VI. *An account of the preliminary experiments and ultimate construction of a refracting telescope of 7.8 inches aperture, with a fluid concave lens. In a letter addressed to* Davies Gilbert, *Esq. President of the Royal Society. By* Peter Barlow, *Esq. F.R.S. &c.*

Read December 18, 1828.

I HAVE great pleasure in forwarding to you the following account of the continuation of my experiments on the construction of refracting telescopes with fluid lenses; and after the interest you have taken in the experiments, and the recommendation you were pleased to give on the subject to the Board of Longitude, through whose aid I have been enabled to pursue them, I cannot but flatter myself that it will be satisfactory to you to submit this communication to the Royal Society, who have done me the honour of publishing my first proposition on this subject in their Transactions.

The instrument I intend more particularly to describe in this paper has a clear aperture of 7.8 inches, exceeding, I think, by about an inch the largest refracting telescope in this country. Its tube is 11 feet, which together with the eye-piece makes the whole length 12 feet; but its effective focus is, on the principle explained in my former paper*, 18 feet. It carries a power of 700 on the closest double stars in South's and Herschel's catalogue; and the stars are with that power round and defined, although the field is not then so bright as I could desire.

The telescope is mounted on a revolving stand, which works with considerable accuracy as an azimuth and altitude instrument, so as greatly to facilitate the direction of the instrument to any star whose right ascension and declination are given, although it may not be distinctly visible to the naked eye. To give steadiness to the stand it has been made substantial and heavy, its weight by estimation being 400 pounds, and that of the telescope 130 pounds; yet its

* Phil. Trans. 1828: Art. VII.

motions are so smooth, and the power so arranged, that it may be managed by one person with the greatest ease, the star being followed by a slight touch, scarcely exceeding that required for the keys of a piano-forte*.

In the first instance I erected this stand on a platform in my garden, but I soon found that exposure to the weather very much injured its action; moreover, the difficulty of mounting and dismounting the telescope was considerable, and liable to derange its adjustments. I was therefore almost under the necessity of erecting an observatory to contain it. This is an excellent light piece of carpentry by Mr. SMART of Lambeth, 16 feet clear in diameter, with a revolving conical roof rising 9 feet above the walls.

The roof contains 360 superficial feet, and weighs by estimation about 10 cwt. It is however by a simple apparatus made to revolve and open to any required azimuth, by the application of a force of about 10 or 12 pounds. The whole is well fitted up, and forms a neat light building, which by permission of His Lordship the Master General is erected on a piece of Ordnance ground adjoining my premises, commanding an entire view of the heavens for all altitudes exceeding 10°.

Having thus stated generally the nature of my operations, I shall proceed to explain them more particularly under distinct heads in the following pages.

Preliminary Experiments.

In my former paper (Phil. Trans. 1828: Art. VII.) I have endeavoured to show the effect which opening the lenses to different distances produces on the secondary spectrum; my first object, therefore, in these experiments was to ascertain by actual observation the best position of the lenses for the diminution of this defect.

In order the better to classify my experiments on this head, it will be best to refer to the original formula for the destruction of colour, given in my paper in the Phil. Trans. 1827: Art. XV. in which I have shown, that with open lenses we have, when the colour vanishes, $\frac{(f-d)^2}{ff'} = \delta$.

* I ought to state that I am indebted for the design, arrangement, and superintendence of the construction of this apparatus to Mr. JOHN KINGSTON, acting master millwright in His Majesty's Dock Yard at Woolwich: a highly ingenious and valuable member of that establishment.

Where f = focal length plate lens
f' = focal length fluid lens
δ = dispersive ratio
d = distance of the lenses

Or calling $f - d = nf$ = remaining focus of plate beyond the fluid, this becomes

$$\frac{n^2 f}{f'} = \delta \qquad (1)$$

$$\text{or } f' = \frac{n^2 f}{\delta} \qquad (2)$$

If now we call f'' the resulting focus from this combination, reckoning from the fluid, we have by common principles $\frac{1}{nf} - \frac{\delta}{n^2 f} = \frac{1}{f''}$

$$\text{Whence} \quad f'' = \frac{n^2 f}{n - \delta} = \text{resulting focus} \qquad (3)$$

$$\text{Consequently } f''' = \frac{nf}{n - \delta} = \text{equivalent focus} \qquad (4)$$

$$l = \frac{(n - 1 - n\delta)}{n - \delta} f = \text{whole length} \qquad (5)$$

From which equations all the relations between these six quantities, viz. f, f', f'', f''', n, and δ are readily determined; where it may be observed that f''' is the focal length of a telescope on the usual construction to which this telescope is equivalent, and l the whole length of the tube.

If we consider l, n, and δ as given quantities, we have

$$f = \frac{(n - \delta)\, l}{n - 1 - n\delta} = \text{plate focus} \qquad (6)$$

from which f', f'', and f''' may be determined.

It is obvious from this last equation, since n and l may be assumed at pleasure, (at least within all practicable limits,) that this form of telescope will admit of great variety of proportions between the different quantities, and that some classes of these have a practical advantage over others may be reasonably expected. From the experiments I have made, it appears to me that the secondary spectrum is reduced as the lenses are opened, or as n decreases, but that the general field is enlarged and improved by increasing the value of n.

I however directed my attention principally to the destruction of the secondary spectrum; and with this view I ordered two 4½-inch tubes, 5 feet long, to be fitted up to receive in succession lenses of different focal powers, depending principally upon the value given to n, which I assumed as follows: viz. $n = .60$, $n = .55$, $n = .50$, $n = .45$, $n = .40$, the length in each case being 60 inches. Resting on these numbers, the following values were determined, the plate glass having an index .515, the fluid .634, and the dispersive ratio .308.

Tabular value of the different quantities.

$n = .60$	$f = 39.72$	$f' = 46.42$,	$f'' = 48.97$	$f''' = 81.6$
$n = .55$	$f = 35.53$	$f' = 34.67$,	$f'' = 44.11$	$f''' = 80.2$
$n = .50$	$f = 33.30$	$f' = 27.02$,	$f'' = 43.35$	$f''' = 86.7$
$n = .45$	$f = 30.30$	$f' = 19.91$,	$f'' = 43.20$	$f''' = 96.0$
$n = .40$	$f = 25.62$	$f' = 13.30$,	$f'' = 44.56$	$f''' = 111.4$

I soon found, however, that it was impossible to get all the lenses of equally good material and figure; and as, in consequence, one defect might be mistaken for another, I altered my plan, and availed myself of the two telescopes I had constructed before, in one of which $n = .50$, and in the other $n = .54$. These two I had fitted with other lenses carefully made, making in one the value of $n = .60$, and in the other $n = .40$. I had also a new one made with the value of $n = .47$; and after a careful and patient examination of all these five, I determined, and I was supported in that determination by others, that the best effect was produced, at least as regarded the object I had in view, when the distance of the lenses was about one half the focal length of the plate lens, and with these proportions, therefore, I determined to construct my 8-inch telescope.

Construction of the Telescope.

Having as above stated decided that the distance of the lenses ought to be about half or a little more than half the focal length of the plate lens, I determined upon a focal length of 78 inches for my plate lens, and 59.8 inches for that of my fluid; which at the distance of 40 inches would produce a focal length of 104 inches, a total length of 12 feet, and an equivalent focus of 18 feet. For the curves of the parallel meniscus checks for containing the fluid, I proposed — 30 inches and + 144 inches, the latter towards the eye, and then computing the proper curves for the plate by the formula given in my paper, Phil. Trans. 1827: Art. XV. I found the proper curves to be 56.4 and 144, and to these curves Messrs W. and T. GILBERT worked the several glasses and the circular ring. Mr. DONKIN undertook to draw the tubes, which I was desirous of having 8 inches in the interior diameter, but his nearest treblet was only 7.8 inches, to which size therefore I was confined. The tube was drawn in three pieces, each 3 feet 8 inches, making in all 11 feet; and to this the pipe for the eye-piece being attached, gave the full length 12 feet: two of the above pieces of 7.8-inch tube are strongly and accurately jointed by a lining piece, and the other part is made to screw on for more conveniently getting in and adjusting the fluid lens which is near this joint, and is inclosed in a cell which screws on to an interior tube 5 inches in diameter, and 3 feet 6 inches long, sliding in two collars properly turned for the purpose, having a notch in each to receive a feather attached externally to the tube to preserve a parallel motion.

The other end of this tube of course reaches to within about 4 feet of the eye end of the large tube, and to the former is fixed a brass nut properly fitted to receive a screw on the end of a brass rod 4½ feet in length; this rod works in a coupling box or collar, fixed on the inside of the large tube about 1 foot 9 inches from the end, and the end of the rod passes through the front end of the large tube, where it is cut square to receive a milled head or a universal joint key, by means of which the tube carrying the cell may be moved backwards or forwards; and the adjustment is thus made for colour in the first instance, and afterwards the focus is obtained by the usual rack motion.

The difficulty of centering two lenses at so great a distance from each other is considerable, if not properly provided for. In this instance the front lens is placed in a thin detached cell and confined by a counter cell. It is then placed with its first cell in another which screws and unscrews at the object end of the telescope as usual; except that the last cell is sufficiently large to admit of adjusting the interior one carrying the lens by means of two pair of opposite pushing screws. These provisions being made, the telescope is placed opposite to a proper object, the centering is produced by trial, by means of these screws; and when every thing is right, the cell is made fast by four other screws, to prevent any trifling blow or other slight accident putting the glass again out of adjustment. In this state the telescope may be said to be completed; it has of course to be furnished with a finder, proper eyepieces, an apparatus for illuminating the field, &c., as in the usual cases.

With respect to inclosing the fluid, the following, after various trials, appears to me to be quite effectual. After the best position has been determined practically for the checks forming the fluid lens, these with the ring between them ground and polished accurately to the same curves, are applied together, and taken into an artificial high temperature, exceeding the greatest at which the telescope is ever expected to be used. After remaining here with the fluid some time, the space between the glasses is completely filled, immediately closed, cooled down by evaporation, and removed into a lower temperature: by this means a sudden condensation takes place, an external pressure is brought on the checks, and a bubble formed inside, which is of course filled with the vapour of the fluid; the excess of the atmospheric pressure beyond that of the vapour being afterwards always acting externally to preserve contact; the extreme edges are then sealed by the serum of human blood, or, which I believe to be equally efficacious, by strong fish glue and some thin pliable metal surface: by this process I have every reason to believe the lens becomes as durable as any lens of solid glass.

At all events I have the satisfaction of stating that my first 3-inch telescope has now been completed more than fifteen months, and that no change whatever has taken place in its performance, nor the least perceptible alteration either in the quantity or quality of the fluid. I must think, therefore, that the advantages to be gained by this means of supplying the flint glass are such as to entitle the experiments to an impartial examination; and I cannot doubt, if the prejudice against the use of fluids could be removed, that well directed practice would soon lead to the construction of the most perfect and powerful instruments on this principle, at a comparatively small expense. I am for instance convinced, judging from what has been paid for large object glasses, that my telescope, telescope stand, and the building for observation, with every other requisite convenience, have been constructed for a less sum than would be demanded for the object glass only, if one could be produced of the same diameter, of plate and flint glass; and this surely is a consideration which ought to have some weight, and encourage a perseverance in the principle of construction.

The telescope and the particulars relative to it being thus described, it only remains for me to state the tests to which I have subjected it, and its performance in those cases.

The first observations of this kind are commonly on Polaris; the small star here is of course brilliant and distinct; it is seen best with a power of 120, but is visible with a power of 700.

The small star in Aldebaran is very distinct with a power of 120.

The small star in α Lyræ is distinctly visible with the same power.

The small star called by Mr. HERSCHEL Debilissima, between 4 ε and 5 Lyræ, —whose existence, he says, could not even be suspected in either the 5 or 7-feet equatorial, and invisible also with the 7 and 10-feet reflectors of 6 and 9 inches aperture, but seen double with the 20-feet reflector,—is seen very satisfactorily double with this telescope.

η Persei, marked as double in SOUTH and HERSCHEL's catalogue at the distance of 28″, with another small star at the distance of 3′ 57″ both *n p*, is seen distinctly sixfold, four of the small stars being within a considerably less distance than the remote one of η marked in the catalogue: and rejecting this remote star, the principal and the other four small stars form a miniature representation of Jupiter and his Satellites, three of them being nearly in a line on one side, and the other on the opposite: there are also other small stars within the same distance, but the most remarkable are those arranged in a line as above stated.

A number of other small stars which are spoken of as difficult to observe from their minuteness, are seen more or less distinctly with this instrument.

Amongst the closer and larger stars I have tried the telescope upon those commonly selected as tests, viz.

Castor; which is distinctly double with 120, and well opened and stars perfectly round with 360 and 700.

γ Leonis and α Piscium are seen, with the same powers, equally round and distinct.

In ε Bootis the small star is well separated from the larger, and its blue colour well marked with a power of 360.

η Coronæ Borealis is seen double with a power of 360 and 700; 52 Orionis, ζ Orionis, and others of the same class, are also well defined with the same powers.

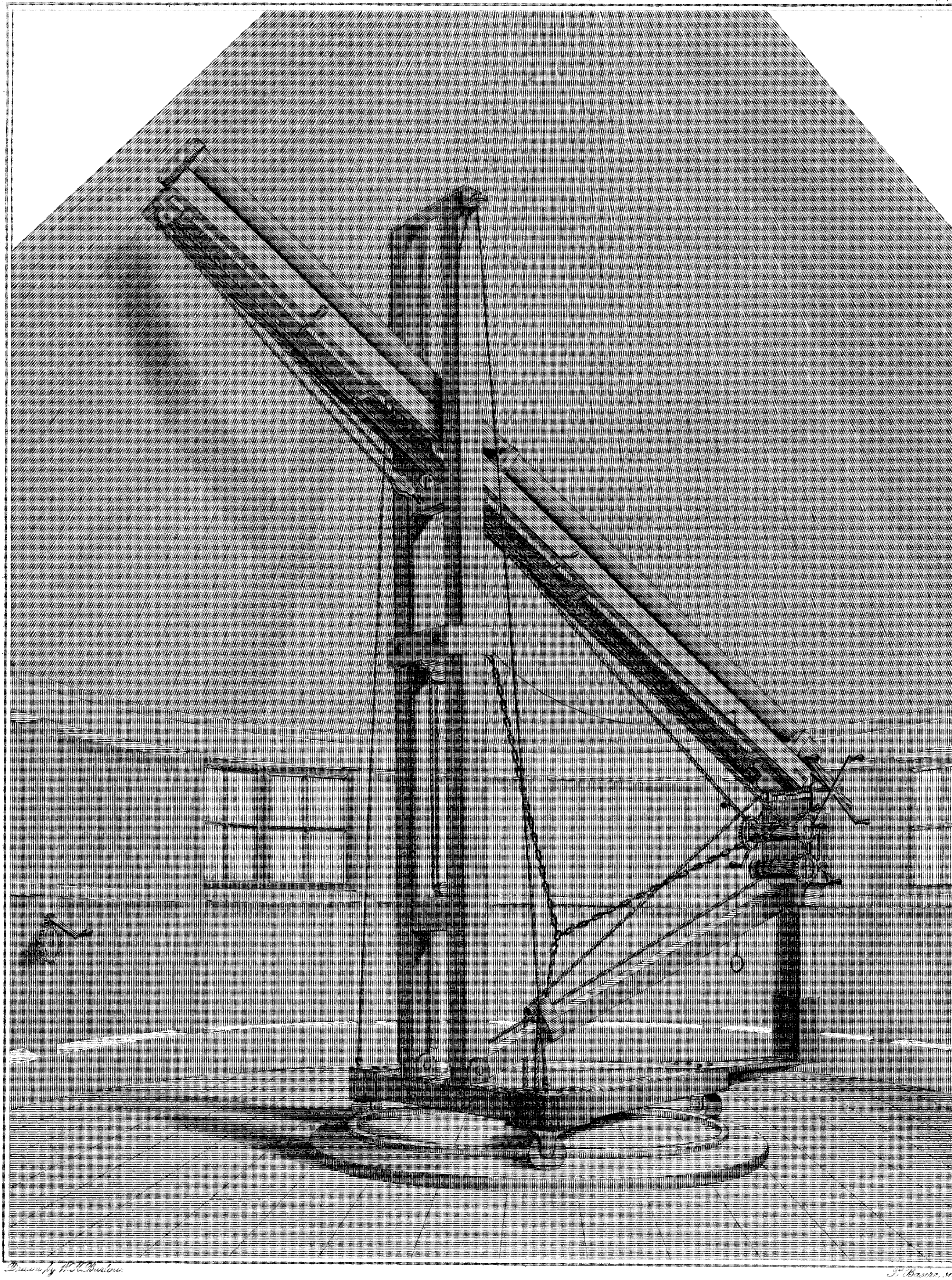
Still, however, it must be admitted that the telescope is not so competent to the opening of the close stars, as it is powerful in bringing to light the more minute luminous points.

Of the planets, I have only had an opportunity of trying the telescope on Venus, Saturn, and Mars; and the latter is too low to furnish a good test. Venus is beautifully white and well defined with a power of 120, but shows some colour with 360. Saturn with the 120 power is a very brilliant object, the double ring and belts being well and satisfactorily defined, and with the 360 power it is still very fine. The moon also is remarkably beautiful, the edges and the shadows being well marked, while the quantity of light is such as to bring to view every minute distinction of figure and shade.

Description of the Telescope Stand.

A correct representation of the stand, with the telescope upon it within the building, is given in Plate III. The fixed base is a strong built oaken curb six feet in diameter and six inches broad, imbedded on a circular brick foundation: to this is screwed an interior fillet or ribband, projecting higher than the other part of the curb, and serving the double purpose of keeping the stand to its centre and of receiving graduations to degrees and quarters, thus forming an azimuth circle. The outer part of the curb is beveled to the centre, and on this run three cast-iron rollers made to the same bevel: by these means the principal azimuth motion of the instrument is effected.

At the corners of the triangular base are three strong cast-iron sockets for receiving the ends of three oaken bars four inches square, which form the moveable base of the stand, the plate below each socket being a detached casting, screw-bolted through the timber and upper side, admitting thereby of being screwed up and tightened, in case any shrinkage takes place in the wood.



Drawn by W. H. Barlow

J. Basire, sc.

The front socket is different from the others, as it forms one piece with an upright socket which carries a strong oaken stancheon, to the upper part of which the machinery described below is attached. This stancheon having to support a great part of the weight of the telescope, at least in some positions of the latter, is strongly braced back by an oaken beam to the opposite ledge of the triangular base.

The principal upright part of the stand are two oaken bars framed or secured together in the middle and on the top, and turning on strong iron bolts in two cast-iron ears below; about which bolts this part, called the swinging frame, has a motion. These bars are cased on the outside by grain-cut oaken facings, and thus form two grooves in which an interior frame slides freely. This frame, on one of its interior sides carries a fixed racket, not seen in the plate, its whole length; and between the two connecting pieces in the centre of the swinging frame, is a spring pall which catches each tooth of the racket as it passes, being intended to prevent any accident in case of the breaking of a rope when the telescope is elevated.

To the pall is attached a string which descends near the upright stancheon; and when it is necessary to let down the telescope, this string is pulled by one hand, and the other having hold of the proper apparatus, the descending motion takes place in the most gentle and easy manner possible.

On the upper part of the front upright stancheon are two strong wrought-iron checks, terminating about two inches above it, having two circular holes $\frac{7}{8}$ths of an inch diameter, in which turns, as in two collars, a strong iron screw $1\frac{1}{4}$ inch in diameter, having two threads to the inch: on this works a strong brass nut with corresponding threads, and to this nut the frame which carries the telescope, and is called the bearing frame, is properly united, turning on a moveable joint near the screw. The screw is turned by four long cross handles, seen in the plate, by means of which the azimuth motion of a star or planet is followed. The length of the screw is about 11 inches and of the nut 3 inches, leaving a motion of 8 inches, which enables a star to be followed for a considerable time without moving the stand: the turning point on which this motion of the frame takes place, is exactly in the centre of the upper part of the interior or sliding frame, where a pin is fixed, which traverses in a parallel groove under the bearing frame; but to prevent confusion this is not shown in the plate.

On the upper part of the same interior frame are fixed two cast-iron rollers, on which the bearing frame rests, serving to relieve the machine of the friction that would otherwise take place when the telescope is raised or lowered. The two iron rods seen on each side, turning in two eyes below and adjustable at top by nuts and screws, were intended to serve as braces and to preserve steadiness; they are not, however, essential, as the instrument has every requisite stability without them.

Such is a general description of the stand; the manner of working it will be understood from what follows.

Below the fixed cross pieces, in the middle of the swinging frame, is a double fixed pulley, and to the lower part, on the inside of the sliding frame, is another double pulley, which rises and falls with the sliding frame. The end of the rope is fixed to the cross piece, descends and passes over one of the lower pulleys, thence over one of the upper, again descends, passes over the other lower pulley, then over the upper pulley, thence again to another single fixed pulley on the diagonal brace; it then passes over the lower barrel, which is turned by means of the wheel, pinion, and handle, shown in the plate. The power gained by the pulleys is 4 to 1, by the wheel and pinion 4 to 1, and by the barrel and handle 4 to 1, making in all 64 to 1. By these means the telescope may be raised even at its heaviest purchase with great facility.

This part of the machinery, however, is only intended to bring the telescope to an approximate altitude; after which, the part employed for bringing a star into the field, and for following it in altitude motion, is as follows.

At the extreme end of the bearing frame is a fixed pulley: to the back of the sliding frame, another; to the front of the same frame is another similar one; and a fourth at the other end of the bearing frame. The rope is first made fast at the extreme end, then passes over the pulley at the back of the sliding frame, thence over the pulley at the extreme end; whence it comes directly to the upper barrel; and after a few turns about this barrel, passes to the pulley on the front of the sliding frame, and returning passes over the pulley in the bearing frame near the upright stancheon, then over a fixed pulley on the brace: to the end of the rope is attached an iron weight of fifty-six pounds, which passes through a hole in the floor and hangs suspended in a well-hole below, serving thus to take in the slack of the rope, thereby keeping it always tight on the barrel, and also serving as a counterpoise to the swinging frame when thrown out beyond its perpendicular position, as is necessary to bring the instrument to small angles of elevation.

This counterpoise is not, however, sufficient; another therefore is introduced, by suspending a chain from the swinging frame to the front stancheon; to the centre of which a 56-pound weight is suspended, passing over another pulley on the brace into the same well-hole: by this contrivance the tension of the chain increases as it approaches most to a straight line; that is, when the frame is thrown furthest out, and where its weight acts with greater force. By a slight adjustment of the length of the chain and weight, we may thus produce a perfect equilibrium in the whole machine, and the telescope is of course obedient to the slightest power sufficient to overcome the friction.

Things being thus equipoised, in order to render the motion as gentle as possible, a wheel and pinion are attached to the barrel last mentioned, similar to the one already described, but with four cross handles like those belonging to the screw. The power thus gained is 2 to 1 by the pulleys, 4 to 1 by the wheel and pinion, and about 9 to 1 by the handles, equivalent to 72 to 1. The slightest touch therefore of one of these handles will produce a change of elevation of the telescope, either to increase or diminish it, accordingly as that motion tends to pull in or out the swinging frame.

The operation therefore of putting the instrument on a star is: first, to swing round the whole stand towards the star, on the circular curb; then to bring it nearly to its proper altitude by the apparatus first described; then, being seated at a proper height, the eye being applied to the finder, with the handle belonging to the screw in one hand and that belonging to the altitude motion in the other, the star is brought immediately to the centre of the field, and is of course then in the large telescope. The observer is thus seated at perfect ease and follows the star at pleasure, one of the four handles on each side being always ready to receive a touch of the finger, which is sufficient for the purpose.

I have observed that this stand acts with considerable accuracy as an altitude and azimuth instrument: it may therefore be proper to say a few words on this subject. Such a purpose was not contemplated in its construction, and therefore, notwithstanding the usual accuracy of millwright workmanship, it could hardly have been expected to find the stand susceptible of such a degree of accuracy; and it will not of course be understood that I am now speaking of extreme astronomical accuracy.

I found, however, the action so complete, that I determined to try how far it could be useful in this way. The lower curb was therefore carefully divided by hand into degrees and quarters, the meridian obtained by the best means in my power, an index fixed to the bottom of the frame and adjusted to the zero of the circle. A graduated circle, not seen in the plate, was then attached to the bearing frame with a suspended plummet, the telescope put upon a meridian star whose altitude was known, and the arc adjusted accordingly. With these apparently rough means, and another for converting right ascension and declination into azimuth and altitude; and with the help of an excellent pocket chronometer by Messrs. PARKINSON and FRODSHAM, my son, who has acquired great dexterity in the use of the instrument, can at any time select the right ascension and declination of the star from the catalogue, convert these into azimuth and altitude, direct the instrument towards the object, and be seated quite at his ease observing, in three minutes.

In a bright night,—and for observing a known star this is of course unnecessary; but for less conspicuous stars, which are scarcely distinguishable except by their catalogue positions, as also for finding any star before daylight is quite gone, or a planet in the day-time, these means, although far short of those afforded by an accurate equatorial, are very serviceable.

It should be observed that the stand was originally designed to work from the horizon to the zenith, which it is capable of doing; but I have limited its present action to an altitude of 65°, this being the greatest height I can obtain without cutting the upper curb of my observatory roof, which I am rather unwilling to do, for obtaining what is at best, with such an instrument, a very inconvenient position for observation.

Description of the Observatory.

It has been already stated that this room is circular, having a clear diameter of 16 feet. It is constructed as follows: A foundation wall 4 feet deep of 14-inch brickwork is first laid, and on this is imbedded a circular wooden curb in two thicknesses, each 2 inches deep and 4 broad, properly united with bolts, screws, and keys. Another exactly similar curb, united in the same way, forms the upper part of the wall; and between these two are mortised 17 upright stancheons, each 2 inches by 4; and round the middle are framed other pieces of the same dimensions, viz. 2 inches by 4, cut also circular. These form the framing, which is lastly covered with inch boards properly tongued to keep out the wind and rain. Four windows are introduced, the size of the upper divisions, as seen in the plate, with a door not seen, being in the part supposed to be removed to show the instrument. The height of the boards is 6 feet 8 inches above the brickwork, and 7 feet 3 inches above the floor.

In another curb, exactly like those already described, are placed 12 iron rollers, which run on a circular plate of iron laid on the upper fixed curb. On the interior face of this moveable curb are also fixed 12 other iron rollers, which keep the curb to its centre by running against a plate of hoop iron, properly fixed to a fillet nailed to, but projecting above, the upper fixed curb.

This moveable curb is, as we have seen, 16 feet 8 inches exterior diameter, and forms the base of the roof. The latter is formed of about 60 six-inch boards cut nearly diagonally, the broader end being securely nailed to the bottom curb of the roof, and the smaller to an upper curb 2 feet 8 inches in diameter, the boards being each 12 feet in length and securely dowelled together. Two rafters, each 12 feet long, 2 inches broad, and 4 inches deep, placed parallel to each other from the upper to the lower curb, and $16\frac{1}{4}$ inches asunder, form an opening for observation; these are closed at other times by two shutters which turn on hinges in opposite ways the whole length of the roof. The joints of the boards of the roof are covered externally by canvass fillets of $1\frac{1}{4}$ inch in breadth, secured by white lead in oil; and lastly, the whole is protected by three thick coats of paint. The force necessary to overcome the friction of the roof is sixty pounds, and the motion is produced by an inch-and-a-half tarred rope passing externally round the moveable curb under the projecting eave-boards, which protect it from the weather: it then passes over two guide pulleys, and descends to a drum about 8 inches in diameter, turned to the proper curve for surging; it takes three turns round this drum, which is fixed to an axle that passes inside; this axle carries a toothed wheel, which is worked by a pinion and handle, seen in the plate. The power thus gained is 8 to 1; so that to move the roof ought to require but a force of eight pounds: but in consequence of the extra friction, it practically requires twelve pounds: it may, however, be turned round with comparative ease in about a minute. The two ends of the rope, as will have been understood, are fixed to the upper curb, crossing each other about 2 feet, viz. double the distance of the guide pulleys where they pass through holes in the curb to the inside, one of them being left so as to allow of taking in the slack of the rope, which is requisite in the beginning: but after being in use a few days this operation is no longer necessary, the rope being every where protected from the weather; viz. the part round the curb by the eaves of the roof, and the two descending parts by an external casing of wood. As the stand will work from very nearly a horizontal position to a vertical one, it was at first intended that, after the building was completed, the upper curb should be cut away, on one side, the breadth of the shutters, and its place supplied by an iron bolt; and thus, by having a shutter in the upper flat part of the roof, the instrument might have been brought vertical. This, however, has not been done; so that at present the limit of observation is between 10° and 65°; and through this range the instrument may be managed with the greatest possible facility by one person.

Such is the general description of my operations; and for the rest, I have only to express my hope, that this attempt to introduce a new principle of construction for achromatic telescopes will be examined with candour and impartiality: that the instrument is so complete and delicate in its action as the most perfect refractors which constitute the chefs-d'œuvre of opticians, will scarcely be expected. To produce such results requires a great deal of well directed practice, and selections from numerous attempts. I trust, however, I may say that the principle has been shown to be practicable, and that the result is by no means unsatisfactory: and when I state, that, with less than an ounce of the sulphuret of carbon, of the value of three shillings, I have supplied, in point of material, the place of the most perfect lens that could be procured of flint glass 8 inches in diameter, it will at least be admitted that the success of the experiment is not altogether uninteresting to the patrons and promoters of astronomical science.

I will only add, that I should feel no hesitation in undertaking the construction of another telescope of double the dimensions of the present.