PHILOSOPHICAL TRANSACTIONS.

XII. *A description of a vertical floating collimator; and an account of its application to astronomical observations with a circle and with a zenith telescope.* *By Captain* HENRY KATER, *V.P.R.S.*

Read April 24, and May 1, 1828.

IN the Philosophical Transactions for 1825, I gave an account of a floating collimator, and added a suggestion for the construction of a vertical floating collimator which had not then been carried into effect. I have since had an instrument of that description made, with such improvements as occasion required, and the results which it has afforded have been so satisfactory that I am induced to lay them before the Society.

The collimator which formed the subject of the paper I have mentioned was a *horizontal* floating collimator. This, in the manner in which I then used it, was the worst form in which the instrument could have been employed; as it was necessary to take the float out of the mercury and replace it in order to complete each observation. The result was therefore liable to be vitiated by any particle of dust or minute bubble of air which might have found a place between the float and the mercury. It cannot therefore but be considered as surprising, that out of one hundred and fifty-one results, only twenty-eight were found in error to an amount exceeding one second, the greatest error being 2″.58 and the next 2″.

The horizontal floating collimator was tried by the Rev. Dr. BRINKLEY, the present Bishop of Cloyne at the Dublin Observatory, and by the Rev. Dr. ROBINSON at the Observatory at Armagh. An account of Dr. BRINKLEY's observations is given in the Philosophical Transactions for 1826, where it may be

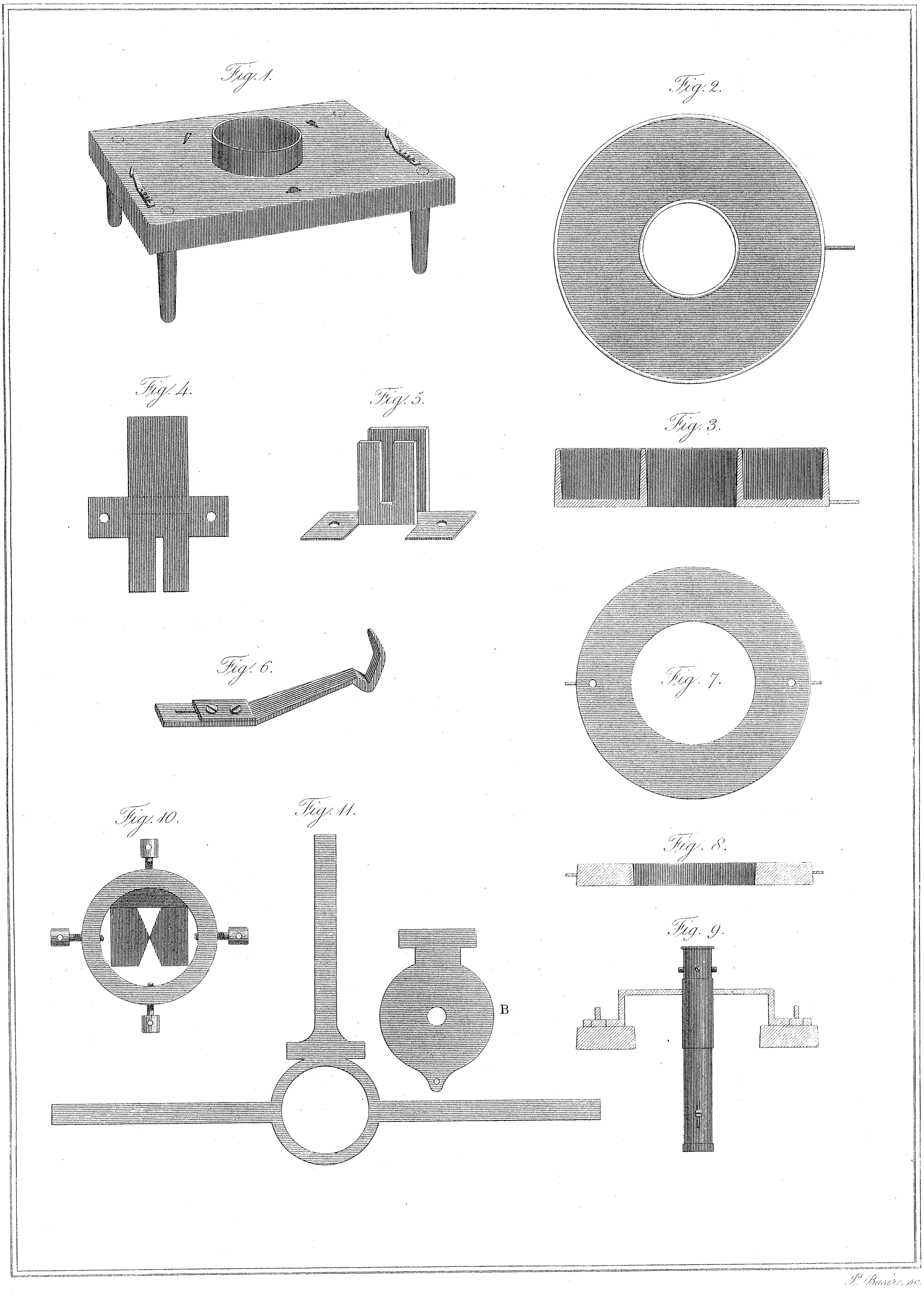
seen that the mean difference between the results of Dr. Brinkley's catalogue of 1823, and those obtained by means of the horizontal floating collimator by observations upon twenty stars, is only 0″.03.

Dr. Robinson, by ten observations of five stars made with the horizontal floating collimator and his equatorial, obtained a latitude differing only 0″.02 from the latitude resulting from his observations of the preceding two years, when the level was employed; and by thirteen observations with the collimator at the winter solstice of 1825, the deduced obliquity of the ecliptic for the beginning of the year, differed only 0″.33 from that given in the Nautical Almanac.

These results should seem to leave little to be desired in point of accuracy; but the method of using the horizontal floating collimator is so inconvenient, as to constitute no small objection to the general employment of the instrument in this form. To which may be added, the possibility of error arising, as before stated, from the necessity of taking the float out of the mercury and replacing it. From both these objections the vertical floating collimator is wholly free.

The vertical floating collimator has also this further advantage, that it may not only be used with a circle, but may be applied to a telescope, either of the refracting or reflecting kind; such a telescope furnished with a wire micrometer and directed to the zenith, becomes a zenith telescope, free from all the objections to which the zenith sector and the zenith telescope with a plumb-line are liable.

In Plate XIII. I have given plans and sections of the different parts of which the vertical floating collimator is composed. Fig. 1. represents a board of well seasoned mahogany fourteen inches square, and an inch and a half thick. Into this board four legs are screwed, at the distance of an inch and a half from the edge of the board to the centre of each leg. In the middle of the board a circular hole is made, four inches in diameter, into which a tube of sheet iron is firmly driven, of such a length as to project about an inch or an inch and a half above the upper surface of the board. At the distance of five inches and a half from the centre, three brass rollers are let into the board. These are equidistant from each other, and are intended to support the iron pan hereafter to be described, and to facilitate its being moved round about the sheet iron tube as a centre, with but little friction.



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Figs. 2. and 3. are the plan and section of a cast iron circular pan; this is one foot in diameter, and has a circular opening of four inches, which passes easily upon the tube of sheet iron just described, and about which the pan is intended to be turned. The sides of the pan (fig. 3.) are 2.4 inches high on the outside, the inside depth being two inches, which leaves four-tenths of an inch for the thickness of the bottom of the pan. The sides of the model for the pan must be sloped as in the section, for the convenience of casting. Into the side of the pan at the bottom a stout iron wire is screwed, intended, as will be seen, to serve as a stop to prevent the pan from being turned round more than 180 degrees.

Figs. 4. and 5. represent (in half its real dimensions) one of two guides made of sheet iron, destined to receive pins, which are intended to prevent the float, presently to be described, from moving horizontally. A piece of plate iron is cut into the form represented at fig. 4. This is afterwards turned up as at fig. 5. leaving the distance of a quarter of an inch between the front and back. Two of these guides are screwed to the bottom of the pan in the inside, (their backs touching its sides,) in that diameter which is at right angles to the iron pin projecting from the outside of the pan.

Fig. 6. represents a spring of about two inches and a half long. The flat part has a longitudinal slit in it, through which screws pass which attach it to the mahogany board, fig. 1. A piece of plate brass is interposed between the screws and the spring. The longitudinal slit is for the purpose of adjusting the spring to its required position. At its extremity the spring is formed into a Y, terminating in a hook, as represented in the figure. Two of these springs are fixed to the mahogany board; the Y of each being distant a little more than six inches from the centre of the board, in opposite directions, and the direction of the spring is at right angles to this diameter. The springs both point the same way.

If now we suppose the pan to be placed upon the sheet iron tube, fig. 1. and it be turned round, the iron pin will come in contact with one of the springs, which will yield to the weight of the pan until the pin is lodged in the Y, beyond which it will be prevented from going by the projecting hook. On turning the pan the contrary way, the inclined plane of the Y will yield to the pressure of the pin and permit it to escape; and when the pin has gone through

nearly a semicircle, the same process will take place at the other spring; these springs, therefore, afford the means of limiting the horizontal motion of the pan to 180 degrees.

Figs. 7. and 8. are the plan and section of a float of cast iron, 10.6 inches diameter, one inch thick, and having an opening in the middle of 5.7 inches diameter, consequently the breadth of the annulus is about two inches and a half. Into the sides of this float, at opposite points and equidistant from the two surfaces, two steel pins are screwed, of such a thickness as to pass freely into the grooves of the guides before mentioned with a very little shake. The ends of the pins are to be hemispherically rounded, and very smooth. When the float is placed in the pan, with the pins in the guides, the distance between the terminations of the pins should be such as to leave them just clear of the backs of the guides.

A section of the float with the bridge and telescope attached to it is given at fig. 9. The bridge is made of wrought iron. The length at the top is seven inches, and the perpendicular part of the bridge is of a sufficient height to enable the bridge to clear the middle part of the pan when the float is placed in it. In my vertical floating collimator the bridge is an inch and three-quarters above the float. The middle of the bridge consists of a piece of brass tube three or four inches long, destined to receive the telescope, which fits tightly into it. The width of the iron part of the bridge is half an inch, and the thickness about a quarter of an inch; but this may be varied according to circumstances which will hereafter appear. The parts where the bridge is screwed to the float have cross pieces four inches long, intended to give a firmer bearing. The heads of the screws are long, to serve as pins, upon which weights with holes in them may be placed, for the purpose of adjusting the float.

The bridge is screwed to the float in such a position that its length is at right angles to the pins inserted in the edge of the float, as before described. The intention being, that when the collimator is employed, the bridge should be in the direction of the meridian, and the guides at right angles to it. Two additional pins are fixed perpendicularly in the float near the guide pins. These are represented in the plan, fig. 7, and are intended to receive some of the weights by which the float is to be adjusted.

The telescope is achromatic, the object-glass in my collimator being about

eight inches focal length, and one inch and a quarter aperture. The object-glass is fixed in a separate piece of tube, which slides within another tube, to which, after adjustment, it may be firmly attached by two opposite screws moving in longitudinal slits.

In the focus of the object-glass of my collimator, a diaphragm is placed, carrying fine cross wires flattened. These wires, however, do not form angles so neat as could be wished, in consequence of their thickness, and of a want of perfect straightness of their edges; and I am indebted to Dr. WOLLASTON for the suggestion of a method of constructing a substitute for the cross wires, which has been applied to a vertical floating collimator made for Captain FOSTER, R.N. and which I found to answer perfectly well.

The surfaces of a plate of brass (bell metal would perhaps be preferable), about the twentieth of an inch thick, were ground parallel. The plate was then cut in half, and the surfaces cemented together. One of the sides of this double plate was then formed by grinding, into a salient angle of about 135°, the faces of this angle being slightly bevilled and carefully finished. The plates were then separated, and their opposite surfaces cemented together, the angular points and edges being made accurately to coincide. One of the sides (not that opposite to the angle) of this compound plate was then ground at right angles to the surface, and the plates again separated and carefully cleaned.

A circular piece of glass having been fitted into the diaphragm, a bit of brass with a straight edge was cemented to the glass on one side by shell lac. This was at such a distance from the middle of the diaphragm, as to allow the angular points of the brass plates to be in its centre, when their ground sides were in contact with the straight edge.

One of the brass plates was now attached by shell lac to the glass, having its ground edge in contact with the brass straight edge, the obtuse angle of the bevilled edge being next the glass, and the angular point in the middle of the diaphragm. It is now evident that if the ground edge of the other brass plate be placed in contact with the straight piece of brass, the obtuse angle of the bevil being next the glass, the two angular points will, upon sliding the brass plate along the straight edge, be brought accurately into contact, and in this position the brass plate was fixed to the glass by shell lac.

This arrangement afforded an object having well defined acute angles of

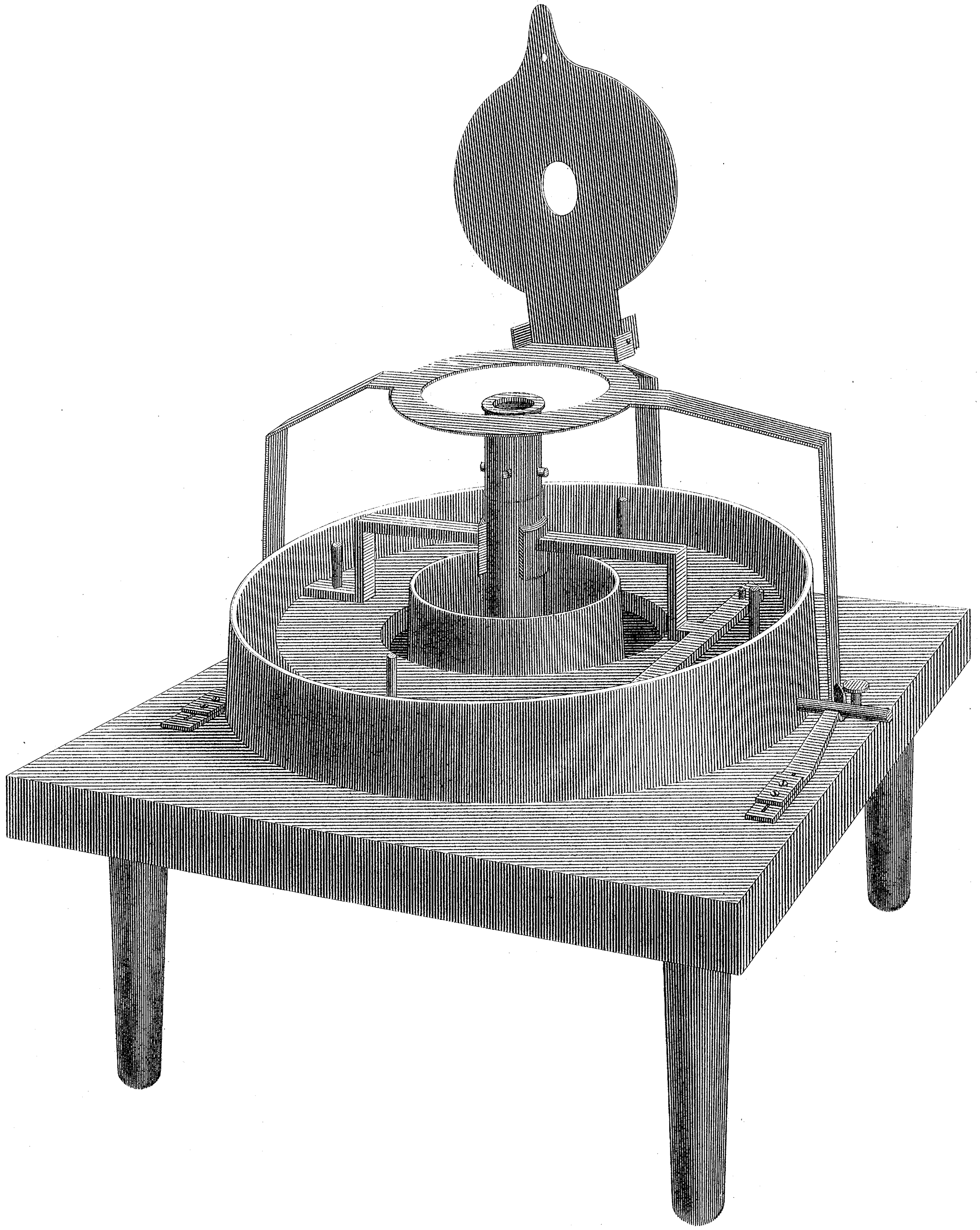
about 45°, which could be bisected with great precision. As this is a very important part of the instrument, I have been induced to describe thus minutely the manner in which it may be made. The diaphragm is placed in the telescope, with the brass plates next to the object-glass, in order that when the edges of the plates are seen with perfect distinctness, no particles of dust may be visible which may have lodged upon the surface of the glass. The angular point is brought into the centre of the tube in the usual manner, by means of opposite screws passing into the diaphragm. A piece of plane glass closes the end of the telescope, to keep out dust and to protect the diaphragm from accident. The diaphragm is represented at fig. 10*.

When observations are made with the floating collimator, it is necessary that all light should be excluded, except that which passes through its telescope. For this purpose a piece of sheet iron is formed, as represented at fig. 11. The aperture is the same as that of the iron basin of the collimator, and one side externally is straight, in order to form a hinge upon which the plate B moves. This plate may be raised to a perpendicular position, and when permitted to fall, rests steadily upon the ring. In the centre of the plate B, is a circular opening, rather less in diameter than the telescope. The three projecting parts of fig. 11. are intended, when bent close to the ring, to form legs, to be attached to the mahogany support, fig. 1, the length of these legs being such as to allow the plate B, when resting on the ring, to be quite clear of the telescope of the collimator.

For the purpose of illuminating the diaphragm of the collimator, a small plane mirror is used, similar to that of a microscope. This is attached to the plate B over the opening, by a short firm pedestal, the manner of doing which is so obvious, as to need no figure. The instrument is represented in Plate XIV.

The collimator being thus completed, it will be found convenient to adjust the object-glass of its telescope very nearly to the distance of its focal length from the diaphragm. For this purpose, any telescope may be employed which has been carefully adjusted to distinct vision upon a fixed star. The telescope of the collimator is to be supported in a convenient position for looking into it through its object-glass with the other telescope, and a lamp so placed as to illuminate the diaphragm. All false light being excluded from the telescope

* Since the above was written, I have found that a cross of strong spiders threads answers very well.



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employed, by a black paper screen surrounding that of the collimator, the diaphragm is to be viewed, and the distance of the object-glass from it to be varied until its angles appear sharp and well-defined. This I consider merely as preparatory to the final adjustment; but if the telescope used has a magnifying power of about one hundred, this adjustment will probably be found to be sufficiently accurate.

Two beams of wood are to be fixed horizontally to the walls of the observatory in the direction of the meridian, beneath the opening in the roof, and at such a distance from each other as that the legs of the support of the collimator may pass between them, and the board rest upon the beams. It may then be moved along upon the beams, the legs confining the motion in the direction of the meridian. In order to render this motion more free, and to prevent the beams from wearing, their upper surfaces are covered with sheet iron, and four rollers are let into the board near the legs, one of the rollers being attached to a spring in order that all four may be always in contact with the beams.

The instrument employed for the final adjustment of the collimator and in the zenith observations which will hereafter be detailed, was a reflecting telescope of the Newtonian construction, having an aperture of six inches and a quarter, a focal length of forty inches, and a magnifying power of ninety-nine times. This was furnished with a spider's thread micrometer, each of the divisions of which is equal to half a second.

A slight frame of wood was made to receive the tube of the telescope when placed in the direction of the zenith. This frame consisted of a triangle embracing the tube a little below the micrometer. From the corners of this triangle, three rods of wood pass into the extremities of a T made of wood, the cross piece being about two feet in length. Near the extremities of the T, are also inserted coarse iron screws, for the purpose of placing the telescope in the direction of the zenith. The tube of the telescope is kept steady in the triangle by two small wedges of wood, the end containing the mirror resting on the middle of the perpendicular bar of the T. The telescope previously to its being placed in the observatory, was very nicely adjusted to distinct vision upon a fixed star*.

* I have stated rather what ought to have been done, than what was actually effected at the time, as will be seen hereafter.

The room in which the observations were made, has a pit in it about two feet and a half wide, six feet long, and seven feet deep, filled with sand, upon which are laid two flat stones clear of the sides of the pit. These form a support for any instrument I employ, which is thus secured from any perceptible tremor which might be occasioned by passing carriages.

The Newtonian telescope, in its wooden frame, is placed under the collimator in such a position, that a plumb-line let fall from the centre of the collimator, passes on one side of the plane mirror of the telescope. The micrometer in my telescope is on the east side of the meridian, the micrometer head being to the right-hand of the observer; consequently the moveable line is perpendicular to the horizon, and from the nature of the telescope parallel to the equator. This line should be nicely adjusted so as to represent a parallel of declination, by turning the micrometer round in the eye-tube until a fixed star (γ Draconis in my observatory) runs along the wire.

A sufficient quantity of mercury is put into the basin of the collimator to support the float without risk of its touching the bottom. The diaphragm is illuminated by a lanthorn furnished with a lens, and placed upon a support attached to the board of the collimator. The illumination of the diaphragm was attended with much trouble in my first trials, but I afterwards discovered a method by which the difficulty was obviated. The end of the Newtonian telescope being closed by its cover, a sheet of white paper was placed upon it; the light of the lanthorn was thrown upon the plane mirror, and the position of the mirror varied until the shadow of the diaphragm appeared upon the paper.

If the diaphragm should not now be visible in the telescope, the telescope must be inclined to one side or the other by means of the foot-screws, till the diaphragm is seen in the centre of the field of view.

The next step is to place the line of collimation of the telescope of the collimator nearly in the direction of the zenith. For this purpose, the telescope is to be adjusted by its foot-screws, so that the horizontal thread of the micrometer shall pass through the angular point of the diaphragm, when the basin of the collimator must be turned half round. It is now possible that the diaphragm may be no longer in the field of view; in which case, whilst an assistant looks through the telescope, the float of the collimator must be depressed by the finger on one side or the other, until the diaphragm is again seen just

within the field. Weights must then be put upon the pins to which the pressure was applied, and the process repeated till the centre of the diaphragm remains in the middle of the field of view, upon the collimator being turned half round. The telescope must of course be made to follow these adjustments by means of its foot-screws. The telescope of the collimator must now be turned round in its tube, (the pin on the outside of the basin being in one of the Y's,) until the diaphragm is brought into that position in which both its angles can be bisected by the moveable line of the micrometer. When the adjustment is sufficiently accurate, the angular point of the diaphragm will remain upon the horizontal line, or very near it, and not depart much from the moveable line of the micrometer when the collimator is turned half round.

The collimator is now to be moved along the cross beams until the angles become faintly illuminated, when they are to be carefully bisected with the moveable line. The collimator is then to be slid the contrary way till the angles again become faint, when, if the bisection is not as perfect as before, the distance of the object-glass of the collimator from the diaphragm is not adjusted to the last degree of precision. If the diaphragm appears to have moved from the line in the opposite direction to that in which the collimator was moved, the rays diverge, and the object-glass is too near the diaphragm. If the diaphragm has moved in the same direction as the collimator, the rays converge, and the object-glass must be brought nearer to the diaphragm. When the angles continue perfectly bisected in both positions of the collimator, the object-glass is to be secured in its place by means of the screws for that purpose.

We have seen that when the iron pin was in one of the Y's, the telescope of the collimator was turned round in the tube which carries it, till the angles of the diaphragm could be bisected by the moveable line of the micrometer. But it is possible that upon lodging the iron pin in the other Y, the angles may no longer be capable of bisection. This would happen if the basin of the collimator had not described a semicircle; and in that case, the spring or Y must be shifted till the angles can be perfectly bisected, when it must be firmly fixed in its place*.

* It is evident that the adjustments which have been, I trust with sufficient minuteness, described, may be effected by employing the telescope attached to an astronomical circle, instead of using a detached telescope for the purpose.

I shall now show the manner in which the vertical floating collimator is to be used for determining the zenith point of an instrument, and the degree of dependence that may be placed upon the results.

The collimator is to be turned half round, and the iron pin lodged in one of the Y's. This is done merely to agitate the float slightly, in order to release the parts from any possible constraint. When the float is quite steady, which it will be in about half a minute, the angles of the diaphragm are to be carefully bisected by the moveable thread of the micrometer, and the division read off and registered. I have generally bisected the opposite angles separately, as will be seen in the tables which follow. The collimator is now to be turned half round, the angles again bisected, and the division of the micrometer read off. The mean of these readings will be the zenith point of the instrument employed, and half their difference will be the angle formed by the line of collimation of the telescope of the collimator with the zenith.

It must be evident that the accuracy of the results afforded by the floating collimator (excepting the unavoidable errors of observation) is wholly dependent upon the permanency of its line of collimation to the zenith, during the very short interval between the two observations, or bisections of the angles of the diaphragm which have been described. But this inclination may vary considerably from expansion, or otherwise, between any two determinations of the zenith point, without at all influencing the accuracy of either.

The agreement of the several determinations of the zenith point with each other, will depend upon the degree of stability with which the astronomical circle, or the zenith telescope is supported, and upon the supposition that its parts suffer no relative change of position from unequal temperature or otherwise. The time required for completing the determination of the zenith point by means of the vertical floating collimator, does not exceed two minutes; and if to this be added the time necessary for another determination of the zenith point, the whole time required will not be more than five minutes, during which, it may be allowable to suppose that no very sensible change can take place, either in the collimator or in the instrument, from variation of temperature. We will therefore consider the mean of these two separate determinations as the true zenith point, and conclude the difference between this mean, and the first determination of the zenith point to be the probable error with which such first determination can be charged. The second determination of

the zenith point will have the same error as the first, but with a contrary sign. This second determination, however, will also have another error deduced by taking the difference between it, and the mean of the second and third readings of the zenith point. The mean of these two errors is considered to be the probable error of the second zenith point, and so of the rest. It would not be safe to take the mean of all the determinations of the zenith point which constitute a series for the standard of comparison, as the instrument may, and probably will, have suffered some slight change of position during so long a period. If the errors (supposed to belong to the floating collimator) be applied to the observed zenith points, the results will show the whole change of position which the zenith telescope may have suffered during the observations constituting the series; and as it may be interesting to see the degree of stability of an instrument supported in the slight manner I have described, I have added a column of the corrected zenith points.

I shall now proceed to detail the experiments that have been made; and in order that the inferences may not rest solely upon my own authority, I shall give the observations of such gentlemen as have been from time to time kind enough to assist me.

The Collimator turned half round rapidly and without care.

Date. 1827.	Reading of the Micrometer. Divisions.	Mean.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.	Corrected Zenith Point.
Oct. 20.	79.5 77.3 71.7 74.8	78.40 73.25	2.57	1.28″	75.82	37.91″	+0.10″	37.81″
	79.0 75.7 72.8 74.2	77.35 73.50	1.92	0.96	75.42	37.71	+0.00	37.71
	78.8 76.0 73.0 72.2	77.40 72.60	2.40	1.20	75.00	37.50	−0.11	37.61
						Mean....	0.00	

The Collimator turned half round rapidly and without care.

Date. 1827.	Reading of the Micrometer. Divisions.	Mean.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.	Corrected Zenith Point.
Oct. 21.	63.0 63.0 83.0 87.7	63.00 85.35	11.17	5″.58	74.17	37″.08	−0″.11	37″.19
	64.2 64.2 82.0 88.0	64.20 85.00	10.40	5.20	74.60	37.30	+0.05	37.25
	65.0 65.0 82.0 86.7	65.00 84.35	9.67	4.83	74.67	37.33	−0.02	37.35
	66.0 66.0 81.7 86.0	66.00 83.85	8.92	4.46	74.92	37.46	+0.01	37.45
	64.5 64.5 81.0 88.3	64.50 84.65	10.07	5.03	74.57	37.28	−0.10	37.38
	66.0 66.0 81.0 87.0	66.00 84.00	9.00	4.50	75.0	37.50	+0.08	37.42
	65.0 65.0 80.0 85.8	65.00 82.90	8.95	4.47	73.95	36.97	0.00	36.97
	64.0 64.0 78.0 85.5	64.00 81.75	8.87	4.43	72.87	36.43	−0.18	36.61
	63.5 63.5 80.0 86.0	63.50 83.00	9.75	4.87	73.25	36.62	+0.08	36.54
	64.0 64.0 78.2 85.5	64.00 81.85	8.92	4.46	72.92	36.46	+0.07	36.39
	62.0 62.0 78.0 86.0	62.00 82.00	10.00	5.00	72.00	36.00	−0.13	36.13
	63.0 63.0 78.2 84.3	63.00 81.25	9.12	4.56	72.12	36.06	+0.02	36.04
	61.8 61.8 79.2 85.5	61.80 82.35	10.27	5.13	72.07	36.03	−0.02	36.05
						Mean....	−0.01	

The Collimator turned half round slowly and carefully.								
Date. 1827.	Reading of the Micrometer. Divisions.	Mean.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.	Corrected Zenith Point.
Oct. 22.	7.0 7.0 42.0 47.0	7.00 44.50	18.75	9″.37	25.75	12″.87	−0″.36	13″.23
	8.0 8.0 43.8 49.0	8.00 46.40	19.20	9.60	27.20	13.60	+0.23	13.37
	8.0 8.0 43.0 48.2	8.00 45.60	18.80	9.40	26.80	13.40	−0.14	13.54
	8.0 8.0 43.8 50.3	8.00 47.05	19.52	9.76	27.52	13.76	+0.29	13.47
	7.0 7.0 42.3 47.3	7.00 44.80	18.90	9.45	25.90	12.95	−0.26	13.21
	7.2 7.2 42.7 48.3	7.20 45.50	19.15	9.57	26.35	13.17	+0.04	13.13
	7.0 7.0 44.2 47.7	7.00 45.95	19.47	9.73	26.47	13.23	+0.06	13.17
	6.2 6.2 43.8 48.2	6.20 46.00	19.90	9.95	26.10	13.05	0.00	13.05
	6.7 6.7 43.0 46.8	6.70 44.90	19.10	9.50	25.80	12.90	−0.08	12.98
						Mean....	−0.02	

Oct. 27.	88.2 91.1 78.0 73.8	89.65 75.90	6.87	3″.43	82.77	41″.38	−0″.07	41″.45
	86.2 91.7 78.0 76.3	88.95 77.15	5.90	2.95	83.05	41.52	−0.11	41.63

Date. 1827.	Reading of the Micrometer. Divisions.	Mean.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.	Corrected Zenith Point.
Oct. 27. (Continued.)	88.0 93.1 79.0 76.8	90.55 77.90	6.32	3″.16	84.22	42″.11	+0″.23	41″.88
	85.4 92.5 78.6 77.5	88.95 78.05	5.45	2.72	83.50	41.75	+0.31	41.44
	84.1 89.0 78.0 76.0	86.55 77.00	4.77	2.38	81.77	40.88	+0.03	40.85
	82.5 86.3 77.0 73.3	84.40 75.15	4.62	2.31	79.77	39.88	−0.28	40.16
	82.0 87.0 76.8 74.4	84.50 75.60	4.45	2.22	80.05	40.02	+0.05	39.97
	82.0 87.0 77.0 73.7	84.50 75.35	4.57	2.28	79.92	39.96	−0.08	40.04
	82.7 87.5 77.0 74.8	85.10 75.90	4.60	2.30	80.50	40.25	+0.14	40.11
						Mean . .	+0.02	
Oct. 28.	63.5 70.2 23.0 24.7	66.85 23.85	21.50	10″.75	45.35	22″.67	+0″.21	22″.46
	60.6 70.0 23.0 24.5	65.30 23.75	20.77	10.38	44.52	22.26	−0.21	22.47
	62.0 68.7 24.5 26.3	65.35 25.40	19.97	9.98	45.37	22.68	+0.05	22.63
	60.8 68.7 25.7 27.9	64.75 26.80	18.97	9.48	45.77	22.88	+0.11	22.77
	60.7 66.0 26.2 28.5	63.35 27.35	18.00	9.00	45.35	22.67	−0.11	22.78
						Mean . .	+0.01	

Experiments by Mr. Herschel.

Date. 1827.	Reading of the Micrometer. Divisions.	Mean.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.	Corrected Zenith Point.
Nov. 26.	87.2 85.0 21.8 14.6	86.10 18.20	33.95	16″.97	52.15	26″.07	+0″.37	25″.70
	85.9 83.0 20.3 13.5	84.45 16.90	33.77	16.88	50.67	25.33	−0.21	25.54
	86.4 83.2 21.4 12.6	84.80 17.00	33.90	16.95	50.90	25.45	+0.25	25.20
	87.1 81.2 17.8 10.6	84.15 14.20	34.97	17.48	49.17	24.58	−0.09	24.67
	84.2 82.2 16.2 10.1	83.20 13.15	35.02	17.51	48.17	24.08	−0.11	24.19
	83.8 81.0 16.2 11.4	82.40 13.80	34.30	17.15	48.10	24.05	−0.02	24.07
						Mean....	+0.03	

Experiments by Mr. Baily.

Date.	Reading of the Micrometer. Divisions.	Mean.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.	Corrected Zenith Point.
1828. Jan. 20.	17.0 9.3 32.2 31.2	13.15 31.70	9.27	4″.68	22.42	11″.21	+0″.39	10″.82
	16.2 9.9 31.9 29.5	13.05 30.70	8.82	4.41	21.87	10.43	−0.39	10.82

Experiments by Colonel Colby.

Date.	Reading of the Micrometer. Divisions.	Mean.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.	Corrected Zenith Point.
Jan. 20.	36.0 33.2 18.7 10.9	34.60 14.80	9.90	4″.95	24.7	12″.35	+0″.51	11″.84
	35.2 32.6 14.0 8.9	33.90 11.45	11.22	5.61	22.67	11.33	−0.42	11.75
	34.9 32.1 17.0 12.2	33.50 14.60	9.45	4.72	24.05	12.02	+0.34	11.68
						Mean....	+0.14	

Experiments by Mr. South.

Date. 1828.	Reading of the Micrometer. Divisions.	Mean.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.	Corrected Zenith Point.
Jan. 22.	25.3 22.7 64.1 60.3	24.00 62.20	19.10	9.55″	43.10	21.55″	+0.29″	21.26″
	24.6 22.3 60.5 60.5	23.45 60.50	18.52	9.26	41.97	20.98	+0.09	20.89
	22.8 20.3 58.5 58.8	21.55 58.65	18.50	9.25	40.10	20.05	−0.51	20.56
	25.3 18.7 63.8 61.7	22.00 62.75	20.37	10.18	42.37	21.18	+0.48	20.70
	23.3 19.6 59.3 60.8	21.45 60.05	19.30	9.65	40.75	20.37	−0.41	20.78
						Mean....	−0.01	

Experiments by Captain Sabine.

Date. 1828.	Reading of the Micrometer. Divisions.	Mean.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.	Corrected Zenith Point.
Jan. 25.	69.0 64.8 30.0 25.0	66.90 27.50	19.70	9.85″	47.2	23.60″	+0.13″	23.47″
	67.8 64.6 29.0 25.4	66.20 27.20	19.50	9.75	46.7	23.35	−0.19	23.54
	67.6 63.8 31.5 27.9	65.70 29.70	18.00	9.00	47.7	23.85	+0.32	23.53
	66.3 64.8 28.0 25.3	65.55 26.65	19.45	9.77	46.10	23.05	+0.03	23.02
	65.5 61.2 27.7 24.6	63.35 26.15	18.60	9.30	44.75	22.37	−0.34	22.71
						Mean....	−0.01	

For greater convenience, I shall now give in one view the errors with which each of the preceding determinations of the zenith point can be charged, classing together such as do not exceed one-tenth of a second; those between one and two tenths; those between two and three tenths; those between three and four tenths; those between four and five tenths; and such as exceed half a second.

TABLE of the Errors of the preceding determinations of the Zenith Point.

Not exceeding One Tenth of a Second.	Between One and Two Tenths.	Between Two and Three Tenths.	Between Three and Four Tenths.	Between Four and Five Tenths.	Above Five Tenths.
+.10	—.11	+.23	—.36	—.42	+.51
.00	—.11	+.29	+.31	+.48	—.51
+.05	—.18	—.26	+.37	—.41	
—.02	—.13	+.23	+.39		
+.01	—.14	—.28	—.39		
—.10	—.11	+.21	+.34		
+.08	+.14	—.21	+.32		
.00	+.11	—.21	—.34		
+.08	—.11	+.25			
+.07	—.11	+.29			
+.02	+.13				
—.02	—.19				
+.04					
+.06					
.00					
—.08					
—.07					
+.03					
+.05					
—.08					
+.05					
—.09					
—.02					
+.09					
+.03					

We may here perceive, that of sixty independent determinations of the zenith point, there are twenty-five, the error of each of which does not exceed one tenth of a second, thirty-seven under two tenths, forty-seven under three tenths, fifty-five under four tenths, three between four and five tenths, and two a little above half a second.

But it is probable that the greater part of these errors, minute as they are, must be attributed to want of power in the micrometer; for I found that when

the collimator was stationary, the repeated bisections of the same angle would generally differ one or two divisions from each other; and it must be remembered that one division is equal to half a second. The focal length of the telescope employed is only forty inches, and the power or scale of the micrometer, and consequently the precision of which it is capable, is directly as the focal length of the object-glass or mirror of the telescope to which it is attached.

The zenith telescope, and the telescope of the collimator, may be considered as forming together a compound microscope, having, as it were, a separable object-glass, the two parts of which may be placed at any distance from each other without altering the effect. The magnifying power of this microscope may be found in the usual manner, by dividing the focal length of the zenith telescope by that of the telescope of the collimator, and multiplying the result by the power of the eye-glass, or by the quotient of ten inches divided by its focal length. Thus the focal length of the zenith telescope being forty inches, and the magnifying power ninety-nine times, the focal length of the eye-glass will be about four tenths of an inch. Then dividing forty inches by eight inches, the focal length of the telescope of the collimator, and this again by the power of the eye-glass, we have $\frac{40}{5} + \frac{10}{0.4} = 125$ for the magnifying power exerted upon the diaphragm of the collimator.

The collimator I have described has a float 10.6 inches diameter; but I have had one constructed on a much smaller scale for Captain Foster, R.N. the float of which is only five inches in diameter, and its telescope about five inches long.

Some experiments have been made with this little instrument, the results of which have so far exceeded my expectations, that I think they may not prove uninteresting*.

* On taking down my collimator after it had been exposed for six months, in order to replace it by that made for Captain Foster, I found it very rusty, and the mercury very dirty. On taking out the float, it appeared that the mercury had adhered to it, so as to form a kind of coating like amalgam. These circumstances may have slightly affected the accuracy of the instrument. I have since discovered that by rubbing the float with chalk, and afterwards wiping it, the adhesion of the mercury is prevented.

Experiments with Captain Foster's Collimator.

Date. 1828.	Reading of the Microm. Divisions.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.
			"		"	"
Feb. 22.	90.7 84.0	3.35	1.67	87.35	43.67	−0.12
	89.0 86.7	1.15	0.57	87.85	43.92	+0.23
	87.0 86.0	0.50	0.25	86.50	43.25	−0.45
	87.3 90.2	1.45	0.72	88.75	44.37	+0.27
	86.0 91.6	2.80	1.40	88.80	44.40	+0.17
	87.0 88.0	0.50	0.25	87.50	43.75	−0.14
	85.0 89.7	2.35	1.17	87.35	43.67	−0.04
	84.0 91.0	3.50	1.75	87.50	43.75	+0.21
	81.0 91.0	5.00	2.50	86.00	43.00	−0.71
	85.4 95.0	4.80	2.40	90.20	45.10	+0.53
	84.3 96.0	5.85	2.92	90.15	45.07	+0.15
	83.0 94.0	5.50	2.75	88.85	44.42	−0.33
					Mean..	−0.02

Experiments by Captain Foster.

			"		"	"
Feb. 23.	63.2 118.0	27.40	13.70	90.60	45.30	+0.09
	65.0 115.5	25.25	12.62	90.25	45.12	−0.01
	63.5 116.5	26.50	13.25	90.00	45.00	+0.14
	64.0 113.3	24.65	12.32	88.65	44.32	+0.02
	66.2 108.0	25.90	12.95	87.10	43.55	−0.28
	67.8 107.8	20.00	10.00	87.80	43.90	+0.08
					Mean..	+0.01

Experiments by Mr. Harvey.

Date. 1828.	Reading of the Microm. Divisions.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.
			"		"	"
Feb. 26.	69.4 57.5	5.95	2.97	63.45	31.72	+0.35
	69.7 60.0	4.85	2.42	64.85	32.42	−0.17
	69.5 60.2	4.65	2.32	64.85	32.42	+0.02
	68.3 61.0	3.65	1.82	64.65	32.32	+0.13
	69.6 57.2	6.20	3.10	63.40	31.70	−0.43
	67.7 62.7	2.50	1.25	65.20	32.60	+0.34
	69.5 59.8	4.85	2.42	64.65	32.32	+0.14
	68.8 59.4	4.70	2.35	64.10	32.05	+0.29
	65.0 57.5	3.75	1.87	61.25	30.62	−0.67
	69.5 58.0	5.75	2.87	63.75	31.87	+0.62
					Mean..	+0.06

The following Table contains the Error of each of the preceding determinations of the Zenith Point, by Captain Foster's Collimator.

Not exceeding One Tenth of a Second.	Between One and Two Tenths.	Between Two and Three Tenths.	Between Three and Four Tenths.	Between Four and Five Tenths.	Above Five Tenths.
−.04	−.12	+.23	−.33	−.45	−.71
+.09	+.17	+.27	+.35	−.43	+.53
−.01	−.14	+.21	+.34		−.67
+.02	+.15	−.28			+.62
+.08	+.14	+.29			
+.02	−.17				
	+.13				
	+.14				

I leave the results of the little floating collimator to speak for themselves, and shall now return to my larger collimator before described.

On the manner of using the Vertical Floating Collimator in Astronomical Observations.

The instrument employed in the observations which I shall first detail, was the portable azimuth and altitude circle described by the Rev. F. Wollaston in his "Fasciculus Astronomicus," and was the property of the late D. Moore, Esq. F.R.S. This circle is only one foot in diameter; the divisions are dots upon brass, and it is also divided by lines. Of the dots, though they are the divisions used, I cannot learn the history. Many of them are much injured, and some nearly obliterated.

The instrument is furnished with two microscopes, the micrometer heads of which are divided to two seconds; but I have attempted by the eye to estimate the readings to tenths of a second. The focal length of the telescope is twenty inches, and it magnifies about thirty times.

I shall now describe the manner in which the different adjustments of an altitude and azimuth circle may be readily effected by means of the vertical floating collimator.

To adjust the Line of Collimation.

The circle being placed in the meridian, and the vertical floating collimator over it, the meridian wire is to be brought to the angular point of the diaphragm of the collimator, by means of one of the foot-screws of the circle. The axis is now to be taken out of the Y's and reversed; when if the meridian wire is no longer on the angular point of the diaphragm, the space over which it has moved is equal to double the error of the line of collimation. Bisect this space by moving the meridian wire by means of the screws in its diaphragm, and the line of collimation will then be at right angles to the axis. This is proved by the meridian wire suffering no change of place when the axis is reversed*.

To place the Horizontal axis of the Circle at right angles to the Vertical axis.

Bring the meridian wire to the angular point of the diaphragm of the collimator by means of the foot-screw. Turn the circle half round in azimuth, and then note the distance of the meridian wire from the angular point. Half this distance is the error of the horizontal axis, or its deviation from perpendicularity to the vertical axis. Cause the meridian wire to bisect this distance by

* The operation just described, is nothing more than the process of adjusting the line of collimation of a transit instrument, the angular point of the diaphragm of the collimator serving instead of a distant terrestrial object. It may be done with great convenience by means of the horizontal floating collimator.

means of the screw which acts upon that Y which is opposite to the microscopes, and the horizontal axis will be perpendicular to the vertical axis. This adjustment is known to be perfect when the meridian wire remains upon the angular point after the circle has been turned half round in azimuth.

To place the axis of the circle parallel to the Horizon.

Lodge the iron pin of the basin of the collimator in one of the Y's, and by means of one of the foot-screws bring the meridian wire to the angular point of the diaphragm. Turn the collimator half round, and note the distance (if any) of the meridian wire from the angular point. Half this distance is the error of the axis or its deviation from horizontality. Cause the meridian wire to bisect this distance by means of the foot-screw, and the axis of the circle will then be parallel to the horizon. Examine this adjustment by turning the collimator half round; when if it is correct, the angular point will be equally distant on either side from the meridian wire, of which the eye will judge with considerable accuracy*.

These are all the adjustments that are necessary; and whoever has enjoyed the superior convenience and facility of effecting them by means of the floating collimator, will scarcely prevail on himself to return to the instability and uncertainty of a level.

Should it be necessary, the telescope of the collimator must be turned in its tube (the iron pin being lodged in one of the Y's) until the angles of the diaphragm can be bisected by the horizontal wire of the circle, when the instrument is ready to be employed in celestial observations. I have of course taken it for granted that the float has been adjusted by the application of weights to it, so that the angular point of the diaphragm remains either upon or very near the meridian wire, and does not depart far from the horizontal wire when the collimator is turned half round.

Before quitting the subject of adjustments, I may remark, that the vertical floating collimator affords the most perfect method of adjusting the line of collimation of a mural circle, or of placing it at right angles to the axis. But for this purpose it will be necessary to employ two of these instruments, one placed above, and the other below the circle. Bring then the meridian wire

* I scarcely need point out the value of this mode of adjustment as applied to a transit instrument. It insures the line of collimation describing a vertical circle, and is independent of any inequality in the size of the pivots.

of the mural circle to the angular point of the diaphragm of the upper floating collimator. Turn the collimator half round and bring back the meridian wire by adjusting the axis of the circle through half the distance it has appeared to move from the angular point. Look now into the lower collimator, and note the distance at which the angular point appears to be from the meridian wire. Turn this collimator half round, and remark whether the angular point is at the same distance as before on the other side of the meridian wire; and if the distance is not the same, halve the estimated difference by moving the meridian wire by means of the adjusting screws of its diaphragm. Repeat these operations until in both collimators the angular point appears to move to an equal distance on each side of the meridian wire on the collimator being turned half round, when the line of collimation will be at right angles to the axis, and the axis will by the same process have been placed parallel to the horizon.

It will be found convenient before the observation of the star is made, to ascertain that the illumination of the collimator is perfect, as it must be evident that it is important to determine the zenith point of the instrument as soon after the observation of the star as possible.

Should the star be at such an altitude as for the view of it to be intercepted by the collimator, the collimator must be moved as far as may be requisite along the beams. After the star has been carefully bisected, and before the microscopes are read off, the shutter of the observatory is to be closed, and the collimator is to be brought back to its place and turned half round. The microscopes are then to be read off and registered, and by the time this is completed, the collimator will be steady. The angles of the diaphragm are now to be bisected by the horizontal wire, and the collimator immediately turned half round. The divisions of the circle are then to be examined, and the microscopes read off and registered. Long before this, the collimator will again be steady, when the angles are again to be bisected, and the readings of the microscopes registered. This forms a complete observation; but it is desirable to repeat the operation for the determination of the zenith point, in order to preclude or detect error. The mean of the readings at the collimator will be the place of the zenith point upon the circle, and the difference between this and 90 degrees or zero, will furnish a correction to be applied with its proper sign to the reading at the star, for the purpose of obtaining its apparent altitude or its zenith distance.

The refractions used in the following Table, are those given by Dr. Young in the Nautical Almanac.

Observations with the Astronomical Circle.—(*Face West.*)

Date. 1827.	Star.	Readings.	Mean.	Mic^s	Collimator.	Collimator reversed.	Incl. of Collim.	Zenith Point.	Correction.	Apparent Altitude.	Barom.	Extern. Therm.	Refrac-tion.	True Altitude.	Latitude.
		° ′ ″	° ′ ″		° ′ ″	° ′ ″	″	° ′ ″	′ ″	° ′ ″	Inches.	°	′ ″	° ′ ″	° ′ ″
June 20	α Herculis	50 4 7.0 4 34.5	53 4 20.75	A B	89 59 13.5 59 17.0	89 59 11.0 59 6.8	3.17	89 59 12.07	+0 47.93	53 5 8.68	29.90	54	0 43.21	53 4 25.47	51 31 20.23
	α Ophiuchi	51 10 0.3 10 28.0	51 10 14.15	A B	89 59 6.5 59 13.0	89 59 12 59 17	2.37	89 59 12.12	+0 47.88	51 11 2.03	29.90	54	0 45.97	51 10 16.06	51 31 25.94
22	α Serpentis	45 26 34 27 25	45 26 59.5	A B	89 58 45.0 58 55.8	89 58 52.5 59 3.0	3.67	89 59 54.07	+1 5.93	45 28 5.43	30.16	55	0 56.34	45 27 9.09	51 31 26.71
23	Arcturus	58 33 18 33 32	58 33 25	A B	89 59 0.8 59 0.0	89 58 46.5 58 45.5	7.20	89 58 53.2	+1 6.8	58 34 31.8	30.18	58	0 34.49	58 33 57.31	51 31 14.47
	α Coronæ	65 45 59.7 46 17.8	65 46 8.75	A B	89 58 59.8 58 57.8	89 58 47.0 58 46.7	5.97	89 58 52.82	+1 7.18	65 47 15.93	30.18	58	0 25.80	65 46 50.13	51 31 22.33
	Antares	12 29 18.0 29 27.2	12 29 22.6	A B	89 58 50.0 58 49.5	89 58 56.0 58 54.5	2.75	89 58 52.50	+1 7.5	12 30 30.1	30.18	56	4 13.88	12 26 16.22	51 31 20.68
	α Herculis	53 3 57.5 4 12.8	53 4 5.15	A B	89 58 55.0 58 52.5	89 58 50.0 58 49.0	2.12	89 58 51.62	+1 8.38	53 5 13.53	30.18	55	0 43.12	53 4 30.41	51 31 16.29
	α Ophiuchi	51 9 50.0 10 8.0	51 9 59	A B	89 58 52.5 58 46.2	89 58 55.2 58 49.0	1.37	89 58 50.72	+1 9.28	51 11 8.28	30.18	53.5	0 46.32	51 10 21.96	51 31 20.60
24	α Coronæ	65 45 52.3 46 12.0	65 46 2.15	A B	89 58 44.5 58 47.5	89 58 45.8 58 48.5	0.57	89 58 46.57	+1 13.43	65 47 15.58	30.18	61	0 25.64	65 46 49.94	51 31 22.71
	Antares	12 29 6.0 29 28.8	12 29 17.4	A B	89 58 47.5 58 52.0	89 58 42.5 58 47.5	2.37	89 58 47.37	+1 12.63	12 30 30.03	30.17	59.5	4 11.94	12 26 18.09	51 31 19.86
26	Antares	12 29 12.2 29 35.5	12 29 23.85	A B	89 58 52.5 58 56.4	89 58 54.7 58 59.0	1.20	89 58 55.65	+1 4.35	12 30 28.20	30.09	62	4 9.92	12 26 18.28	51 31 19.61
	α Herculis	53 3 54.0 4 12.3	53 4 3.15	A B	89 58 57.0 58 58.2	89 58 48.0 58 52.3	3.72	89 58 53.87	+1 6.13	53 5 9.28	30.09	60.5	0 42.61	53 4 26.67	51 31 20.63
	α Ophiuchi	51 9 47.0 10 16.0	51 10 1.50	A B	89 58 51.0 58 51.2	89 58 55.5 58 58.4	2.92	89 58 54.02	+1 5.98	51 11 7.48	30.09	60	0 45.72	51 10 21.76	51 31 21.37
														Face West, Mean...	51 31 20.88

(*Face East.*)

Date. 1827.	Star.	Readings.	Mean.	Mic^s	Collimator.	Collimator reversed.	Incl. of Collim.	Zenith Point.	Correction.	Apparent Altitude.	Barom.	Extern. Therm.	Refrac-tion.	True Altitude.	Latitude.
		° ′ ″	° ′ ″		° ′ ″	° ′ ″	″	° ′ ″	′ ″	° ′ ″		°	′ ″	° ′ ″	° ′ ″
July 6	α Coronæ	65 46 9 46 9.7	65 46 9.35	B A	89 58 41.3 58 38.8	89 59 1 58 56.5	11.85	89 58 46.9	+1 13.10	65 47 22.45	30.45	67	0 25.60	65 46 56.85	51 31 17.87
	Antares	12 29 7.2 29 19.2	12 29 13.2	B A	89 59 3.2 59 2.0	89 58 28 58 31	16.45	89 58 46.05	+1 13.95	12 30 27.15	30.45	67	4 10.35	12 26 16.80	51 31 20.86
7	α Coronæ	65 46 8.5 46 13.5	65 46 11	B A	89 58 51.2 59 1	89 58 48 58 46	4.55	89 58 51.55	+1 8.45	65 47 19.45	30.44	71	0 25.40	65 46 54.05	51 31 21.63
	Antares	12 29 8 29 15	12 29 11.5	B A	89 58 50 58 53	89 58 52.8 58 57	1.70	89 58 53.2	+1 6.80	12 30 18.3	30.44	71	4 8.12	12 26 10.18	51 31 27.46
8	α Coronæ	65 45 45 45 54	65 45 49.5	B A	89 58 29 58 29.7	89 58 31.2 58 30	0.62	89 58 29.97	+1 30.03	65 47 19.53	30.41	74	0 25.31	65 46 54.22	51 31 20.82
	α Serpentis	45 26 34.3 26 47	45 26 40.65	B A	89 58 26 58 32.3	89 58 27 58 31	0.07	89 58 29.07	+1 30.93	45 28 11.58	30.41	74	0 54.78	45 27 16.80	51 31 20.88
	Antares	12 28 45.3 28 55.3	12 28 50.3	B A	89 58 27 58 28.2	89 58 28.7 58 30	0.87	89 58 28.47	+1 31.53	12 30 21.83	30.41	71	4 7.87	12 26 13.96	51 31 23.66
	α Herculis	53 3 44 3 43	53 3 43.5	B A	89 58 34.7 58 33	89 58 29 58 26.2	3.12	89 58 30.72	+1 29.28	53 5 12.78	30.41	70	0 42.25	53 4 30.43	51 31 19.09
	α Ophiuchi	51 9 38 9 52.5	51 9 45.25	B A	89 58 29 58 24	89 58 31.3 58 28.2	1.62	89 58 28.12	+1 31.88	51 11 17.13	30.41	69	0 45.38	51 10 31.75	51 31 13.57
														Face East, Mean...	51 31 20.65
														Face West, Mean...	51 31 20.88
														Mean...	51 31 20.76

The resulting latitude of York Gate is 51° 31′ 20″.76.

The mean of 40 observations of different stars in 1825, using the horizontal floating collimator and the same circle, gave 51° 31′ 20″.94.

If we analyse the observations detailed in the preceding table, we may form an estimate: 1st, of the stability of the instrument, and the efficiency of its telescope and microscopes: 2dly, of the degree of accuracy with which a star has been bisected; and 3dly, of the equality or otherwise of the divisions of the circle.

On examining the column of the zenith point, we perceive that on the same evening the differences are but small: for example, on the 23rd of June the greatest difference from the mean was only 2″.25. From which we may infer, that the support of the instrument suffered little change of position during that evening, and that the telescope and microscopes were of a power sufficient to determine this quantity.

On referring to the corresponding inclination of the collimator, we find it in the course of the evening to have varied considerably, without affecting the accurate determination of the zenith point. The cause of this variation I conceive to be the bridge having in the first instance been made very slight, and being consequently readily affected by change of temperature when the shutter of the observatory was opened.

If the bisection of a star could be accurately made, and there existed no uncertainty with respect to refraction, the same latitude would be given on different evenings by the same star; as its altitude is determined by reference to the same division of the instrument. But, we may see that in the preceding table these results differ. With α Herculis the greatest difference is 4″.34, with α Ophiuchi 5″.34, and with Antares the difference amounts to 6″.6. From this we may conclude that, taking an unfavourable state of the atmosphere into consideration, the uncertainty in bisecting a star with this telescope may probably be about three seconds.

As the altitude of each star is referred to a different division of the circle, if the mean of the latitudes given by each star be taken, and these means be compared together, they ought, if the circle is well divided, to agree, and their difference will give some idea of the error in this respect. The observations of each star have not been sufficiently numerous to determine this with accuracy; but I am inclined to think it probable that the error of such points of the circle as have been used does not exceed three seconds.

It is possible that the dots to which the zenith point is referred may be in error; in which case, all the altitudes will be affected to an amount equal to that error. This however is destroyed by reversing the circle, observing with the face the contrary way, and taking the mean of the results in both positions.

If the circle should be upon stone pillars, or so circumstanced that there should be room for the floating collimator below it, it may be employed in that position, its legs serving as a support. The only alteration then necessary will be to invert its telescope, placing the object-glass uppermost, and illuminating the diaphragm from below by means of a mirror attached to a small mass of lead, which may be placed on the ground. The telescope of the circle will then look into that of the collimator downwards; and this, if the circle should not be too high, may sometimes be the more convenient method.

Of the Application of the Vertical Floating Collimator to a Zenith Telescope.

So much has already been said which is appropriate to this subject in describing the adjustment of the collimator, and the determination of the zenith point, that little remains to be added. The Newtonian telescope was the instrument employed; and in the two first observations of γ Draconis, its wooden frame not being finished, the telescope was brought nearly in the direction of the zenith by three small wedges of wood placed under the mirror end, and forming, it must be confessed, a very frail support. The focus of the telescope, too, had not been accurately adjusted, and the moveable wire was placed parallel to the equator merely by estimation. Between the two observations, the telescope was removed; they are recorded, however, as matter of curiosity, but I have not included them in the mean of the observations detailed, though they would not have vitiated the result.

Should the star pass the meridian at night, it will of course be requisite to illuminate the wires of the micrometer in the usual manner. The collimator having been moved along the beams which support it, out of the way of the telescope, the star is to be carefully bisected by the moveable wire, the collimator to be brought back and turned half round, and then the reading of the micrometer at the star to be registered. The angles of the diaphragm are now to be bisected, and the collimator having been turned half round, the divisions of the micrometer are to be recorded. Lastly, the angles of the diaphragm are again to be bisected, and the reading of the micrometer registered. This com-

pletes the observation, which altogether requires about five minutes. The mean of the readings at the collimator will give the zenith point; and the difference between the zenith point and the reading at the star, will be the star's zenith distance in divisions of the micrometer to be converted into seconds.

It will be advisable to repeat the determination of the zenith point as directed in observations with the circle, to guard against error.

If the aperture of the zenith telescope should be sufficiently large to render the loss of light from the interposition of the telescope of the collimator of no consequence, it may not be necessary to remove the collimator; but the iron cover B, (see Plate XIII.) may be raised, and the star observed through the opening in the support of the collimator. The cover is then to be replaced, and the zenith point determined in the usual manner.

The diameter of the opening of my collimator being four inches, and the extreme diameter of the telescope an inch and a half, the loss of light would be about one seventh part of the whole; I have not yet tried this method of observing, and perhaps it may be found that the bridge of the collimator (which for this purpose should be thin and deep) may occasion some distortion in the image of the star.

TABLE of Observations with the Zenith Telescope.

Date. 1827.	Reading at the Star. Divisions.	Reading at the Collimator. Divisions.	Zenith Point. Divisions.	Star's Zenith Distance. Divisions.	Star's Zenith Distance. Seconds.	Sum of Corrections.	Zenith Distance reduced to Jan^y 1827.	Remarks.
July 9.	367.5	278.0 385.5	331.75	35.75	17″.87	+13″.17	31″.04	Bad image, and nothing well adjusted.
Aug. 31.	247	294.2 141.0	217.6	29.4	14.7	+25.51	40.21	Bad image, and nothing well adjusted.
Sept. 1.	237	237.5 235.2 196.5 202.0	217.8	19.2	9″.6	+25″.61	35″.21	Excellent.
5	169	158.0 162.0 142.7 137.5	150.05	18.95	9.47	+25.99	35.46	Star past the meridian.
6	89	74.0 77.0 64.5 66.6	70.52	18.48	9.24	+26.07	35.31	Tremor.
Oct. 24.	63.7	21.2 31.8 42.0 48.4	35.85	27.85	13.92	+24.14	38.06	Focus bad, and adjusted a moment before the observation.

Observations with the Zenith Telescope. (Continued.)

Date. 1827.	Reading at the Star. Divisions.	Reading at the Collimator. Divisions.	Zenith Point. Divisions.	Star's Zenith Distance. Divisions.	Star's Zenith Distance. Seconds.	Sum of Corrections.	Zenith Distance reduced to Jan^y 1827.	Remarks.
Oct. 24. Continued.		21.0 31.7 44.8 49.0	36.64					
		21.9 32.6 45.0 49.5	37.25					
31	81.5 79.0	18.7 10.7 91.8 88.8	52.5	27.75	13.87″	+22.83″	36.70″	
		18.8 11.8 86.7 85.5	50.7					
		21.0 12.3 86.5 88.0	51.95					
Nov. 2.	145.6	143.0 160.7 82.5 97.3	120.87	24.73	12.36	+22.42	34.78	Doubtful.
5	62	47.5 0.0 72.0 24.0	35.87	26.13	13.06	+21.80	34.86	Line not well adjusted.
12	42.7	26.5 19.7 7.0 7.0	15.05	27.65	13.82	+20.17	33.99	Cloudy. Star scarcely visible.
22	137	118.0 112.0 83.0 78.7	97.92	39.08	19.54	+17.45	36.99	Flying clouds.
		119.8 110.7 81.0 78.7	97.55					
24	135.8	78.0 76.0 120.8 114.3	97.27	38.53	19.26	+16.86	36.12	
		80.0 78.0 119.8 114.0	97.95					
29	110.5	60.0 46.0 93.0 75.0	68.5	42.0	21.0	+15.40	36.40	

Observations with the Zenith Telescope. (Continued.)

Date. 1827.	Reading at the Star. Divisions.	Reading at the Collimator. Divisions.	Zenith Point. Divisions.	Star's Zenith Distance. Divisions.	Star's Zenith Distance. Seconds.	Sum of Corrections.	Zenith Distance reduced to Jan^y 1827.	Remarks.
Dec. 6.	164	150.8 135.0 107.0 95.0	121.95	42.05	21.02″	+13.18″	34.20″	Very favourable.
		149.2 133.0 110.0 95.4	121.90					
20	167.3	90.0 87.0 140.0 131.5	112.1	55.2	27.6	+ 8.82	36.42	Very favourable.
		93.0 89.3 141.0 130.0	113.32					
21	126.2	46.0 43.5 98.7 93.0	70.3	55.9	27.95	+ 8.13	36.08	Very favourable.
		47.3 43.4 99.3 90.0	70.0					
23	122.5	92.5 82.5 44.3 42.3	65.4	57.1	28.55	+ 7.45	36.00	
		91.0 82.0 42.0 41.2	64.05					
1828. Jan. 3.	134.1	108.0 84.0 52.0 35.0	69.75	64.35	32.17	+ 4.37	36.54	Flying clouds.
		107.3 82.2 53.2 35.6	69.57					
19	183.6	144.0 119.5 83.7 65.7	103.22	80.38	40.19	− 0.94	39.25	Very hazy.
		142.0 119.5 86.0 64.0	102.87					
Mean rejecting the last.							35.82	
Mean rejecting the last and Oct. 24th. .							35.67	

In the preceding Table I have given, as is my practice, every observation which has been made:—the first two, as I before said, are inserted merely as matter of curiosity, though their mean happens to be the same as that ultimately adopted. The last observation I consider inadmissible, as the weather was so hazy that the star was scarcely visible, and that only at intervals. The observation of the 24th of October I feel no hesitation in rejecting, from the disturbance the instrument might have suffered from adjusting the focus of the telescope to the star the moment before the star was bisected, and the consequent hurry in which the observation was made. I therefore consider $35''.67$ as the mean, which is nearest the truth. The corrections for aberration, &c. &c. have been taken from the Tables just published by the Astronomer Royal.

It is far from my wish that the astronomical part of the observations here given should be considered as proofs of the utmost accuracy which a telescope so employed is capable of attaining; for it may readily be conceived that had the telescope been firmly fixed by stone- or brick-work, and time taken to place the moveable line of the micrometer accurately parallel to the equator, the bisection of the star might probably have been effected with a much greater degree of precision.

The focal length of the telescope employed was only forty inches, and the scale of the micrometer, or the number of divisions which are equal to a second, it has been remarked, is in proportion to the focal length of the telescope. The shortness of my telescope therefore, may be justly conceived to have taken somewhat from the accuracy of the results; and I ought also to mention, that by far the greater number of these observations, namely, those from the 24th of October, were made in the day time.

Notwithstanding these considerations, the power of the floating collimator is such, that I shall venture to compare the preceding observations with those made under the most favourable circumstances, and with an instrument which is justly esteemed the most perfect of its kind ever constructed, the Zenith Sector belonging to the Board of Ordnance*.

In a series of observations, one or two may perhaps be found which may accidentally differ considerably from the mean of the whole. But the difference

* This instrument is furnished with an achromatic telescope of eight feet focal length.

between such insulated observations and the mean, cannot be considered as a measure either of the power of the instrument, or of the skill of the observer. These will be more justly estimated by taking the difference between the general mean, and the mean of such observations as exceed and fall short of it*.

In this manner I have examined the observations made with the zenith sector at the Stations of the Trigonometrical Survey, and the following are the results:

Number of Observations.	Difference from the Mean.		
7	+0.49″	−0.74″	β Draconis.
7	+0.88	−0.65	
9	+0.81	−1.02	η Ursæ.
8	+0.39	−0.71	β Draconis.
8	+0.52	−0.30	γ Draconis.
7	+0.42	−0.44	
7	+0.28	−1.70	β Draconis.
7	+0.67	−0.89	
8	+0.85	−0.84	γ Draconis.
9	+0.17	−0.57	51 Draconis.
9	+0.68	−0.55	κ Cygni.
8	+0.33	−0.63	ι Cygni.
Mean. . 8	+0.54	−0.75	

The above may be considered as a fair representation of the power of the zenith sector; and I may add, that I have selected those sets which consist of the greater number of observations, and have confined myself to such stars as passed within two degrees of the zenith, to avoid any possible error which might have arisen from uncertain refraction.

I shall now divide the fifteen zenith distances obtained by means of the floating collimator into two sets, consisting of seven and of eight observations each, in order that they may be similarly circumstanced with the observations made with the zenith sector. Proceeding in the same manner as before, we obtain the following results:

Number of Observations.	Difference from the Mean.	
7	+0.48″	−0.65″
8	+0.40	−0.66
Mean. . 8	+0.44	−0.66

* I am indebted for this suggestion to Dr. WOLLASTON.

The comparison then between the zenith sector and the zenith telescope used with the vertical floating collimator, will stand thus:

Mean of errors by the zenith sector	$+0''.54$ and	$-0''.75$
Mean of errors by the zenith telescope used with the floating collimator*	$+0''.44$ and	$-0''.66$

I shall now proceed to deduce the latitude of York Gate from the observations made with the zenith telescope.

	°	′	″
The polar distance of γ Draconis for January 1827, with which I have been favoured by the Astronomer Royal from the mean of 296 observations, was 38° 29′ 14″.64; which gives for the zenith distance of γ Draconis at Greenwich	0°	2′	6″.36
Add zenith distance at York Gate	0	0	35 .67
Difference of latitude between Greenwich and York Gate	0	2	42 .03
Latitude of Greenwich	51	28	38 .96
Latitude of York Gate	51	31	20 .99

* It may be remarked, that if the first eight observations and the last seven had been taken to form the two sets, the result would have been less favourable to the zenith telescope. But in the last seven observations there would then have been only a single observation less than the mean; and this, as I have before said, is an inadmissible case for comparison. Were this observation excluded, and the two sets made to consist of eight and of six observations, the resulting differences from the mean would have been far more favourable. The following is a view of the results.

Number of Observations.	Difference from the Mean.	
8	+0″.97	−0″.58
7	+0.29	−1.77*
Mean. . 8	+0.63	−1.17
8	+0″.97	−0″.58
6	+0.19	−0.19
Mean. . 7	+0.58	−0.38

* One observation only, less than the mean, and result therefore inadmissible.

As any difference in the tables of refraction employed will equally affect the latitude and the zenith distance deduced from it, no correction is necessary on this account.

We have then for the latitude of York Gate,

By the azimuth and altitude circle and the horizontal floating collimator	51° 31′ 20″.94
By the same instrument and the vertical floating collimator	51 31 20 .76
By the zenith telescope and the vertical floating collimator	51 31 20 .99
Mean . . .	51 31 20 .90

In my description of the horizontal floating collimator, I have recommended it to be employed in an observatory *as a fixed point;* its zenith distance being determined by means of the vertical floating collimator. For this purpose the box should be of cast iron, the openings in the ends of the box closed by pieces of plane glass, and the cover rendered air-tight. We have seen that the error in the vertical floating collimator is scarcely appreciable, though the mercury and float are agitated by turning the instrument half round; and it is not too much to anticipate, that where there is no such cause of disturbance, the horizontal floating collimator will suffer no change of inclination. This, however, may readily be ascertained by experiment.

If I have succeeded in the object of this paper, I shall have demonstrated that the vertical floating collimator is an instrument capable of determining the zenith point with a precision hitherto unknown; that by its aid a meridional observation of an altitude or of a zenith distance may be completed, not only the same evening, but within the space of a very few minutes, and that too, without the necessity of turning the circle in azimuth. These are advantages which no other method of observing affords, and which astronomers well know how to appreciate. If to these be added the facility with which the floating collimator may be constructed, the ease with which it is used, and its general applicability to all astronomical circles, whether small or of large dimensions, it may not perhaps be too much to infer that ere long the use of the level and of the plumb-line in celestial observations will be wholly abandoned.