn) is marked E, F: that of the upper level G, H. In front of the level is seen the glass shade, intended principally to protect the level from the heat of the lamp β in figure 22. I propose at some time to change this construction of levels for the German construction (in which the glass tube rests in Y's) adopted in the levels upon the base-plate shewn in figure 9. The latter levels were at first constructed on the English form, and, being very long, shewed very strikingly the defects of that construction, not only by the instability of their readings, but also by the changes in the value of the scale-divisions: and it was there found absolutely necessary to change the construction for the superior German construction. Hitherto no absolute necessity for the change of construction of the other levels has been felt; but it will doubtless be prudent to make the change.

The form of the ends of the microscopes (which is the same as for the microscopes T, figure 8) may also be seen. A thin tube of brass, lined with white plaster, and so long as very nearly to touch the divided limb (leaving the smallest possible interval) surrounds the microscope and is screwed to it: in one side of it is a hole for the admission of light; and within it is a reflector of the usual form, but covered with white plaster. The effect of this construction is, that, when sufficient illumination is used, the divisions are seen as dark strokes upon a light ground, without any appearance of specular reflexion and without any bright lines at their edges. The idea of this mounting of the illuminators was borrowed from instruments which I saw in Germany.

I will make one more remark common to all the microscopes of this instrument. The only adjustment which has been possible in the mounting of the object-glasses is, to put them in focus, without attempting to give any definite values to the divisions of the microscope-micrometers. The values of these divisions are therefore determined by trial, and they are (as might be expected) different for the different microscopes, and have no near relation to the ordinary sexagesimal divisions.

Figure 15 is a front view, on a larger scale, of one of the brackets supporting a Y, with the Y, the nut that draws it downwards, and the pivot. In the center of the pivot is a small plate carrying a fine dot, to be observed by the micrometer-microscope *z* (figure 22), for ascertaining the movements and consequently the form of the pivot. On the unperforated pivot, this plate is carried by the piece of metal which closes the pivot: on the perforated pivot, it is carried by a piece of glass which closes the pivot.

Figure 16 is a view from above of the cast-iron upper plate of the revolving frame.

f, *f*, &c., are the ribs diverging from the center.

g, the flange, which is bolted to the flange **p**, of the vertical cheeks, figure 10.

h, *h*, two cast-iron ribs (in the same cast of metal) upon which the upper levels are mounted.

i i, *i i*, two levels, similar in construction to that shewn in figure 14. The numeration of their scales proceeds continuously from the end next the vertical cheek which carries the microscopes to the other end. The level which is nearest to the observer when the graduated face of the vertical circle is Right is marked **i, k**; the other is marked **l, m**.

j, *j*, the roofed glass shades over the levels.

k, the upper pivot, of gun-metal, which turns in the Y marked N, figures 3 and 4.

Figure 17 is a section through the upper plate, in its longest direction. It exhibits the method of fixing the upper pivot.

The weight of the upper plate and pivot is 189 lbs.

Figure 18 is a side-view of the gun-metal vertical circle and telescope, on the side opposite to that which carries the divided limb.

l, *l*, &c., are curved spokes of the circle.

m is the clamp, which takes hold of the ring *d*, figures 12 and 13.

n is the toothed pinion which acts in the toothed wheel *e*, figures 12 and 13. This toothed pinion is intended to give a moderately-slow motion to the vertical circle; it is used for the observation of transits in azimuth across the vertical wires, to insure that the transits take place across the middle of the wires. There is no very-slow motion in zenith-distance.

o, the object end of the telescope, in the same cast of gun-metal with the greater portion of the circle. The object-glass is screwed into this.

p, the eye end, in the same cast of metal. The intermediate part of the telescope is a tube of thin brass.

q, the eye-piece, of brass, screwed into *p*.

r, a projecting plate, with a small eye-hole, and *s* a projecting ring with a larger hole. These two holes constitute the finder of the telescope.

It does not appear necessary to give a view of the other side of the circle, as it contains nothing peculiar except the graduated limb. The divisions are to every 5′: the numeration proceeds from 0° to 360°, in the order opposite to that of a watch-dial.

Figure 19 is a view of the vertical circle in the plane of the circle, the object-glass being in view.

t is the drum or intermediate part of the circle.

Figure 20 is a view of the eye-end, on a larger scale.

u is a rapid screw, by which the first slider is carried horizontally across the wires.

v is a pinion mounted in the first slider and acting in a rack attached to the second slider, by which the second slider is carried vertically over the wires.

w, the eye-piece, carried by the second slider. The parallel lines across it represent the groove in which dark glasses for observations of the Sun can be placed.

The system of wires in the eye-piece consists of six horizontal wires at intervals of 2′ very nearly, and of six vertical wires at intervals of 4′ very nearly.

Figure 21 is a section of the vertical circle through its pivots, shewing the connection of the two sides. The whole vertical circle, except the clamp, the pinion-mounting, the optical parts, the intermediate tube, and the finder, is formed in two casts. One cast comprehends the drum, the groove for the silver on which the divisions are cut, the spokes and pivot on one side, the object-end of the telescope, and the eye-end of the telescope. The other cast comprehends the spokes and pivot on the other side. The two sides are connected by powerful screws. The weight of the vertical circle is 401 lbs.

The weights above given are those of the castings, unfurnished with the instrument-maker's fittings. The weight of the latter (micrometers, levels, eye-pieces, &c.) is 210 lbs.

Figure 22 is a general elevation of the instrument complete, viewed in the plane of the vertical circle.

x, *x*, *x*, are glass shades protecting the levels which are parallel to the plane of the vertical circle. Their positions have been determined by the considerations that the levels are exposed to the radiation from the lamp *β*, and also to the occasional radiation from a hand-lamp which is necessarily held above the levels.

y, *y*, are two large projecting pieces of brass, for carrying two microscopes *z*.

z is one of the micrometer-microscopes for examination of the point on the pivot (figure 15). Microscopes are adapted to both the pieces *y*, *y*, but that on the side on which the lamp is placed is usually removed, to allow the light of the lamp to enter the perforated pivot. The microscope can be placed with its micrometer-head horizontal or vertical: and it is used first in the former position, to ascertain the horizontal movements of the point on the pivot as the vertical circle is placed in different positions; and then in the latter position, to ascertain the vertical movements of the point on the pivot as the vertical circle is placed in different positions.

α, α, α, are three rods supporting the lamp β.

The regulator of the illumination is omitted in this view.

Figure 23 is a general elevation of the instrument, viewed on the side of the graduated limb of the vertical circle.

γ is the regulator of illumination, turning upon a screw fixed in the wheel-frame **x**.

δ is a slender rod, sliding in two small pieces screwed to the brackets **q q**, with a pin which acts in the lower end of the lever carrying the regulator γ.

ϵ is a set of three reflectors on each side. The two smaller reflect the light of the lamp to the microscopes *b*, *b*, and abundantly illuminate the divisions under them. The larger reflects the light downwards to the two reflectors Y which illuminate the divisions under the microscopes T, T: when the reflectors are well polished this light is sufficient; at other times the assistance of a hand-lamp is desirable.

The woodcut at the commencement of the volume (for which the work is indebted to the proprietors of the *Illustrated London News*) represents the instrument as in use. The step-ladder, it will be seen, turns in a circle round the central pier. It has been found convenient to attach to the revolving frame two boards, whose edges are in a plane parallel to the plane of the vertical circle; the eye being directed along these to view the object, the instrument is placed very nearly in the proper azimuth; and then the telescope is directed accurately by the ring-finder *r s*. These boards are omitted in the views.

The dome is cylindrical, with double sides, between which the air can pass freely, and with sliding shutters. Its clear inner diameter is 10 feet.

The following is a history of the examinations and changes of the instrument made from its erection to the end of 1847. They are not given exactly in the order in which they were made.

I. Examination of the Graduations of the Horizontal Circle.

On various days from March 19 to April 20, Messrs. Dunkin and H. Breen were employed in the successive steps of this examination. The logical order is as follows:—First, it was assumed that, as no absolute assurance of the non-displacement of the center of the revolving frame could be given, there was no possibility of discovering the relation of the errors of two opposite divisions, whether fundamental (as 0° and 180°) or derivative: and therefore all our process through the larger arcs must consist in an examination of the relation of diameters; and we might assume the errors of both 0° and 180° to be zero, and might attribute the errors of other diameters equally to their terminal graduations: but in the subdivision of small arcs we might satisfy ourselves with examining one end of a diameter at a time, using for the terminal errors those found as above mentioned. Next (α), the errors of the diameter 90°—270° were found, and attributed equally to the two divisions 90° and 270°. Then (β), the errors of the diameters 45°—225°, 135°—315°, were found in like manner by bisecting the angles made by the last mentioned diameters, and were attributed equally to their opposite divisions. Then (γ), all the angles included between the diameters inclined 90° were bisected by a similar diametral process, and thus the errors of all the diameters inclined 15° were found. Then (δ), the arcs of 15° were trisected, not using the diametral process: and thus the error at every division of 5° was found.

(α). The four microscopes **a**, **b**, **c**, **d**, were read; **a** being placed first over 0°, then over 90°, then over 180°, then over 270°. This operation (of 16 readings) was repeated 20 times. The readings with **a** over 0° and **a** over 180° were grouped together and their means taken; similarly with **a** over 90° and **a** over 270°. In the former case, $\frac{\mathbf{b}+\mathbf{d}}{2} - \frac{\mathbf{a}+\mathbf{c}}{2}$ was found $= +\ 4''\cdot53$; in the latter, $\frac{\mathbf{b}+\mathbf{d}}{2} - \frac{\mathbf{a}+\mathbf{c}}{2} = +\ 2''\cdot13$. Half the excess of the former above the latter is the error due to the graduations 90° and 270°, and is freed from the errors of position of the microscopes. Hence, error of reading of division 90° = error of reading of division 270° $= +1''\cdot20$.

(β). Two microscopes p and q were clamped to the base-plate in positions advanced 45° beyond **a** and **c** respectively, and **a**, **c**, p, q, were read, **a** being placed at 0°, 45°, 180°, 225°, for one diameter, and at 90°, 135°, 270°, 315°, for the other. Each complete set was repeated ten times. The excess of $\frac{p+q}{2} - \frac{\mathbf{a}+\mathbf{c}}{2}$ when **a** was upon 0°, above the same quantity when **a** was upon 45°, was $+\ 2''\cdot29$; hence the error (in reading) of the diameter 45° — 225° above the mean of the two primary diameters is $+\ 1''\cdot15$, or its absolute error $+\ 1''\cdot75$. The excess of $\frac{p+q}{2} - \frac{\mathbf{a}+\mathbf{c}}{2}$ when **a** was upon 90°, above the same quantity when **a** was upon 135°, was $+\ 0''\cdot40$: hence the relative error of the diameter 135°—315° was $+\ 0''\cdot20$, and its absolute error $+\ 0''\cdot80$.

(γ). The microscopes p and q were clamped to the base-plate in positions advanced 30° beyond **a** and **c** respectively, and then by three steps of 30° each an arc of 90° was covered. These arcs were begun successively at 0° and 180°, at 90° and 270°, at 45° and 225°, and at 135° and 315°. Each complete set was repeated ten times. The value of $E = \frac{p+q}{2} - \frac{\mathbf{a}+\mathbf{c}}{2}$ being ascertained for each diameter at an interval of 30°, and the mean of three successive values being taken, and the excess of each individual E over the mean of the three being found; then (supposing the arc to begin at 0°) the first excess is the relative error of the diameter 30° — 210°, and the first excess + second excess is the relative error of the diameter 60° — 240°. To obtain the absolute errors, there must be added to the first of these $\frac{2}{3}$ of the error of the diameter 0° — 180° and $\frac{1}{3}$ of the error of the diameter 90° — 270°; and to the second of them $\frac{1}{3}$ of the error of the diameter 0°—180° and $\frac{2}{3}$ of the error of the diameter 90° — 270°. In this way were found the following numbers :—

Diameter.	Relative Error.	Absolute Error.
° °	″	″
30 — 210	— 0·70	— 0·30
60 — 240	— 0·94	— 0·14
120 — 300	+ 0·21	+ 1·01
150 — 330	— 0·17	+ 0·23
75 — 255	+ 0·29	+ 1·73
105 — 285	+ 0·22	+ 1·33
165 — 345	+ 0·36	+ 1·47
195 — 15	— 0·45	+ 0·99

(δ). Two microscopes *r* and *s*, whose construction admitted of their being brought within 5°, were clamped upon the base-plate at an interval of 5°, and by three steps of this arc an arc of 15° was covered. This was repeated five times for each arc. The process is in every respect the same as under (γ), except that diameters were not used, and therefore there was no taking of means in opposite positions or for opposite microscopes. The results are as follows :—

Division.	Relative Error.	Absolute Error.
°	″	″
5	— 0·53	— 0·20
10	— 0·22	+ 0·44
20	+ 0·04	+ 0·60
25	+ 1·33	+ 1·46
35	+ 0·75	+ 1·13
40	+ 0·88	+ 1·95
50	— 0·39	+ 0·73
55	+ 0·35	+ 0·84
65	0·00	+ 0·49
70	+ 0·39	+ 1·49
80	— 0·49	+ 1·06
85	— 0·71	+ 0·67
95	+ 0·09	+ 1·33
100	+ 0·08	+ 1·37

Division.	Relative Error.	Absolute Error.
°	"	"
110	+ 0·43	+ 1·66
115	− 0·16	+ 0·95
125	+ 0·29	+ 1·23
130	+ 0·42	+ 1·29
140	− 0·61	0·00
145	− 0·38	+ 0·04
155	− 0·18	+ 0·46
160	+ 0·52	+ 1·58
170	− 0·25	+ 0·73
175	+ 0·44	+ 0·93
185	− 0·63	− 0·30
190	+ 0·43	+ 1·09
200	− 0·35	+ 0·21
205	+ 0·42	+ 0·55
215	+ 0·15	+ 0·53
220	+ 0·09	+ 1·16
230	+ 0·55	+ 1·67
235	+ 0·49	+ 0·98
245	+ 0·43	+ 0·92
250	+ 0·14	+ 1·24
260	+ 0·14	+ 1·69
265	+ 0·26	+ 1·64
275	+ 0·29	+ 1·53
280	+ 0·47	+ 1·76
290	− 0·64	+ 0·59
295	− 1·43	− 0·32
305	− 0·14	+ 0·80
310	− 0·03	+ 0·84
320	+ 0·94	+ 1·55
325	+ 0·32	+ 0·74
335	− 0·54	+ 0·10
340	+ 0·43	+ 1·49
350	− 0·43	+ 0·55
355	− 0·06	+ 0·43

Remarking now that, by the process of reading the four microscopes, **a, b, c, d**, in all cases, the actual result of the error on the estimated position of the instrument will be the mean of the four errors for divisions 90° apart, we get the following Errors of Circle Reading.

Division under a.				Error.	Division under a.				Error.
°	°	°	°	"	°	°	°	°	"
0,	90,	180,	270,	+ 0·60	45,	135,	225,	315,	+ 1·27
5,	95,	185,	275,	+ 0·59	50,	140,	230,	320,	+ 0·99
10,	100,	190,	280,	+ 1·17	55,	145,	235,	325,	+ 0·65
15,	105,	195,	285,	+ 1·16	60,	150,	240,	330,	+ 0·05
20,	110,	200,	290,	+ 0·76	65,	155,	245,	335,	+ 0·49
25,	115,	205,	295,	+ 0·66	70,	160,	250,	340,	+ 1·45
30,	120,	210,	300,	+ 0·35	75,	165,	255,	345,	+ 1·60
35,	125,	215,	305,	+ 0·92	80,	170,	260,	350,	+ 1·01
40,	130,	220,	310,	+ 1·31	85,	175,	265,	355,	+ 0·92

It appeared that these apparent errors were not sufficiently large or sufficiently certain to require systematic correction in the Reduction of the Observations.

A microscope had been prepared for examination of every division, consisting of two optical arrangements in one barrel, at the interval of 1° very nearly (by which it was intended to quinquesect the arcs of 5°), and of two sets of wires carried by one micrometer-screw, at the interval of 5′ very nearly (by which it was intended to measure the interval from each division to the next). But, remarking that the circle was divided by the Dividing Engine, in which (from the nature of the screw-motion by which the circle is carried under the cutter) it is almost certain that the errors of division will very nearly follow a continuous law, and remarking the smallness of the errors at every 5°, it did not appear desirable to go through this laborious process.

II. Examination of the Graduations of the Vertical Circle.

At different times, from March 15 to April 12, Mr. Dunkin and Mr. H. Breen were occupied with the examinations of the graduations of the Vertical Circle. The process of observation and calculation was precisely similar to that for the Horizontal Circle, and (changing merely the figures expressing the equivalents of the micrometer-readings) the very same words will apply without any alteration. It appears therefore unnecessary to give the details, and sufficient to give the ultimate result.

Errors of Circle Reading in the mean of the four microscopes, for the Vertical Circle.

Division under A.				Error.	Division under A.				Error.
°	°	°	°	"	°	°	°	°	"
0,	90,	180,	270,	− 0·69	45,	135,	225,	315,	− 0·98
5,	95,	185,	275,	− 0·43	50,	140,	230,	320,	− 1·48
10,	100,	190,	280,	− 0·76	55,	145,	235,	325,	− 1·60
15,	105,	195,	285,	− 1·32	60,	150,	240,	330,	− 1·22
20,	110,	200,	290,	− 1·54	65,	155,	245,	335,	− 0·63
25,	115.	205,	295,	− 1·35	70,	160,	250,	340,	− 0·60
30,	120,	210,	300,	− 0·69	75,	165,	255,	345,	− 1·05
35,	125,	215,	305,	− 1·02	80,	170,	260,	350,	− 1·26
40,	130,	220,	310,	− 0·44	85,	175,	265,	355,	− 1·10

For the same reasons which applied to the Horizontal Circle, the examination of the errors of the smaller divisions was not continued; and no correction is systematically applied for these errors.

III. Examination of the form of the Pivots of the Vertical Circle.

Two sets of examinations have been made; the latter which was made on 1848, January 6 and 7, by Mr. Dunkin, is selected for detailed description.

(α) Examination of the Pivot opposite to the Graduated Face. The microscope for viewing the dot on the pivot was turned so that its micrometer moved in a truly horizontal direction, its wire being vertical. The observer read the micrometer when the wire touched the left edge, when it bisected the dot, and when it touched the right edge. The circle was turned so that the divisions under the pointer were successively 5°, 15°, 25°, &c., to 355°, then 355°, 345°, &c., to 5°, and the means of the six readings for each position under the pointer were taken. The readings increase as the micrometer-wire moves to the right. The following are the mean readings, expressed in terms of the micrometer revolution :—

Pointer.	Reading.	Pointer.	Reading.	Pointer.	Reading.	Pointer.	Reading.
°	r	°	r	°	r	°	r
5	1·695	95	0·738	185	2·856	275	3·837
15	1·401	105	0·828	195	3·142	285	3·733
25	1·150	115	0·970	205	3·381	295	3·574
35	0·986	125	1·185	215	3·592	305	3·357
45	0·806	135	1·406	225	3·784	315	3·121
55	0·720	145	1·695	235	3·894	325	2·847
65	0·657	155	1·982	245	3·953	335	2·560
75	0·631	165	2·258	255	3·974	345	2·275
85	0·651	175	2·548	265	3·917	355	1·980

In order to take into account the effect of excentricity of the dot, it is assumed that these readings can be expressed by the formula

$$a' + b'.\ \sin \text{pointer-reading} + c'.\ \cos \text{pointer-reading} + z',$$

a' being a constant of the micrometer, and b' and c' being rectangular co-ordinates determining the excentricity of the dot, and z' being a residual irregularity, which in the first instance is neglected. Determining a' by taking the mean of all the readings, b' by comparing the group from 5° to 175° with that from 185° to 355°, and c' by comparing that from 275° to 85° with that from 95° to 265°, we find

$$a' = 2^{r}\cdot 280,\ b' = -37^{r}\cdot 468 \times \frac{\sin 5^\circ}{2},\ c' = -10^{r}\cdot 122 \times \frac{\sin 5^\circ}{2}.$$

The microscope was then turned so that the micrometer moved in a truly vertical direction, the readings increasing as the wire was carried downwards; and the following mean readings were found in the same way:—

Pointer.	Reading.	Pointer.	Reading.	Pointer.	Reading.	Pointer.	Reading.
°	r	°	r	°	r	°	r
5	0·526	95	2·849	185	3·729	275	1·447
15	0·709	105	3·085	195	3·558	285	1·196
25	0·918	115	3·301	205	3·354	295	0·988
35	1·147	125	3·487	215	3·112	305	0·789
45	1·414	135	3·661	225	2·868	315	0·599
55	1·716	145	3·765	235	2·580	325	0·462
65	1·997	155	3·826	245	2·318	335	0·410
75	2·287	165	3·834	255	2·004	345	0·402
85	2·590	175	3·811	265	1·730	355	0·464

Assuming that these readings can be expressed by the formula

$$a'' + b''.\cos \text{pointer-reading} - c''.\sin \text{pointer-reading} + z''$$

the following values were found in the same manner as before:

$$a'' = 2^r{\cdot}137,\ b'' = -36^r{\cdot}813 \times \frac{\sin 5^\circ}{2},\ c'' = -12^r{\cdot}911 \times \frac{\sin 5^\circ}{2}.$$

Now if our operations of every kind had been perfectly correct, since the excentricity which gives rise to the constants b'' and c'' is the same which gives rise to the constants b' and c', we may consider the values found for b' and b'' as two different determinations of the true constant b, and similarly for c. Adopting the mean, we have as the expression for the horizontal measure

$$2^r{\cdot}280 - 1^r{\cdot}618 . \sin \text{pointer-reading} - 0^r{\cdot}502 . \cos \text{pointer-reading} + z'.$$

and for the vertical measure

$$2^r{\cdot}137 - 1^r{\cdot}618 . \cos \text{pointer-reading} + 0^r{\cdot}502 . \sin \text{pointer-reading} + z''.$$

Computing the values of these formulæ for the pointer-readings 5°, 15°, &c., and comparing them with the quantities measured, we find the following values for the residual errors z', z'':

Pointer Reading.	z'	z''	Pointer Reading.	z'	z''	Pointer Reading.	z'	z''	Pointer Reading.	z'	z''
°	r	r	°	r	r	°	r	r	°	r	r
5	+ ·056	− ·042	95	+ ·027	+ ·063	185	− ·064	+ ·025	275	− ·011	− ·050
15	+ ·024	+ ·006	105	− ·018	+ ·046	195	− ·041	− ·013	285	+ ·019	− ·038
25	+ ·008	+ ·035	115	− ·056	+ ·026	205	− ·036	− ·037	295	+ ·041	− ·011
35	+ ·047	+ ·048	125	− ·056	+ ·011	215	− ·028	− ·062	305	+ ·039	− ·007
45	+ ·025	+ ·066	135	− ·084	+ ·026	225	+ ·005	− ·059	315	+ ·053	− ·083
55	+ ·035	+ ·095	145	− ·069	+ ·015	235	000	− ·072	325	+ ·051	− ·061
65	+ ·056	+ ·088	155	− ·069	+ ·011	245	− ·004	− ·046	335	+ ·052	− ·048
75	+ ·044	+ ·086	165	− ·087	+ ·005	255	+ ·002	− ·068	345	+ ·061	− ·042
85	+ ·028	+ ·093	175	− ·091	+ ·019	265	− ·019	− ·046	355	+ ·061	− ·016

These are the irregularities in the motion of a point the nearest possible to the center of the pivot, depending upon nothing but the irregularity of form of the pivots and the errors of observation. The law of the irregularities (as well as that of the discordance between b' and b'', c' and c'') would seem to shew that the two positions of the micrometer were not exactly at right angles; this assumption with a proper amount of error of position would reduce z' and z'' almost to zero.

(β). Proceeding in exactly the same manner with the pivot on the same side as the graduated face, the horizontal measures increasing to the right, and the vertical measures increasing upwards, we get the following residual errors:

Pointer Reading.	z'	z''	Pointer Reading.	z'	z''	Pointer Reading.	z'	z''	Pointer Reading.	z'	z''
°	r	r	°	r	r	°	r	r	°	r	r
5	− ·009	− ·022	95	+ ·017	+ ·014	185	+ ·008	+ ·045	275	+ ·016	− ·002
15	− ·010	− ·032	105	+ ·027	+ ·001	195	+ ·003	+ ·040	285	− ·025	− ·006
25	+ ·012	− ·017	115	+ ·046	− ·005	205	− ·005	+ ·014	295	− ·014	− ·008
35	+ ·002	− ·020	125	+ ·038	− ·007	215	− ·009	+ ·008	305	− ·001	− ·005
45	+ ·005	− ·014	135	+ ·033	− ·007	225	− ·023	+ ·009	315	− ·002	+ ·006
55	+ ·014	− ·023	145	− ·002	− ·028	235	− ·044	− ·010	325	000	+ ·018
65	+ ·014	− ·015	155	− ·009	+ ·009	245	− ·009	− ·003	335	− ·007	− ·003
75	+ ·013	− ·006	165	− ·009	+ ·029	255	+ ·002	− ·009	345	000	− ·011
85	− ·004	+ ·015	175	+ ·004	+ ·065	265	− ·008	− ·013	355	− ·028	− ·012

It was found by trial of the microscopes on the limb of the horizontal circle (radius 18 inches), that, in the mean of the two, $6^{r}\cdot206 = 5'$. Hence in respect to the movement of the horizontal axis of the vertical circle, whose length is 38·75 inches, $1^{r} = 22''\cdot45$ nearly. The greatest apparent error in the position of the axis (which will be the sum of the corresponding values of z' for the horizontal error or of z'' for the vertical error) is $z' + z'$ for pointer-reading 165°, and amounts to $0^{r}\cdot096$, or $2''\cdot1$. The amount of the vertical errors (which are more important) is considerably less. On the whole it has appeared unnecessary and unsafe to attempt to make any correction to the observations for this possible cause of error.

In 1847, May, an examination conducted in exactly the same way indicated smaller errors.

IV. Determinations of the values of the level-scales, and changes of the levels.

On 1847, March 12 and 13, the levels were taken off the instrument and were placed upon a level-prover, lent by Mr. Simms, whose scale was determined by our own measures. The results for the values of one division were

		"
For	$E-F$	1·1996
	$G-H$	1·1395
	$e-f$	1·1802

		"
For	$g - h$	0·9020
	$i - k$	0·9857
	$l - m$	0·9346

These values were used for a time in the reduction of the observations. On comparing however the changes in the position of the vertical axis shewn by the levels $e-f$, $g-h$, $i-k$, $l-m$, in rapid reversion of the instrument, it was found that their indications were so different as to shew that the curvatures of the glass tubes of the levels when mounted on the instrument were different from what they were when placed on the level-prover. To obviate this, on May 28, blocks of wood were placed on the telescope of Troughton's circle, and the levels were screwed upon these as nearly as possible in the same manner as when mounted on the instrument. The results for the values of one division were now as follows:

		"
For	$E - F$	1·1797
	$G - H$	1·0040
	$e - f$	1·1037
	$g - h$	0·7040
	$i - k$	1·1864
	$l - m$	1·1350

The reductions of the observations which had been made with the former values of the level divisions were at once recomputed with these values. The values thus found for $E - F$ and $G - H$ have still been retained; and those for $e - f$, $g - h$, $i - k$, $l - m$, were retained to 1847, November 10.

The levels up to this time were made on the common English construction, the glass tubes being fixed by plaster in brass tubes; and to the ends of these brass tubes were attached more solid pieces of brass, which were screwed down, with a flat bearing, to the supporting parts of the instrument. It was found, however, in the months of May and June, that the levels, especially the longest $e - f$, $g - h$, were perpetually changing their zero, and that this zero was altered by forcing the attaching screws. On June 10, therefore, the bearings of all the levels were altered in such a way that one of the solid brass ends rested upon two points, midway between which the pressing screw acted, and the other upon one point, or rather upon a small ring surrounding the pressing screw: and from this time the anomalies which I have mentioned disappeared.

Still it was evident that the levels $e - f$, $g - h$, were too infirm to be trusted; and the observations made during a journey on the continent having suggested the advantages which would be derived from the adoption of the German construction, on Nov. 14 new levels were mounted in the place of $e - f$, $g - h$, in the form which is explained in the description above.

Mr. Simms having expressed his confidence in the correctness of his values of the scales of the new $e-f$, $g-h$, as well as of $i-k$, $l-m$, intended to represent 1″ in each division, it was thought prudent to adopt those values; and accordingly from that time each division is supposed to be equal to 1″. The following comparisons have been made for the purpose of testing the accuracy of these adopted values. In all the instances in which a considerable change in the levels was produced by reversing the instrument, the amount of that change in level divisions was taken from the different levels, and all were grouped together for each level.

For $E-F$ and $G-H$.

By the mean of 80 reversions between May 23 and December 27, 30·61 divisions of $E-F$ corresponded to 36·66 divisions of $G-H$. These numbers require values differing a little more than those given above.

For $e-f$, $g-h$, $i-k$, $l-m$.

By the mean of 80 reversions between 1847, Nov. 15, and 1848, June 15, the following numbers of divisions were found to correspond.

$e-f$	$g-h$	$i-k$	$l-m$
37·41	38·66	36·93	39·44

These agree nearly enough; and the two lower levels, considered as one group, agree almost exactly with the two upper levels, considered as another group.

V. Determination of the relation of the position of the axis of the Vertical Circle to the axis of revolution in azimuth.

It will be seen hereafter that the observations of stars give the means of determining the Level Reading for the mean of $e-f$, $g-h$, $i-k$, $l-m$, corresponding to the horizontal position of the axis of the Vertical Circle. As these observations cannot always be obtained, and as mean level readings for the vertical position of the axis of revolution can always be obtained by reversion, it appeared desirable to compare them, so as to be able to infer the former from the latter. By 14 comparisons between May 21 and June 22, it appeared that the latter exceeds the former by + 2″·54: this number was used where necessary from May 16 to June 22. From May 21 to July 8, 18 comparisons gave + 2″·18: this was used from June 23 to July 8. From July 18 to September 4, 17 comparisons gave + 0″·35: this was used from July 18 to September 6. From July 18 to October 7, 24 comparisons gave +0″·14: this was used from September 14 to October 7. From October 18 to November 5, 7 comparisons gave —1″·49, which was used from October 13 to November 5. From October 18 to November 10, 8 comparisons gave — 1″·55, which was used on November 10. During the remainder of the month of November the zero derived from the reversion was not used, as it appeared uncertain. From December 11 to December 16, 3 comparisons gave — 1″·63, which was used from December 11 to December 31.

It would appear from the progression of these numbers that the Y's, or (less probably) the pivots of the Vertical Circle, have worn unequally.

VI. Alteration of the counterpoises of the axis of the Vertical Circle, and alteration of the object-glass.

The irregularity of the Zero in Azimuth having made it probable that the pivots of the Vertical Circle were not pressed into their Y's with sufficient force, on July 15 about one-third part of the counterpoises was cut off. The object-glass was also taken off for examination, and apparently was not replaced accurately in the same position.

VII. Determination of the Intervals of Wires in the Eye-piece of the Telescope.

(α). For the intervals of horizontal wires, or those used in the observation of vertical transits.

Fifty vertical transits of stars, from July 21 to November 18, were treated in the following manner:—The means of the wires having been previously formed, the interval between each wire and the mean of all was taken. As in different observations these transits occur in different orders on the wires, it was necessary to adopt one order of passage as the standard. The order adopted for the wires I, II, III, IV, V, VI, is that in which stars pass which are West of the Meridian, the graduated face of the Vertical Circle being Right: when one only of these conditions is changed, the passage takes place in the opposite direction. Due respect was given to this consideration in taking out the intervals between the transit over each wire and the mean of all. The vertical movement of a star in 1^s of sidereal time is $15'' \times$ cos latitude $\times$ sin azimuth from North or South. Hence the angular interval of each wire from the mean, in seconds of arc, is

Observed interval in seconds of time $\times$ $15''$ $\times$ cos latitude $\times$ sin azimuth.

This calculation being performed for every interval of each of the stars, and the mean of the results being taken, the distances of the wires from the mean of wires were found to be as follows:

		"
Wire I	+	300·43
II	+	180·70
III	+	59·78
IV	−	59·85
V	−	180·18
VI	−	300·79

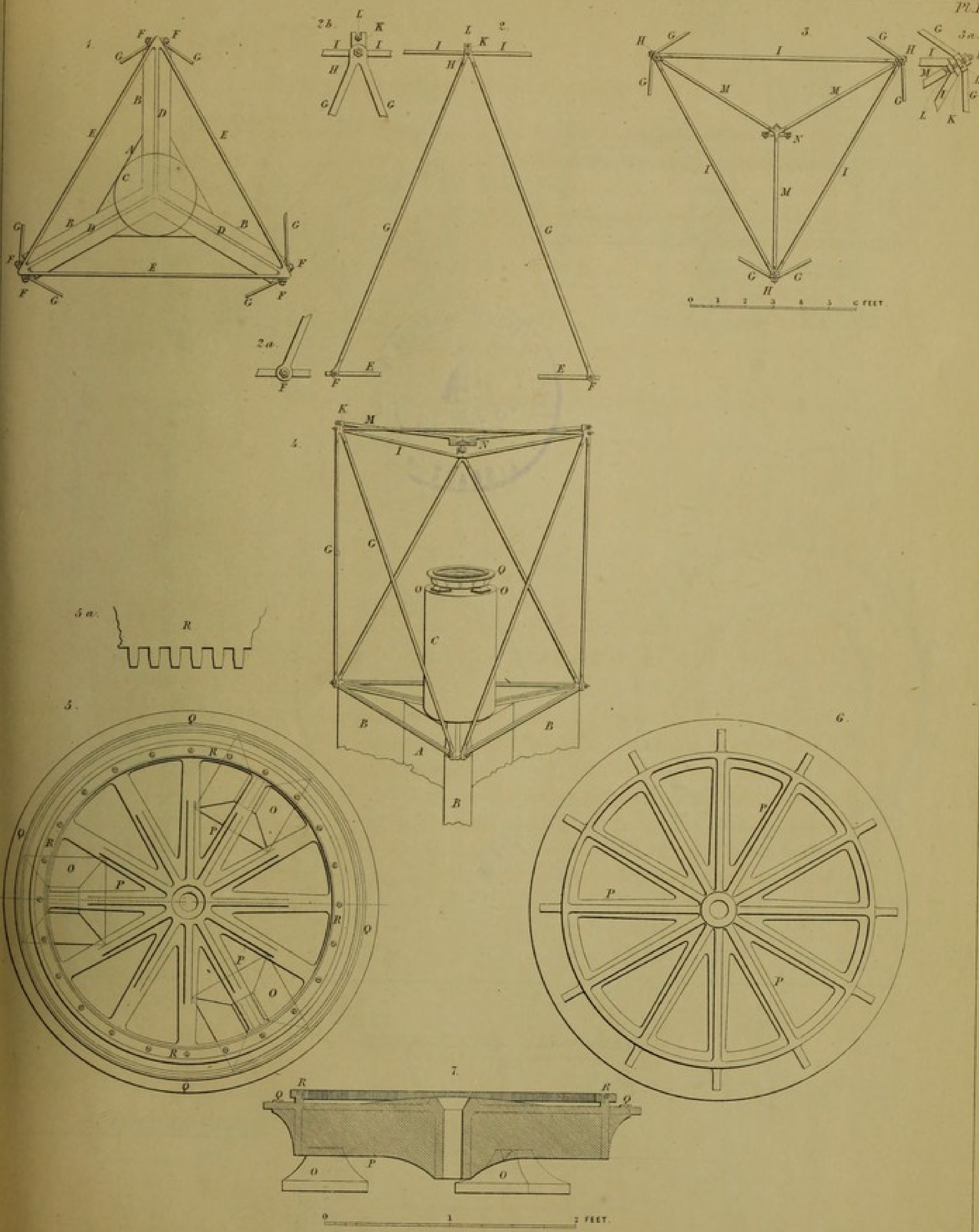
(β). For the vertical wires, or those used in horizontal transits. The process of taking the interval of time between each wire and the mean of all was the same as in the former case.

But as no stars are ever observed higher than the pole, the horizontal motion of stars is always in the direction N., E., S., W., N.; and therefore it was necessary to discriminate the transits only by the position of the instrument. The position adopted for the order of the wires 1, 2, 3, 4, 5, 6, is that in which stars pass when the graduated face of the Vertical Circle is Right. The square of the horizontal movement of a star in one sidereal second, is found by subtracting the square of the vertical movement just found from the square of the whole movement, or $(15'' \times \sin \text{N.P.D.})^2$. Hence, distance of a wire from the mean of wires = interval of time $\times\ 15'' \times \sqrt{\{\sin^2 \text{N.P.D.} - \cos^2 \text{lat.} \sin^2 \text{azimuth}\}}$. The latter term is calculated easily by the use of an auxiliary angle θ, such that $\sin \theta$ = cos lat. sin azimuth. cosec N.P.D. Treating 50 transits in this manner, from July 21 to September 22, the intervals in arc of each wire from the mean of wires were found to be as follows:

		$''$
Wire 1	+	600·04
2	+	363·04
3	+	121·43
4	−	120·89
5	−	361·63
6	−	601·93

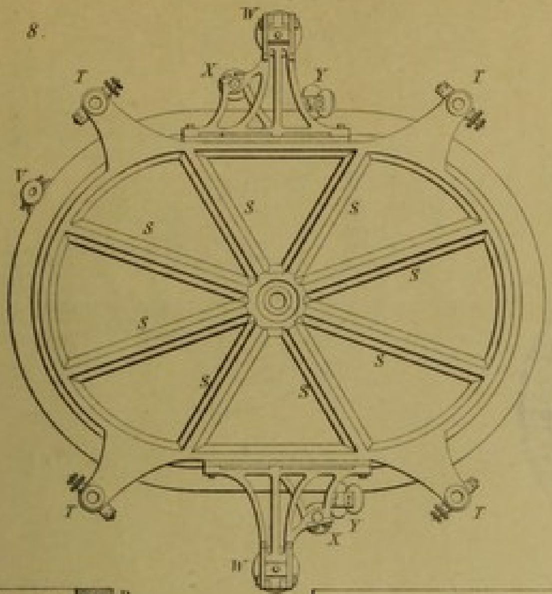
VIII. Examination into the effect of the heat of the Lamp, carried by the Instrument, upon the radial bars of the upper triangle which carry the Y for the upper pivot of the azimuthal axis.

On March 10 and March 11 observations were made, the instrument being so turned that the lamp was immediately under one of the bars. In both the effect was the same: that in 15^m of time the readings of the levels $e-f$, $g-h$, diminished about $2''$, shewing a corresponding expansion of the radial bar. As this expansion does not in itself produce any injurious effect (as the only possible injury would be the change of position between the observation with the telescope and the reading of the levels, or during a very short time), and as the general unsteadiness depending on it is insignificant, no attempt has been made to shield the bars.


1.
2.
2 a.
2 b.
3.
3 a.
0 1 2 3 4 5 6 FEET
4.
5.
5 a.
6.
7.
0 1 2 FEET

ROYAL COLLEGE OF SURGEONS OF ENGLAND
-3 JUN 19
LIBRARY

8.



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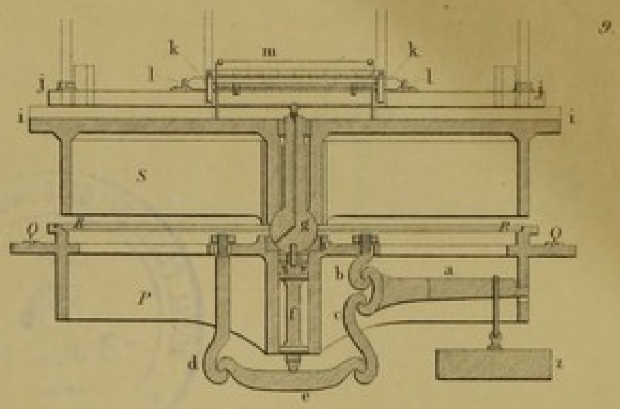

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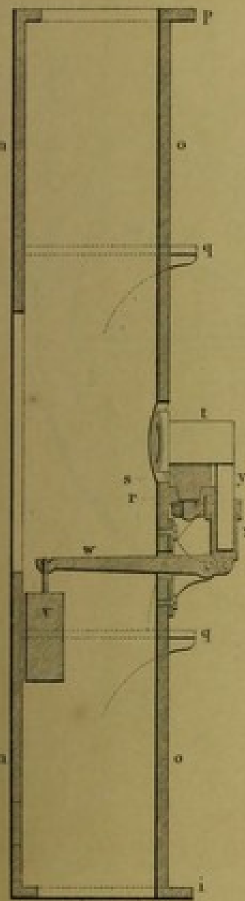

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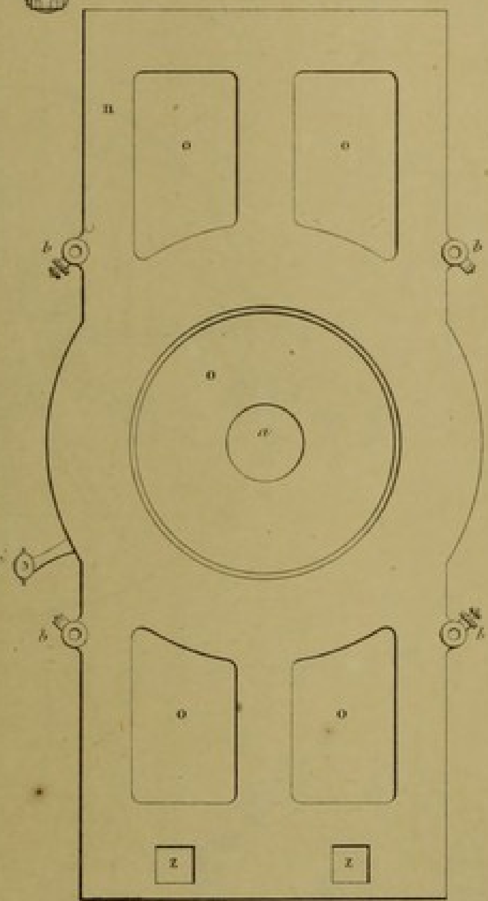

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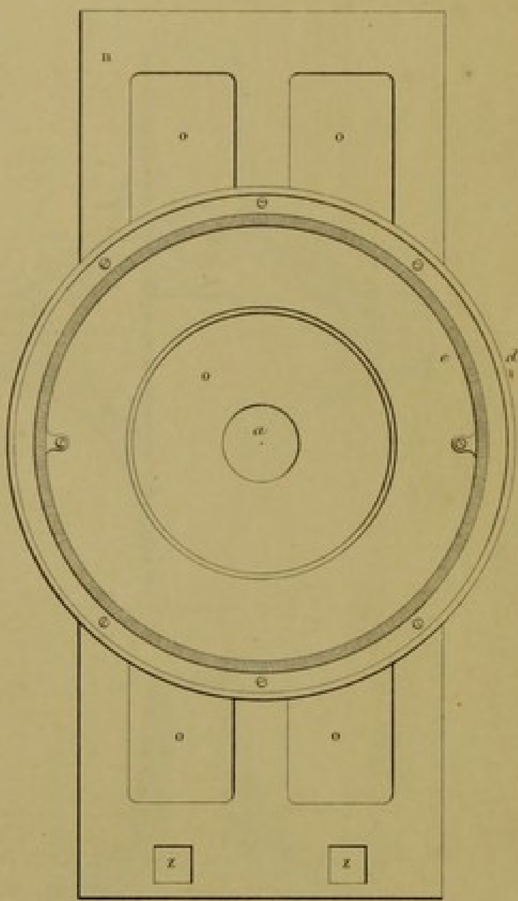
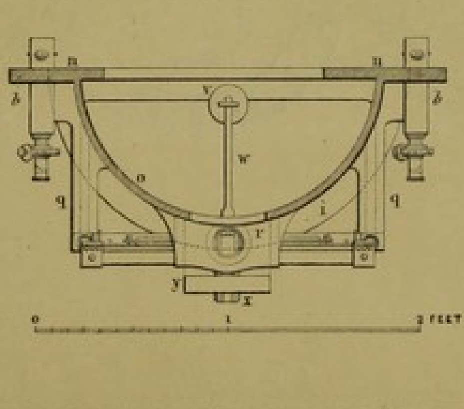


13.

14.



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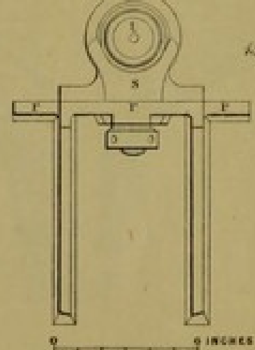

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-3 JUN 19
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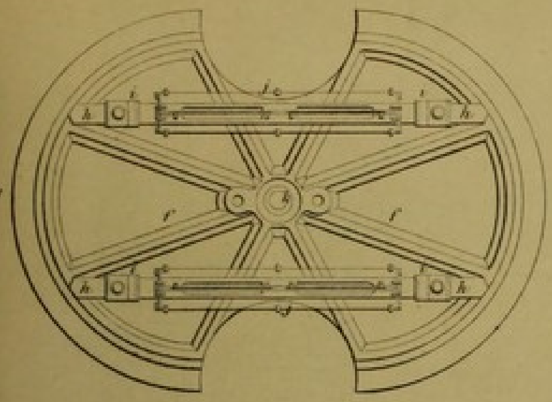
16.



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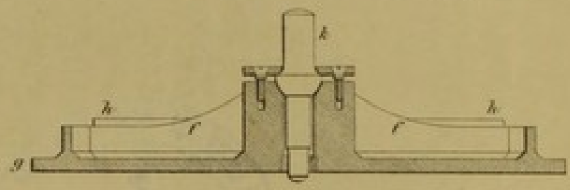

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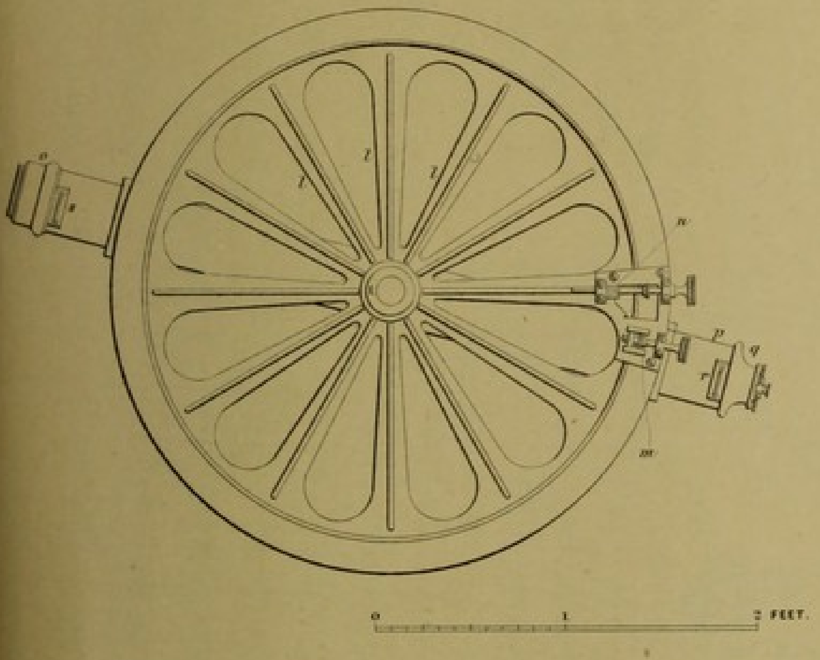

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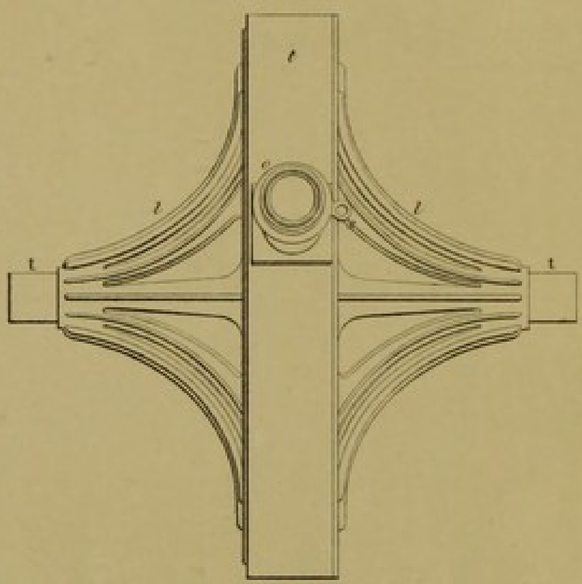

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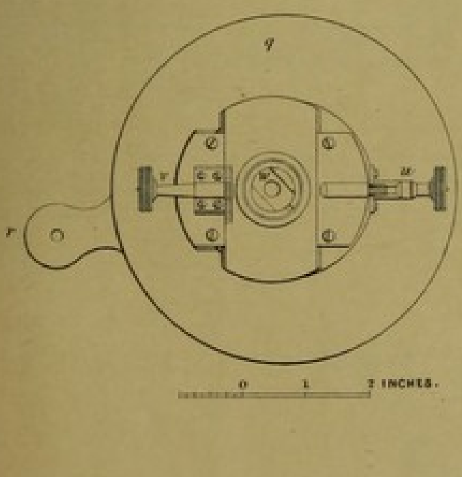

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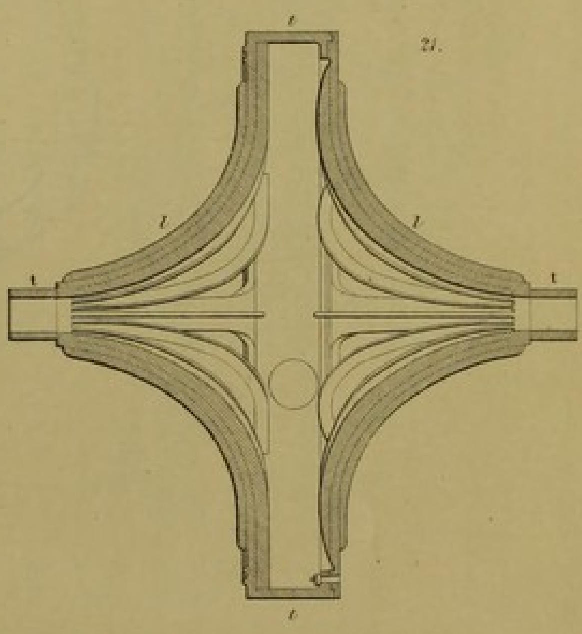

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-3 JUN 19
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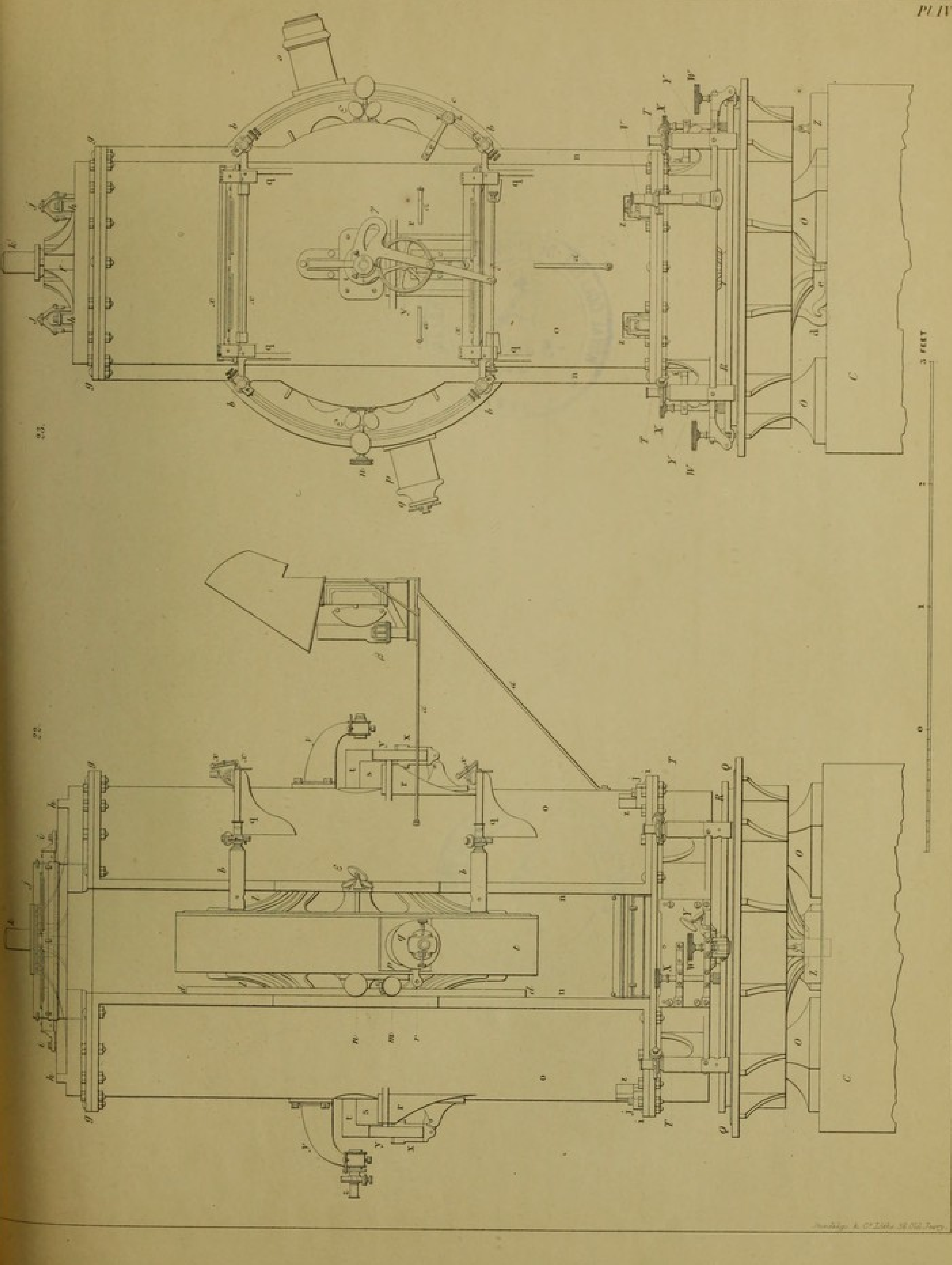
23.
22.
3 FEET

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-3 JUN 19
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