APPENDIX I.

DESCRIPTION

OF THE

REFLEX ZENITH TUBE

OF THE

ROYAL OBSERVATORY, GREENWICH.

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THE peculiar principle embodied in the construction of this instrument first occurred to me in the spring of 1848, and was first described in a short Address to the Visitors of the Royal Observatory, dated 1848, May 12. A further allusion to it was made in the Report to the Board of Visitors, dated 1848, June 3; and a more detailed explanation, illustrated by diagrams, was prepared on 1848, August 9; this paper is bound with the annual volume of Greenwich Observations for the year 1847. The instrument was constructed by Mr. Simms, under my directions, in the year 1851, and all the measures of divisions, &c., necessary for immediate use of it were made in the autumn of that year. It was first mounted in a small room at the north-east angle of the Transit-Circle room; but at the end of 1855 it was transferred to a new room on the western side of the Transit-Circle room, about $22\frac{1}{2}$ feet south of the former. No alteration, however, was made in its construction, except that the principal and largest tube was shortened, so that, instead of being planted on the floor which supported the observer, it is now planted on a raised table; this alteration was made only to allow of a more convenient examination of the quicksilver in its trough. The description which follows applies to the instrument in its new form.

For a clear understanding of the drawings which are subjoined, it is necessary to premise an account of the principle of the instrument.

The star which is to be observed (γ Draconis) being so near to the zenith that it may be seen without confusion with an object-glass whose axis is vertical, the principle of construction assumes that the axis of the object-glass is exactly or very nearly vertical. Suppose, now, that the star is on the meridian; the pencil of rays from the

B 2

star, converging after passing the object-glass, will tend to form an image of the star at a distance below equal to the focal length of the object-glass. Let a trough of quicksilver be placed below the object-glass, at a distance equal to half its focal length. The pencil of rays, after reflection from the plane surface of the quicksilver, will have exactly the same angular convergence as before incidence. It will therefore form an image of the star at the object-glass itself. If the distance of the quicksilver be less than half the focal length, the image will be formed a little above the object-glass; if the distance be greater than half the focal length, the image will be formed a little below the object-glass.

The horizontal ordinate of the image will depend on the zenith-distance of the star. Thus, if the star be north of the zenith, the axis of the pencil of rays passing downwards from the object-glass will pass towards the south, and when reflected upwards from the horizontal surface of the quicksilver, it will still pass towards the south; and finally the distance of the image from a vertical line passing through the center of the object-glass will be precisely that corresponding to the star's zenith-distance with radius equal to the focal length of the object-glass. If, then, we can measure the horizontal distance of this image from the vertical line through the center of the object-glass, we do thereby obtain the elements of measure of the star's zenith-distance.

If a micrometer were attached to the cell of the object-glass at the same distance at which the star's image is formed, and if an eyepiece with diagonal mirror (to prevent the necessity for placing the observer's head in the path of the rays of light from the star to the object-glass) were so placed as to receive the pencil which has been reflected from the quicksilver, and to view the micrometer-wire: this micrometer might, without further modification, be used to measure the changes of the star's zenith-distance from day to day. But it cannot be used to measure the star's absolute zenith-distance, because the vertical line which passes through the center of the object-glass is not visible or discoverable by direct observation. The following arrangement however gives the means of measuring the absolute zenith-distance.

Let the micrometer be attached to and carried by the cell of the object-glass, and let the cell of the object-glass be reversible in azimuth, by turning horizontally round a line parallel to the vertical line which passes through the center of the object-glass,—that is, round any vertical line,—and let the micrometer-wire be placed upon the image of the star, first, when the object-glass-cell has the position first contemplated; secondly, when the object-glass-cell is reversed in azimuth; then it is evident that, wherever the center of the object-glass may be, the star's image is in the two observations formed at equal distances from the vertical passing through that point, and in the same direction from that vertical, as referred to the earth, or in opposite directions from it, as referred to the reversible object-glass-cell. And therefore the distance between the positions of these two images upon the micrometer-frame is double the distance of either from the vertical line, or double the distance which gives the means of computing the angular zenith-distance. And thus the practical problem of measuring the star's zenith-distance is, in its most important and fundamental point, completely solved.

A consideration of this construction will show that it is unimportant whether the object-glass-cell rotate round the vertical through its center, or round any other vertical line, near or distant; and that there is no advantage in connecting the eyepiece or the quicksilver-trough with the tube which supports the object-glass-cell: and that, if the quicksilver-trough be so supported that the quicksilver will be free from tremor, the tube which supports the object-glass-cell may be liable to any degree of unsteadiness without injury to the observations. Two conditions, however, are necessary. First, the unmoving parts of the micrometer (as the *appui* of the micrometer-screw) must be so firmly connected with the object-glass-cell as to retain strictly the same relative position when the object-glass-cell is reversed. This is insured with very great certainty (in consequence of the extremely close proximity of the object-glass-cell and the micrometer) by the ordinary connexions of instrument-maker's work. Secondly, the object-glass must rotate round a vertical line, preserving the same inclination to it in the reversed positions; or, if it does not preserve the same inclination, we must have the means of computing the effect of the difference of inclinations. The following is the theory which applies to this point:—

The vertical line through the center, in the practical sense in which we have used it, is evidently the vertical line which passes through the image of a zenithal star (for the place of the image of a zenithal star must be the zero of the horizontal measure which determines the zenith-distance of any other star: and this zero-character is, in the explanation above, the determining character of the vertical line through the center). And, as the ray from the zenithal star, which passes downwards along this line, does, after transmission and reflection and second transmission, come to a point in the line, it must describe absolutely the same path, in going and returning. Consequently the lower part of its path (having regard to the effect of reflection from the horizontal quicksilver) must be truly vertical; and the upper part is truly vertical. Therefore the vertical line through the center, of which we have spoken, is that vertical line whose direction after emergence is the same as before entrance: or in other words, it is the vertical line which passes through the *focal center* of the lens.

Now, if the plane of motion of the micrometer-wire passed through this focal center, and if the wire were adjusted upon the image of a zenithal star, it would evidently be at the focal center: and this would hold true even if the object-glass were inclined through a considerable angle. Therefore in this case the zero of micrometer-measure is not affected by the inclination of the object-glass, and no correction is required for any change of inclination occurring in the reversed positions But if (as will usually happen) the plane of motion of the micrometer-wire is higher than the focal center; and if the object-glass-cell, carrying with it the micrometer be so inclined that the right-hand side, as viewed by an observer in a given position, be the higher; then the part of the micrometer which ought to be used as zero (defined by the truly vertical line passing through the focal center) is not the same as if the object-glass-cell were horizontal, but is to the right of that point; and, if the image of a star fall to the left of the center, its micrometrical zenith-distance, as referred to an invariable zero on the micrometer, ought to receive an additive correction. The amount of this correction will be = elevation of micrometer-plane above focal center × inclination of object-glass-cell. The inclination, referred to a given position, is easily found by means of a spirit-level attached to the object-glass-cell. When each micrometer-reading is corrected for the observed inclination, on the principles just described, all are referred to a certain constant inclination of the object-glass; and there is no occasion further to consider whether the inclination in reversed positions is or is not the same.

But in order to carry out effectively this process of correction, it is necessary to be possessed of a practical method of determining the place of the focal center. I extract from the paper dated 1848, August 9, (Greenwich Observations, 1847,) the following construction:—

" The apparatus consists of three parts.

" No. 1 is a board about 7 feet long, to which the following parts are attached. Near one end, a stand for a lamp. About 7 inches from that end, a block 8 inches high, having a hole (at a height corresponding to the center of the object-glass to be tried), which is covered by a plate of metal with a fine vertical slit. About 2 feet 10 inches from the same end, another block with a similar hole, plate of metal, and slit. About 3 feet 6 inches from the same end, or near the center of the board, a short vertical pin, on which No. 2 turns. Beyond this, two Y blocks, carrying a 30-inch telescope, at such a height that its center corresponds to the center of the object-glass to be tried. The object-glass of the telescope is turned towards the object-glass which is to be tried.

" No. 2 is a board about 12 inches long, which turns horizontally about the vertical pin on No. 1: its lower surface touching the upper surface of No. 1. At its sides are ledges or beads, between which No. 3 slides.

" No 3 is a board about 10 inches long, to slide between the ledges of No. 2. Attached to it is a Y block in which the object-glass to be tried is firmly lodged, the plane of the object-glass being perpendicular to the direction in which No. 3 slides.

" When a lamp is placed upon the stand of No. 1, and the eye is applied to the eye-end of the 30-inch telescope, so as to receive the light which passes through the two fine slits, through the object-glass to be tried, and through the 30-inch telescope, a line of light is seen, not sharply defined, but sufficiently well defined to enable the eye to perceive a very small movement. Now if No. 3 be slid towards one end of No. 2, and if Nos. 2 and 3 be turned in azimuth, the line of light moves towards one side: if No. 3 be slid towards the other end of No. 2, and if the same azimuthal movement be given, the line of light moves towards the opposite side: by trial, a position of No. 3 will be found such that, whatever azimuthal motion be given to Nos. 2 and 3, the line of light does not appear to move. The center of rotation then passes through that focal center of the object-glass which relates to the side turned towards the lamp.

"It is essential that the azimuthal movement be an accurate rotation round one linear axis, as otherwise the result of the experiment does not prove that the beam of light, which ultimately has a direction independent of the azimuth of the object-glass, has really passed through one point in every position of the object-glass. It is essential also that the 30-inch telescope be accurately in focus for a distant object, as then only does the invariability of the image of the line of light prove the parallelism of the beam of light which emerges from the object-glass to be tried and falls upon the object-glass of the 30-inch telescope. For clear understanding of this necessity it must be borne in mind, that the beam of light is displaced laterally by the oblique refraction through the object-glass to be tried."

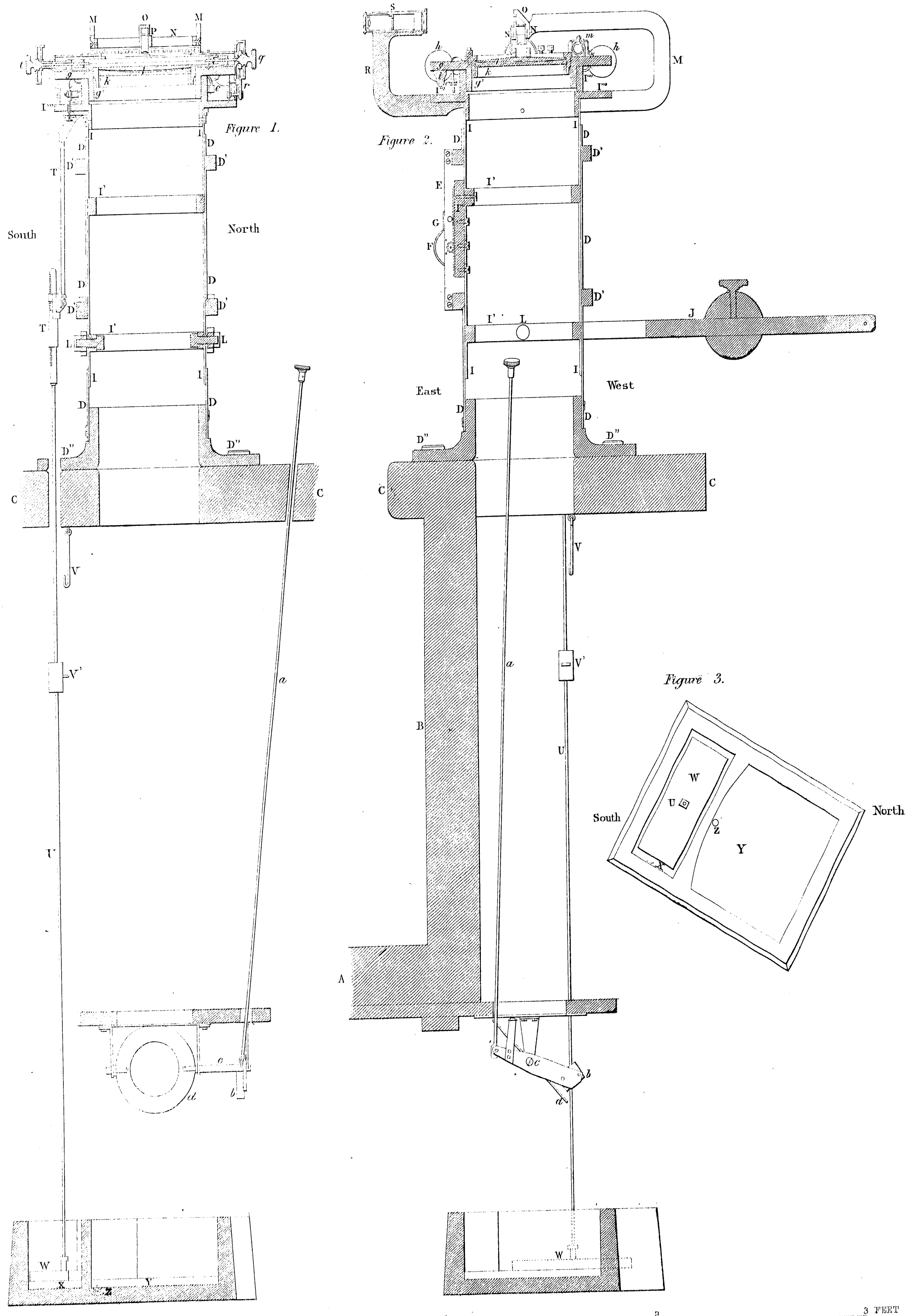
It is necessary to indicate one additional point, of great practical importance. The focal adjustment of the telescope will not depend (as in other cases) upon the adjustment of the distance between the micrometer and the object-glass, for here they are firmly connected. The focal adjustment will depend merely on the distance between the object-glass and the surface of the quicksilver. The simplest indication of adjustment will be obtained by means of a float upon the quicksilver, carrying a scale which is referred to an index attached to the object-glass-tube; and, although it will be desirable, during observation of the star, to remove the float (in order to avoid tremors of the quicksilver), and thus to alter the absolute elevation of the reflecting surface, yet, as the alteration is always the same, no error is introduced into the indications. The simplest mode of effecting the adjustment will be, not to elevate or depress the quicksilver trough, but to elevate or depress the object-glass-tube.

It is proper also to advert to the arrangement for obtaining observations in the reversed positions of the object-glass and micrometer at a single transit of the star. It appeared desirable to provide for this, inasmuch as, if this is not done, the observations in reversed positions must be obtained, one at the transit of one day, and the other at the transit of another day, with an interval between them of, perhaps, many days, in which the material relation of the parts of the instrument may have sensibly altered. But, on account of the rapidity with which the star passes the field of view, it was necessary for this purpose to arrange that each of the two observations might be effected with a very small movement of the micrometer, and that no reading should be required between the two observations. It was also desirable that the same hand should be employed in turning the micrometer at the two observations. These conditions were answered by the following construction:—

The micrometer frame carries two wires, called respectively 15 and 16, at an interval corresponding very nearly to the double zenith-distance of the star. Conceive the point intermediate to these two wires to be cut (or very nearly so) by the vertical line through the focal center of the object-glass; then if wire 15 is placed upon the star in one position of the rotating apparatus, wire 16 will fall nearly upon it in the reversed position; and a very small movement will be required to place wire 16 exactly upon it. The same remark applies if wire 16 be used in the first observation, and wire 15 in the second. It is evidently necessary that the intervals between wires 15 and 16 be precisely known. This interval can be ascertained, in terms of the micrometer, by placing a cross of wires in the focus of the 4th eyeglass, and turning the micrometer till the images of wire 15 and wire 16 alternately fall upon the cross wire, and reading the micrometer each time. Thus the condition, that the movement of the micrometer between the two observations shall be small, is secured.

Tho other requisites are obtained by the following construction:—A micrometer A, whose *appui* is upon the object-glass-cell, moves a frame A; but this frame A does not carry the wires *immediately*. The opposite end of the frame A carries the *appui* of a second micrometer B; and this micrometer B acts immediately upon the frame B, which carries the wires. The movement of either micrometer, therefore, moves the wires; B by acting immediately on the frame B; A by acting on the *appui* of the micrometer B, and thus mediately acting on the frame B. And the readings of their heads can be so arranged that the true reading for a given position of the wire, as referred to micrometer A only, shall be represented by the sum of the two readings diminished by a constant. It will then be indifferent which micrometer is used for placing the wire upon the star's image. Suppose now that the observer is waiting for the star's entrance into the field, with his right hand upon micrometer A (the same remarks will apply if his right hand is on B, substituting A for B, B for A, 15 for 16, and 16 for 15, throughout); he reads and registers the micrometer B before the star enters. When the star has entered, he places wire 15 upon its image by means of micrometer A. Without waiting to read the micrometer, he reverses the rotating frame, thus bringing B to his right hand, and places wire 16 upon its image by means of micrometer B. When the star has passed away, he reads and registers both micrometers. Then the readings which are to be combined are the following:—For the first observation, the reading of A and the first reading of B; for the second observation, the reading of A, the second reading of B, and the interval between wire 15 and wire 16.

Finally, it is necessary to explain how the value of the micrometer-screw is obtained. The frame B carries a series of wires numbered from 1 to 30, whose intervals are nearly the same as that between 15 and 16. The diagonal reflector usually employed is removed, and another eyepiece with its own reflector, which admits of being passed over the whole series of wires, is mounted. In the focus of the 4th eyeglass, there is a cross of wires. Thus, it is easily seen, each interval of wires can be measured by the micrometer, the requisite motion of the micrometer-screw being no greater than is necessary to carry the micrometer-frame through one interval of wires. The intervals of wires being thus obtained in terms of the micrometer-screw, it is necessary, in the next place, to obtain them in terms of some celestial base of measures. For this purpose, the whole instrument is unseated from its attachment to the wooden table, and is turned through 90° of azimuth. Then the image of the star traverses the wires



Day & Son, Lith^rs to the Queen.

GREENWICH OBSERVATIONS 1854. DESCRIPTION OF REFLEX ZENITH TUBE. PLATE 2.

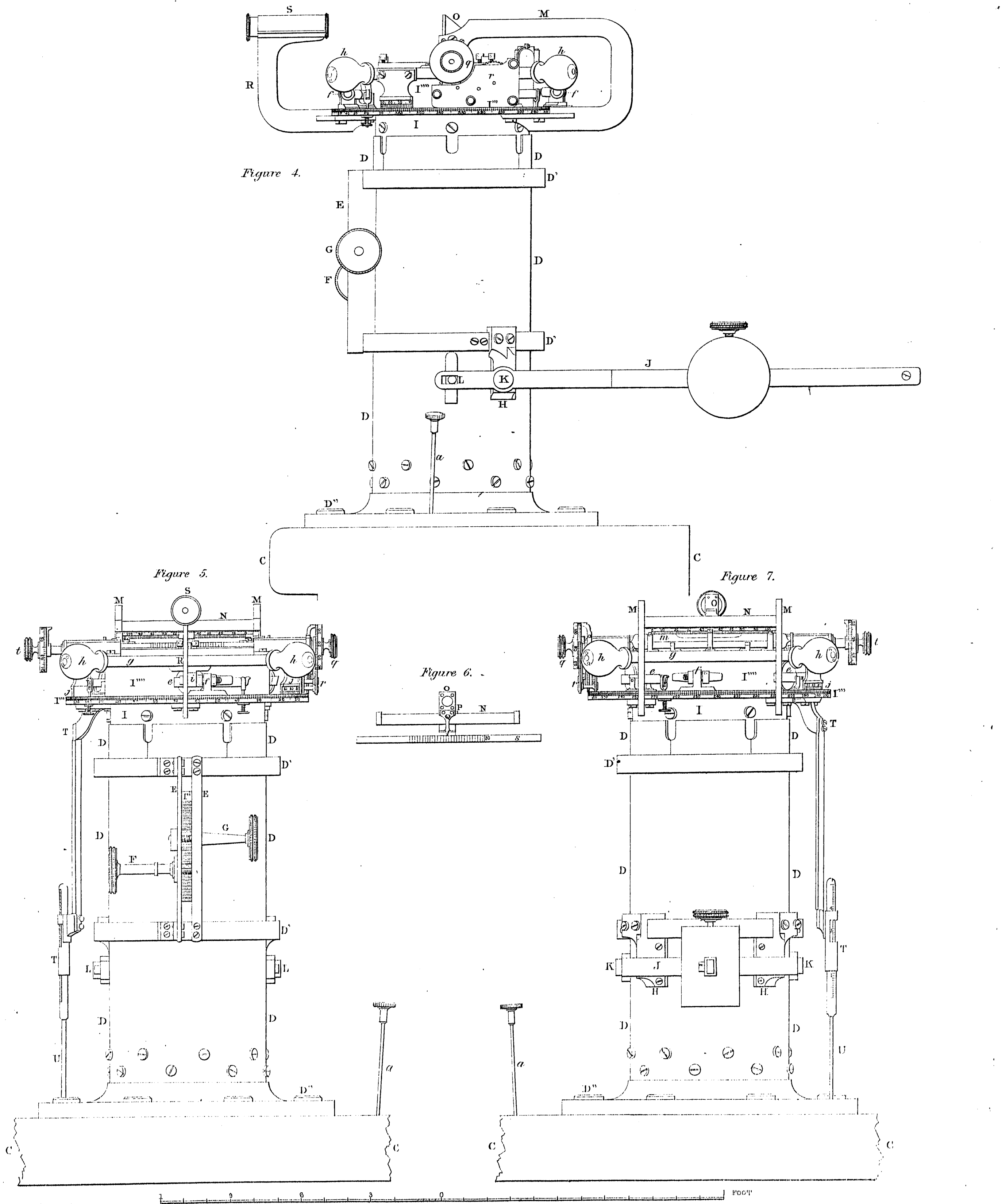


Figure 4.

Figure 5.

Figure 6.

Figure 7.

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Day & Son, Lith^rs to the Queen.

Figure 9.

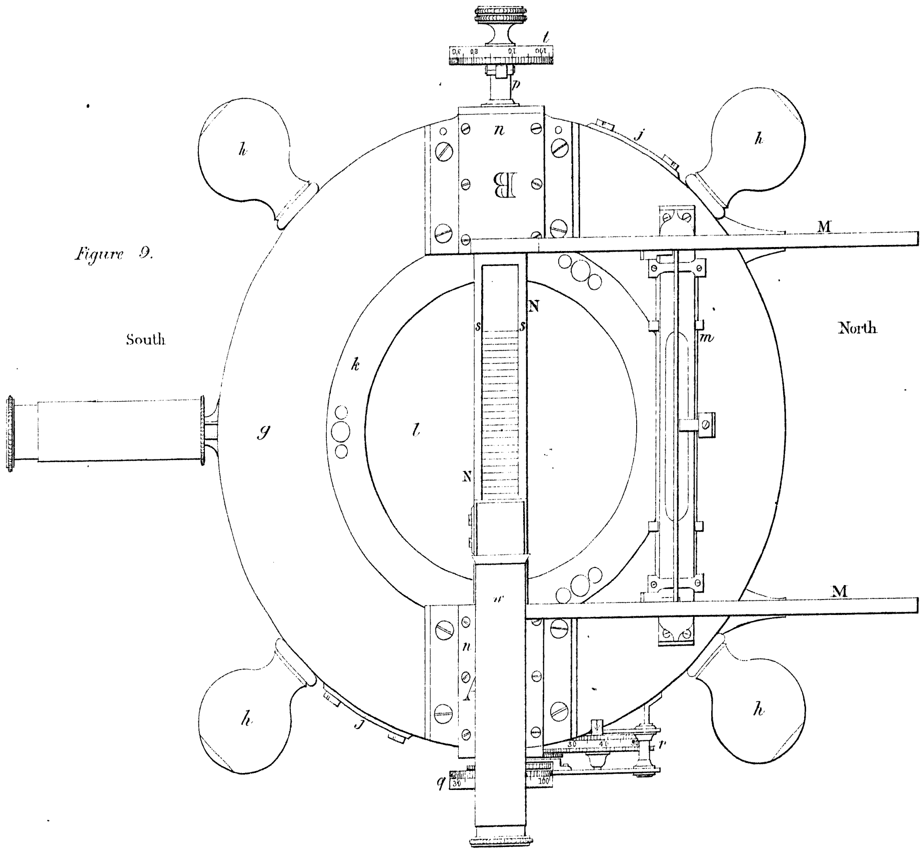
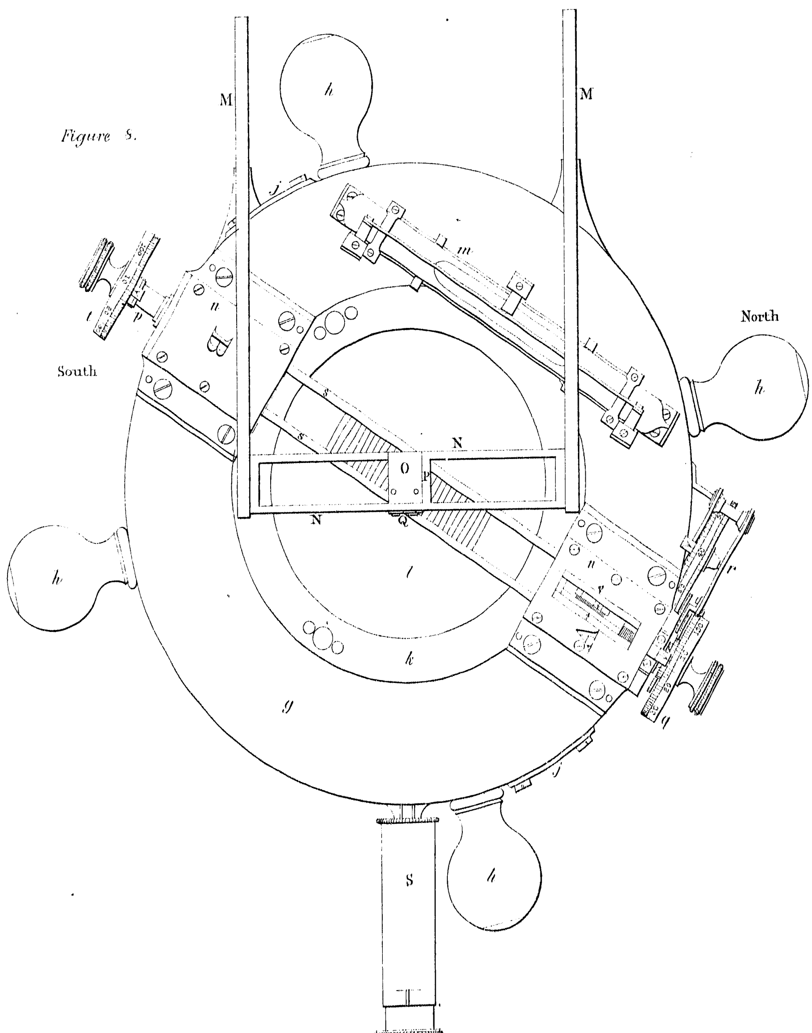


Figure 8.



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Day & Son, Lith[rs] to the Queen.

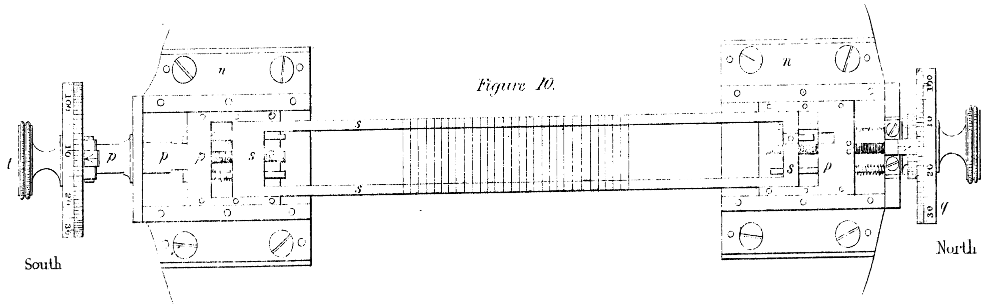


Figure 10.

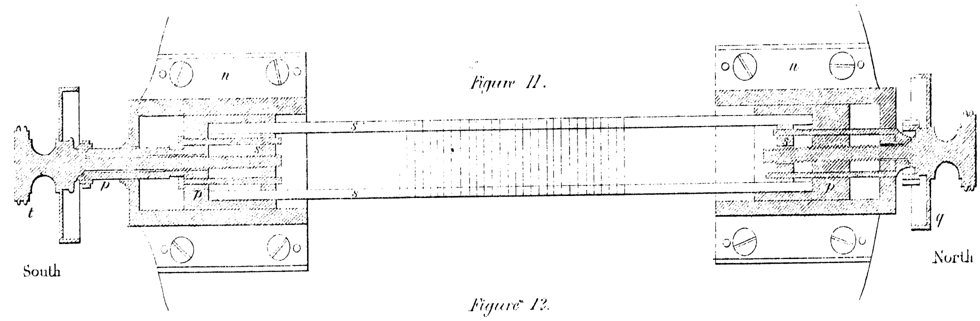
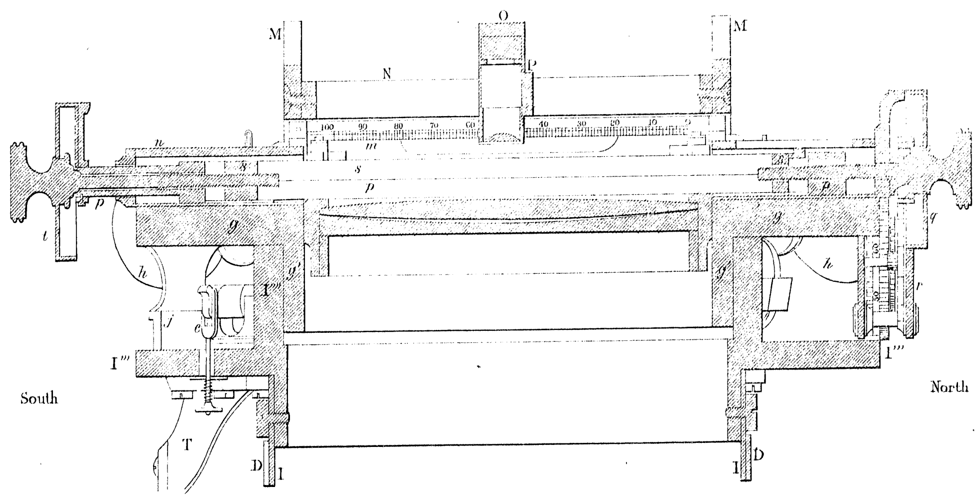


Figure 11.

Figure 12.



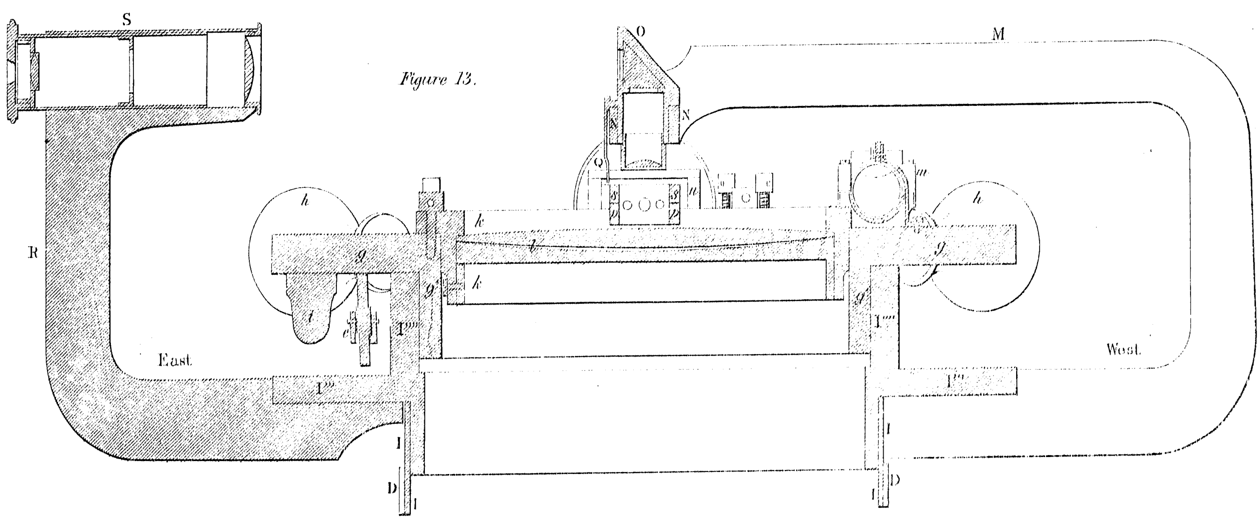


Figure 13.

transversely. The new eyepiece is now employed, (without its cross of wires,) to slide over all the wires, and to observe the time of the star's transit over every wire. In this manner, after proper computation, the intervals of the wires are found in arc ; and comparing these with those obtained in terms of the micrometer-screw, the value of one division of the micrometer in arc is found.

These considerations being premised, we may now proceed with advantage to the description of the plates.

IN PLATE I.,

Figure 1 is a vertical north-and-south section of the instrument through its whole vertical extent, from the micrometer-apparatus above to the quicksilver-trough below.

Figure 2 is a vertical east-and-west section of the same extent. In both these diagrams, some parts, which are not cut by the section, are lightly shewn in view.

Figure 3 is a horizontal plan of the quicksilver-trough. A line through Figure 3, parallel to the bottom of the page, corresponds to the plane of the section in Figure 1.

IN PLATE II.,

Figure 4 is an elevation of the upper part of the instrument, as seen from the North side.

Figure 5 is a similar elevation of the instrument, as seen from the East side. This is the side on which the observer is stationed when making an observation.

Figure 6 is supplementary to Figure 5; it shews the pointer to the micrometer-bar, which is partly hidden in Figure 5.

Figure 7 is an elevation of the instrument as seen from the West side.

IN PLATE III.,

Figure 8 is a horizontal plan of the upper part of the instrument. The revolving parts are shewn as if they were turned through an angle of about 45°, not because they are ever used in that state, but because in this exhibition the eye will more clearly perceive what part of the apparatus rotates, and what part remains fixed.

Figure 9 is a horizontal plan of the upper part of the instrument in the position in which it is used for measure of the value of the micrometer scale, with the aid of a supplementary eyepiece. The whole instrument, it will be seen, is turned through 90°.

IN PLATE IV.,

Figure 10 is a view from above of the micrometer work, when the covering plates are taken off the ends.

Figure 11 is a horizontal section of the same, the micrometer wires (which are above the section) being shewn in view.

Figure 12 is a north-and-south vertical section of the same. It is, in fact, an enlargement of the highest part of Figure 1.

Figure 13 is an east-and-west vertical section of the same. It is an enlargement of the highest part of Figure 2.

In the following references the same letters refer to the same parts in all the different diagrams.

The letters from A to H refer only to fixed parts of the apparatus.

A is the observing floor. It is 4ft. 1in. above the floor of the room. This elevation is given, in order that a person standing on the floor of the room may conveniently examine the quicksilver-trough.

B is the parapet which supports the table C.

C, the table upon which the instrument is planted. It is pierced with one large hole for the pencil of rays to pass, and with two small holes for the float-rod and the illumination-moderator.

D is the fixed tube of the instrument. It has one longitudinal aperture or *slot* on the East side, through which projects the rack I″ of the sliding tube, and two apertures on the north and south sides, through which project the pins L of the sliding-tube, on which the counterpoise-lever acts.

D′ are external rings for strengthening the fixed tube.

D″, the pedestal by which it is attached to C.

E, E, are longitudinal pieces fixed to D and D′ D′, which serve as supports for the pinion F, that acts in the rack I″, and which also serve as clamp-cheeks drawn together by the clamp-screw G, in order to pinch the rack I″, and thus to hold the inner tube fast.

F is the head of the pinion which works in the rack I″. By turning F, the rack I″ is forced upwards or downwards, carrying with it the sliding tube, the object-glass, the eyepiece, and the micrometer-apparatus.

G is the clamp-screw for pinching the rack I″, and thus fixing in position the sliding tube and all which it carries.

H, H, are pieces attached to the fixed tube, which carry the pins K, that serve as centers of motion to the lever J.

The letters from I to T refer only to parts which are fixedly attached to the sliding tube.

I is the sliding tube.

I′ are internal rings for strengthening the sliding tube.

I″ the rack, attached to I and I′, in which the pinion F works.

I‴ the flange of the sliding tube. Its edge is graduated for azimuth, the readings proceeding to 360°.

I⁗ the highest part of the sliding tube, in which the rotating apparatus is inserted.

J is the counterpoise-lever, with adjustible weight, for supporting the weight of the inner tube I, and the apparatus which it carries. In form it is a single rod on which the weight slides, with a forked end embracing the fixed tube D.

K the centers or fulcra upon which J turns.

L the pins fixed in the sliding tube I, and passing through longitudinal openings of D, upon which the lever J acts.

M the bent arms, firmly fixed to the sliding tube I, which carry the bars N. The curved form of these arms is necessary to permit the rotation of the handles *h*, and other parts of the rotating frame.

N, N, the two bars which carry the diagonal reflector O of the eyepiece.

O, the diagonal reflector, a prism of glass. The inclined face, and the lower or horizontal face, are plane; but the vertical face is convex, and thus discharges the office of the second lens (counting from the object-glass towards the eye) in a four-glass eyepiece. Below O there is fixed, in the same mounting, a convex lens, which is the first lens of the four-glass eyepiece. The star (γ Draconis) which is to be observed with this instrument is not in the zenith, but nearly 2′ north of the zenith. Consequently the reflector O and the lens below it are placed, not over the center of the object-glass, but as far south as corresponds to the zenith-distance 2′ nearly.

P a small piece attached to the side of Q, to make the interruption of the object-glass symmetrical about its center, in order that no error may be produced by unsymmetrical diffractions on the image of the star.

Q is a pointer attached to the frame of O, which comes nearly in contact with the frame that carries the micrometer-wires, and indicates to the observer whether it is wire 15 or wire 16 which is viewed by the eyepiece.

R is the bent arm which carries the eye-end of the eyepiece. It is a little excentric in consequence of the excentricity of O.

S is the eye-end, sliding in a socket. It comprises the third and fourth lenses of the eyepiece, or the field-glass and eye-glass.

T is a rod fixed to I‴. Its lower end is a small tube, in which the rod of the float slides. It has an engraved index, pointing to the graduations of the float-rod.

The letters from U to Z relate to the quicksilver and its trough and float; and those from *a* to *d* relate to the illumination-moderator.

U the rod of the float. In the part which passes trough T, it is graduated to $\frac{1}{10}$ parts of an inch, but is read by a vernier to $\frac{1}{100}$ part.

V a hook for supporting the float above the quicksilver trough.

V′ the attachment to U bearing a small staple into which V is hooked.

W the wooden float.

X the quicksilver in the smaller division of the trough. The float drops into this division.

Y the quicksilver in the larger division of the trongh. This is the quicksilver from whose surface the pencil of light is reflected.

Z a curved passage lower than the inside bottom of the trough, which makes a communication between the quicksilver X and Y. By means of this, the surface of the quicksilver in Y may be made perfectly clean; the quicksilver being all poured from Y to X through Z, in such a manner as to carry the dirt with it, and being returned in such a manner that the upper stratum of the quicksilver in X never descends so low as the passage Z.

a, the rod by which the illuminator *d* is turned on its pivots, to graduate the degree of illumination.

b, a counterpoise to the weight of *a*.

c, the axis upon which the illuminating ring or annular illuminator turns.

d, the elliptic annular illuminator. In the position shewn in Figure 2, being illuminated by a gas-lamp nearly at the same level, it transmits the greatest quantity of light to the field of view. If the rod *a* is depressed, the illumination is gradually diminished.

The board which carries the whole of the illuminating apparatus admits of being turned away sideways, so as to permit convenient examination of the quicksilver.

The letters from *e* to *m*, relate to various parts of the rotating apparatus, but do not include the micrometer work.

e, the apparatus for relieving the friction of the rotating frame. Of this apparatus there are three similar specimens equidistant in azimuth. Upon the broad flange I‴ of the sliding tube, there is fixed a forked support of a lever; one end of this lever is pulled downwards by a spiral spring below the broad flange, and the other end of the lever carries a wheel, which is pressed upwards in order partially to support the flange *g* of the rotating apparatus. The action of the spiral spring will be seen best in Figure 12; it is also seen in Figures 4, 5, and 7. The wheel will be seen in section in Figure 13. The lever will be seen in Figures 5 and 7, where it is hid, in different degrees, by other small apparatus.

f, a fixed stop-piece with adjustible screw, to define the position of the rotating apparatus for correct reversion. Of this apparatus there are two specimens, nearly opposed in azimuth. A piece *i*, attached to the rotating apparatus, is to be brought into contact with the head of the screw. In Figure 5, which is a view from the east side, one of the pieces *f* is seen, with the screw-head to the left; in Figure 7, which is a view from the west side, the other piece *f* is seen, with the screw-head to the right. The piece *i*, therefore, in its reversion can only pass the southern semicircle of azimuth. Behind the block *f*, there is seen a spring (its length extended horizontally, with its plane vertical); this spring is intended, by its friction on *i*, to diminish the shock of rapid reversion.

g, the broad flange of the rotating apparatus, which rests with diminished weight upon I''''.

g′, the short tube of the rotating apparatus, which turns within I''''.

h, four handles, by which the observer turns the rotating apparatus for reversion.

i, the piece, firmly attached to *g*, which is brought up to the head of the screw of *f*. In Figure 5, it will be seen in contact with the head of the screw.

j, a vernier attached to the rotating frame, which runs along the graduated edge of the flange I''' of the sliding tube, and thus shows the position of the rotating frame in azimuth.

k, the cell of the object-glass, inserted in *g*′, and connected with *g* at three points. At each of these it is furnished with one drawing and two thrusting screws.

l, the object-glass. This was formerly the object-glass of the 10-feet transit; its focal length is about $9^{\text{ft.}}\ 8^{\text{in.}}$, and its aperture about $5^{\text{in.}}$

m, the spirit-level carried by *g*, which gives the means of computing the correction for inclination of the object-glass. The glass tube is held (as regards end-motion) between a fixed block at one end and a spring at the other.

The letters from *n* to *w* relate to the micrometer-work.

n, the coverings of the micrometer-boxes.

p p, &c. (see especially Figure 12,) the lower micrometer-bars and all the parts which are immoveably attached to them. One of these parts (see the left hand of Figures 10, 11, 12) is the pipe in which the micrometer *t* turns and has its *appui*.

q, the head of the micrometer (called in use micrometer A), which moves the micrometer-bars *p*. It will be seen in Figures 11 and 12 that the *appui* of this micrometer is upon a piece firmly attached to the flange *g*; that its screw is "tapped" in or works upon the bars *p*, moving them and all which is attached to them or carried by them by the action of its screw-thread; but that it passes loosely through the piece *s*, thus permitting *s* to be moved without any motion of *q*.

r, a train of wheel-work for counting the whole number of revolutions of *q*.

s, the upper micrometer-bars. These are the bars which carry the micrometer-wires on their upper surface. It will be seen that, in observation, the bars *p* and *s* lie exactly under the bars N, so that they do not interrupt any other part of the object-glass.

t, the head of the micrometer (called in use micrometer B), which moves the bars *s*. Its *appui* is at the end of the pipe *p*, and partakes of the movement given by the micrometer *q*. Its screw passes freely through *p*, and is tapped in the bars *s*.

v, a graduated scale for counting the whole number of revolutions of the micrometer *t*.

w (in Figure 9 only), the eyepiece and reflector occasionally used to range along the whole length of the bars N, and thus to observe in succession all the wires for determination of their intervals, in time or in micrometer-measure.

I have now only to add a short account of the principal measures for the constants of adjustment.

First. To compare the values of the revolutions of the two micrometer-screws.

1851, July 15 and August 21, the following intervals of wires were measured with the two micrometers :—

Intervals of Wires.	Measures by Micrometer A. r	Measures by Micrometer B. r
3— 4	13 ·042	13 ·034
4— 5	13 ·029	13 ·033
5— 6	12 ·962	12 ·947
6— 7	13 ·011	13 ·016
7— 8	12 ·954	12 ·960
23—26	39 ·031	39 ·027
26—27	12 ·980	12 ·993
27—28	12 ·958	12 ·939
28—29	13 ·019	13 ·008
Sums -	142 ·986	142 ·957

Hence, there is no sensible difference between the two micrometer-screws.

Second. To find the intervals of the wires in micrometer measure.

Third. To find the intervals of the wires in transit-time of γ Draconis.

Fourth. To find the value of one revolution of the micrometer in arc.

The following table contains the results of various observations made between 1851, July 18 and August 15 :—

Intervals of Wires.	Mean of Measures by Micrometer B. r	Mean of Measures by Transits of γ Draconis. s
3— 4	13 ·034	23 ·40
4— 5	13 ·033	23 ·49
5— 6	12 ·947	23 ·24
6— 7	13 ·016	23 ·35
7— 8	12 ·960	23 ·23
8— 9	13 ·038	23 ·57
9—10	13 ·002	23 ·34
10—11	12 ·956	23 ·31
11—12	13 ·017	23 ·45
12—13	12 ·968	23 ·26
13—14	13 ·045	23 ·53
14—15	13 ·001	23 ·34
15—16	12 ·988	23 ·24
16—17	13 ·002	23· 47
17—18	12 ·970	23 ·28
18—19	13 ·045	23 ·45

Intervals of Wires.	Mean of Measures by Micrometer B.	Mean of Measures by Transits of γ Draconis.
	r	s
19—20	12·968	23·37
20—21	12·983	23·23
21—22	13·026	23·37
22—23	12·987	23·30
23—24	13·005	23·44
24—25	12·993	23·20
25—26	13·029	23·52
26—27	12·993	23·27
27—28	12·939	23·36
28—29	13·008	23·43
Sum - 3—15	156·017	280·51
15—29	181·936	326·93

The times, converted into hour-angle, are respectively 1°. 10′. 7″·7 and 1°. 21′. 43″·95, and taking the star's North Polar Distance as 38°. 29′. 12″, the star's distances from the 15th wire, (supposed to be meridional,) at the 3d and 29th wires, are 43′. 38″·48 and 50′. 51″·71. Comparing the tangents of these angles, expressed by seconds of arc, with the micrometrical intervals, the first gives $1^r = 16''·784$, and the second gives $1^r = 16''·775$; the mean 16″·78 has been adopted for use.

Fifth. To find the value of one division of the level *m*, as affecting the results of the observations.

Mr. Simms found that one division of the level corresponds to 6″ in the inclination of the object-glass, and therefore, when the sum of the readings at both ends, increasing in the same direction, is used, the value of each division must be considered =3″, or the inclination (involving a constant error) is, sum of readings × 3″. Now Mr. Simms found, by the operation described above, that the focal center of the object-glass coincides sensibly with its upper surface; and the wires are higher than this by $0^{in}·25$. The focal length is about 116^{in}. Hence the angular amount of correction $=\frac{0·25}{116}\times$ sum of readings of level $\times 3''=0''·00646\times$ sum of readings of level.

Also, when micrometer A is to the south, the reading of either micrometer increases with increasing north zenith-distance of the star. And in this position, the readings of the level-scale increase to the north, or increase as the north edge of the object-glass is raised, which inclination would carry the micrometer wire to the south, or would diminish the micrometer motion to the south that would otherwise be required for placing the wire on the star. Hence the correction to be applied is additive; and this accompanies increasing readings of the level-scale. Therefore, as a general rule, the correction for the level is to be added to the equivalents for the micrometers.

G. B. AIRY.