GREENWICH

ASTRONOMICAL OBSERVATIONS,

1909.

INTRODUCTION.

I. *Personal Establishment and Arrangement.*

At the beginning of the year 1909 the Established Staff in the Astronomical Department of the Observatory consisted of the following persons :—

Chief Assistants,—Philip Herbert Cowell, M.A., F.R.S., formerly Fellow of Trinity College, Cambridge; Arthur Stanley Eddington, M.A., M.Sc., Fellow of Trinity College, Cambridge.

Assistants,—Edward Walter Maunder; Thomas Lewis; William Grasett Thackeray; Henry Park Hollis, B.A.; Andrew Claude de la Cherois Crommelin, B.A.

Clerical Assistant,—Henry Outhwaite.

Established Computer (Higher Grade),—Charles Davidson.

Established Computers,—William Bowyer; Herbert Henry Furner; William Moody Witchell, B.Sc.; Philibert Melotte; William Stevens; William Wood Burkett; Joseph Edward Evans; Richard Thomas Cullen (and one vacancy).

Mr. B. D. Evans was appointed an Established Computer on 1909 Feb. 19.

Mr. W. W. Bryant, Superintendent of the Magnetic and Meteorological Branch, and Mr. D. J. R. Edney, Established Computer in that branch, have also taken part in the Astronomical Observations.

Mr. Cowell and Mr. Eddington have the general superintendence of all the work of the Observatory. Mr. Maunder is charged with the Heliographic photography and reductions. Mr. Lewis has charge of the clocks, time-signals, and chronometers, and of the 28-inch equatorial. Mr. Thackeray superintends the meridian work with the Transit-Circle, and miscellaneous astronomical computations. Mr. Hollis superintends the photographic mapping of the heavens, the measurement of the plates, and the computations for the Astrographic Catalogue. Mr. Crommelin has charge of the Altazimuth and of the observations of occultations. Mr. Davidson has charge of the Thompson Equatorial and the measurement of the photographs taken with it. Mr. Outhwaite acts as responsible accountant officer, has charge of the library manuscripts and stores and conducts the official and general correspondence. Mr. Bowyer, Mr. Cullen, and Mr. Furner, assist Mr. Lewis, Mr. Thackeray, and Mr. Crommelin respectively. Mr. Witchell and Mr. B. D. Evans, under Mr. Thackeray's direction, respectively undertake the reduction of the transits and of meridian zenith distances observed with the Transit-Circle; Mr. Witchell is also charged with the reduction of the Reflex Zenith-Tube observations. Mr. Melotte assists in the reproduction of enlarged prints of the astrographic chart, and also in the measurement and reduction of the Thompson photographs. Mr. Stevens and Mr. J. E. Evans assist Mr. Hollis. Mr. Burkett assists Mr. Outhwaite.

The regular observers with the Transit-Circle are Mr. Witchell, Mr. J. Evans, Mr. Cullen, and Mr. B. Evans. The same four observers undertake the Reflex Zenith Tube observations. Observations with the 28-inch equatorial are generally made by Mr. Lewis, Mr. Bryant, Mr. Bowyer, and Mr. Furner. Observations with the Altazimuth are made by Mr. Crommelin, Mr. Furner, or one of the Computers. Photographs with the Astrographic equatorial are generally taken by Mr. Stevens or one of the Computers, and with the Thompson equatorial by Mr. Davidson, Mr. Edney, or Mr. Melotte. Photographs of the Sun with the Thompson or Dallmeyer photoheliograph are taken by Mr. Maunder, or by one of the Computers under his direction.

The following are the signatures of the observers :—

W. H. M. Christie	WC	C. Davidson -	- CD	B. D. Evans -	- BE
P. H. Cowell -	C	D. J. R. Edney	- DE	S. Daniels -	- SD
A. S. Eddington -	SE	W. Bowyer -	- WB	J. Shepperd -	- S
E. W. Maunder -	M	H. H. Furner	- HF	H. Acton -	- HA
T. Lewis - -	L	W. M. Witchell	- W	A. Witney -	- AW
W. G. Thackeray -	T	W. Stevens -	- WS	G. Cody -	- GC
H. P. Hollis - -	H	P. Melotte -	- PM	H. E. Green -	- G
A. C. D. Crommelin	AC	J. E. Evans -	- E	F. Jeffries -	- J
W. W. Bryant -	B	R. T. Cullen -	- RC	A. Rotherham	- R

II. *Instruments.*

The principal Instruments now in use are the following :—

The Transit-circle, constructed by Messrs. Ransomes and May, as engineers, and by the late Mr. William Simms, as optician, was erected in the year 1850, and brought into use at the beginning of 1851.

The room in which this instrument is mounted occupies the site of the old circle-room, but is extended to the south, so that its entire length is 36 feet. The ridge of the roof is in the north-and-south direction. The opening in the roof, along the ridge, is 3 feet wide, and is covered by four shutters. The vertical openings in the north and south walls are also 3 feet wide, and each is covered by a single shutter.

A detailed description of the instrument, illustrated by plates, is given in Appendix I. of the volume for 1852: a reprint of which, with some modifications, is attached to the volume for 1867. The following particulars may be given here. The centre of the instrument is about $5\frac{1}{2}$ feet south and 19 feet east of the old transit instrument. The focal length of its object-glass is 11 feet 7 inches, and the clear aperture 8·1 inches. It was repolished by Messrs. Troughton and Simms in 1891, and again in 1906. The full aperture of eight inches has been used in all observations, including those of the Sun. The power of the eyepiece ordinarily employed is 195, and of that used for observations of the Sun 180. The axis of the instrument is of cast-iron, in two similar pieces, the length between the extremities of the pivots being 6 feet. The two halves are connected by bolts through flanges at the junction-plane in the middle of the cube. The two portions of the telescope-tube (also of cast-iron, with the exception of the object-glass cell and the eyepiece-work) are bolted on the central cube. The pivots are of "chilled" iron and their diameter is 6 inches, the bearing of each being upon two portions of a concave cylinder, forming the Y. The Y's are firmly screwed down to the massive piers between which the instrument is mounted.

For examination of the form of the pivots, each is perforated; within the hollow of the eastern pivot there is fixed a plate of metal perforated with a hole about 0·01 inch in diameter, behind which a light can be placed for illumination; at the distance of 6 inches from this hole is a lens of 1 inch focal length, producing an image of the hole about 0·002 inch diameter, which in fact is the real mark for collimation; and in the hollow of the western pivot there is fixed an object-glass at a distance from that image equal to its focal length. This combination forms a collimating telescope revolving with the instrument. It is viewed by a telescope of 7 feet focal length, which, when required, is placed on Y's, one of them planted in the opening of the western pier, and the other in a hole made for that purpose in the western wall of the room. During 1905 October 31 to November 18, observations were made for the determination of the relative errors of the form of the pivots of the transit-circle. The process employed is fully explained in *Appendix I.* of *Greenwich Observations* for 1852. The following table contains the residual errors, which define the apparent changes of position of a certain line in the material axis of the instrument :—

N. P. D. Pointer Reading.	Horizontal Error, Micrometer Head to Left.	Vertical Error, Micrometer Head Below.	N. P. D. Pointer Reading.	Horizontal Error, Micrometer Head to Left.	Vertical Error, Micrometer Head Below.	N. P. D. Pointer Reading.	Horizontal Error, Micrometer Head to Left.	Vertical Error, Micrometer Head Below.	N. P. D. Pointer Reading.	Horizontal Error, Micrometer Head to Left.	Vertical Error, Micrometer Head Below.
°	"	"	°	"	"	°	"	"	°	"	"
5	−0·07	−0·10	95	−0·10	−0·13	185	+0·05	+0·05	275	−0·13	+0·31
15	−0·05	−0·08	105	−0·16	+0·03	195	+0·13	0·00	285	−0·18	+0·39
25	−0·05	0·00	115	−0·05	+0·08	205	+0·18	+0·05	295	−0·18	+0·28
35	+0·03	−0·10	125	+0·08	0·00	215	+0·13	−0·03	305	−0·13	+0·18
45	+0·10	−0·13	135	+0·03	0·00	225	+0·13	+0·05	315	−0·08	−0·05
55	+0·03	−0·21	145	+0·16	+0·08	235	+0·08	+0·13	325	−0·03	−0·08
65	0·00	−0·23	155	+0·18	+0·03	245	0·00	+0·16	335	−0·05	−0·16
75	−0·10	−0·23	165	+0·16	−0·05	255	+0·03	+0·13	345	0·00	−0·08
85	−0·08	−0·18	175	+0·13	−0·05	265	0·00	+0·21	355	−0·03	−0·21

A discussion of these errors, showing their effect on the deduced Right Ascensions, is given at the end of the *Transit-Circle Tables.* The corrections have not been applied.

The system of spider-lines in the focus of the telescope consists of a horizontal wire and fourteen vertical wires. Transits recorded chronographically are observed over ten of these wires, so placed that the mean of the ten coincides nearly with the sixth (for stars above pole), generally called the centre wire. The eye-and-ear system consists of seven wires at equal intervals, three wires being common to both systems. The intervals between the wires are given in the *Transit-Circle Tables* at the end of this *Introduction.*

The frame containing the whole system of vertical wires is moved horizontally by a micrometer-screw, whose graduated head is locked up in a small box attached to the eyepiece, to prevent inadvertent disturbance of the micrometer after it has been set to the reading which is adopted for the line of collimation. The micrometer-head is on the eastern side of the eyepiece, and the readings increase as the wire is moved towards the micrometer-head. In 1891 October a new screw was fitted to the micrometer by Messrs. Troughton and Simms, one revolution of which is nearly equal to the distance between two close wires, viz. 37″.

From 1908 April 27 the field of view has been illuminated by the light from a small electric lamp carried near the end of the telescope tube beyond the object-glass. The light, after passing through a condensing lens, falls in a parallel beam on a disk of finely ground opal glass, attached at the centre of the object-glass and inclined at 45° to it, and is scattered down the axis of the telescope. The intensity of the illumination is controlled by a rheostat. The annular illumination formerly in use is still available, and observations are sometimes made by it for comparison of the two methods.

For determining the error of collimation, two horizontal telescopes or collimators of about 6 feet 10 inches focal length and 7 inches aperture, with their axes in the same horizontal line through the centre of the instrument are mounted, one on the north and the other on the south side of the transit-circle. Each collimator is furnished with wires in its principal focus, to be used as collimating marks. For adjustment of the collimators accurately on each other, the plates carrying the wires are moveable by micrometer-screws: that of the south collimator in altitude only, and that of the north collimator in azimuth only. In order to view one collimator by the other, it is necessary to place the transit telescope vertical, and to uncover the perforations in the opposite sides of its central cube, which consist of eight holes of sector-form. The central cube was pierced with these perforations in August and September 1865. This arrangement was brought into use on 1866 December 17, when the collimators of 7 inches aperture were mounted in place of those of 4 inches aperture, used up to that time. To obtain a more perfect view of one collimator by the other, it is necessary to raise the transit-circle by means of a mechanical apparatus provided for the purpose.

Since the end of 1907 October the system of wires in each collimator has been a pair of close vertical wires and a horizontal wire. The separation of the vertical wires in the north collimator is less than that of the wires in the south collimator, and the reading for coincidence of collimators is determined by moving the north wires until they are seen symmetrically between the south wires. The operation is repeated six times, the micrometer being read each time, and the micrometer is left in the position indicated by the mean. The daily observation for collimation of the transit telescope is then made by bringing, by means of its R.A. micrometer, the central vertical wire several times in succession midway between the vertical wires of the south collimator and several times midway between the vertical wires of the north collimator, and reading the micrometer for each observation. The mean of the readings for the north and south collimators gives the reading for the position of the line of collimation.

In June 1882 the form of mounting of the collimators was altered, in order to obtain a greater range of observations of stars by reflexion. In the new arrangement, the collimators are mounted on upright cast-iron arms which turn about centres below, thus allowing them to be swung on one side when not in use. It is now found practicable to observe stars by reflexion (with the full aperture of the object-glass) from Z.D. 20° to Z.D. 67¼°. To test the stability of the collimators during each determination of collimation-error, it is the practice, since the alteration, to observe the coincidence of the corresponding wires of the two collimators immediately after as well as before the observation of the two collimators with the transit-circle. A correction corresponding to the half-difference of the two sets of micrometer-readings is applied to the concluded reading for the line of collimation.

Since 1884 June a reversion-prism made by Messrs. Troughton and Simms has been used from time to time in observations with the collimators as well as with the transit-circle to reverse the apparent direction of measurement or of motion.

The graduated vertical circle for zenith-distance observations is fixed on the cylindrical base of the axis-cone on the west side of the central-cube. It is shielded from the Sun's rays by the steps which are used by the observers for ascending to the upper part of the pier. It is of cast-iron, 6 feet in diameter; it is graduated on its western side by five-minute divisions, which are cut upon a band of silver let into the internal surface of a very flat cone. There is a rough setting circle on the eastern side. The tubes of the reading microscopes are inclined perforations through the western pier, pointing to the graduations on the flat internal conical surface of the graduated circle. Their eyepieces are all carried by one massive brass plate at the back of the pier, and are arranged in a circle, whose centre is 5 feet 2 inches above the floor, and whose diameter is about 21 inches. Their object-glasses are separately attached to the inner or eastern side of the pier, and are arranged in a circle of about 5 feet in diameter. Each of the microscope perforations through the pier is accompanied with a perforation for illumination; these illumination-perforations all diverge from one central electric light near the western face of the pier. Each is furnished with a lens, 3½ inches in diameter, by adjustment of which the light from the electric lamp, after specular reflexion from the graduated surface, is thrown up through the microscope-perforations to the microscope eyepieces. A lining of double tin plates, inserted in the central opening of the pier, screens the stone pier, the brass plate, the micrometers, and the eyepieces. Six micrometer-microscopes denoted by the letters A, C, E, B, D, F, placed at intervals of 60°, are used for reading the circle. Provision is made for four supplementary microscopes to be used in determining errors of division.

The pointer-microscope for reading the integral divisions is placed between microscopes

D and F; but it may be noted that it is not exactly midway between them. When the pointer reads 0° 30′, the division under microscope A is 271°; under C, 211°; under E, 151°; under B, 91°; under D, 31°; and under F, 331°.

The errors of division of the circle were investigated for every 5° in 1851, 1856, 1871, and 1898, two independent determinations having been made in the last year. The mean of the determinations made in 1851 and 1856 was adopted for use up to the end of 1896, and in the sections of Zenith Distances and Star Ledgers in 1897. For 1898 and subsequent years, and in the Star Catalogue and Planetary Results for 1897 the mean of the four determinations made in 1856, 1871, and 1898 respectively was adopted, giving a result in which each of the 5° divisions is equally well determined. The determination made in 1851 was rejected as being discordant. The errors of the single degrees were determined in 1851, 1856, and 1898, the mean of the first two being used to the end of 1896 and in the earlier sections in 1897, and the mean of the three for 1898 and subsequent years, and in the final sections for 1897. Full information on the subject is given in a paper by Mr. Dyson and Mr. Thackeray in the *Memoirs of the Royal Astronomical Society*, vol. liii., and in the *Transit-Circle Tables* at the end of the *Introduction* for 1897.

At the end of 1875 new micrometer-screws were applied by Mr. Simms to the six ordinary micrometers A, B, C, D, E, F. In March 1878 the micrometers A, C, and F were reversed (their heads being at the same time re-figured to read in the opposite direction), so that any effect of wear in the micrometer-screws might be eliminated for each pair of microscopes. At the end of 1885 new screws made of steel instead of gun-metal were applied by Mr. Simms to the six ordinary micrometers A, B, C, D, E, F; and were brought into use on 1886 January 1. Observations for determining the errors of these screws are given in the *Transit-Circle Tables* at the end of the *Introduction* for 1886 (p. cxxxv). Similar observations were made in 1893, 1896, and 1906. The observations are given in the *Transit-Circle Tables* at the end of the *Introductions* for 1894, 1896, and 1906. They show that the wear of the screws is small, and its effect almost entirely eliminated by the reversal of three of the screws.

There are two clamps attached to the eastern pier, at the same height as the centre of the circle (one on the north side, the other on the south side), which can take hold of the clamping circle of the instrument; but they have no slow motion. The end of the telescope contains one horizontal wire, moveable by a micrometer, with which all observations of zenith-distance are made. For reducing every observation, therefore, it is necessary to combine the value of the reading of the telescope-micrometer with that of the mean of readings of the microscope-micrometers. When the telescope points vertically upwards, the head of the zenith-distance-micrometer is on the north side; and the zenith-distance-micrometer-readings increase as the wire is moved towards the head.

A new screw was applied to the micrometer by Messrs. Troughton and Simms in 1906 July. Its pitch is the same as that of the right ascension micrometer.

An apparatus is attached to the zenith-distance-micrometer for mechanical registration of its readings. In this arrangement, punctures corresponding to each bisection of an object, in its passage across the field, are made on a strip of paper, fixed on a light drum immediately above the divided head of the micrometer, and turning with it. To distinguish the several bisections, the pricker by which the punctures are made, is, after each puncture, moved through a definite space in the direction of the axis of the drum, by turning a screw, which carries it, through a quarter turn. After a set of bisections the punctures are successively brought up to a straight edge, $0^{r}\cdot050$ from the pricker, and the micrometer-head is read off; each is then marked with a pencil to distinguish it from any which may be made afterwards. By this arrangement several bisections of an object can be made without the observer having to move his eye from the telescope, and a permanent record is obtained, giving facilities for the correction of mistakes.

A detailed account of the *Chronograph* used with the Transit-Circle illustrated by engravings, is given in the *Appendix* to *Greenwich Observations* for 1856, and a brief description of the chief parts will be found in the *Introduction* for 1880 and preceding years.

The Altazimuth was constructed and erected by Messrs. Troughton and Simms in 1896, but was not brought into regular use till 1899, as it was found that various structural modifications were required particularly in regard to the arrangements for relieving the friction on the Y's.

This Altazimuth is virtually a reversible transit-circle (of Messrs. Troughton and Simms' well known form with some improvements), which can be planted in any definite azimuth (0°, 30°, 45°, 60°, 70°, 80°, 90° E. or W.), and then used for a complete set of observations (including stars for clock and azimuth error) essentially as a transit-circle, giving directly azimuth and zenith distances for the same instant of time. This is arranged by mounting the iron supports of the transit-circle on a circular base resting at three points of its circumference on a circular casting planed on its upper surface. The change from one azimuth to another is effected by turning the instrument about a central pivot on which it is slightly raised, the weight being relieved by friction rollers near the circumference of the circular base.

For observations in the meridian, the instrument is used exactly in the same way as a transit-circle.

The principle of the method of observing when out of the meridian is to secure observations of azimuth and zenith distance such that the mean of the times is as nearly as possible the same for the two sets of observations. Transits are taken over vertical wires and over horizontal wires so arranged as to secure complete observations in both elements in the different azimuths. The near agreement of the means of the times of transit is obtained by providing in addition to the systems of vertical and horizontal wires (each carried on a micrometer slide) a wire carried by a position circle micrometer which is set before the observation to the approximate inclination of the path of the object to be observed. When the star or other object enters the field the telescope is moved in zenith distance till it is on the position wire; the telescope is then clamped, and the transits are observed across a series of vertical and horizontal wires symmetrically with respect to the centre, as the star moves in its oblique course through the centre of the field, the position wire (which is only used for setting) having been previously moved away from the star.

The tube and axis of the telescope are made of phosphor-bronze, the axis and central part of the telescope tube being in one casting. This central part is barrel-shaped (instead of being in the form of a cube as in the transit-circle), and is stiffened inside by diaphragms so as to minimize flexure of the axis. A clear aperture of 6 inches diameter is made in it on each side, to admit of one collimator being viewed by the other when the telescope is in a vertical position. The two portions of the telescope tube, which are exactly alike and are slightly conical, are bolted to the central casting. Two zenith distance circles are provided, one of which is fixed while the other can be turned on the axis, and, by means of a clamp and slow motion, fixed in any position, so that it may be made available for the determination of division errors by comparison of corresponding angular intervals on the two circles. These circles are discs of phosphor-bronze 3 feet in diameter, the divisions being on thin bands of palladium silver alloy let into the face of the bronze discs.

The pivots are of steel, and of 6 inches diameter. They rest on segmental bearings of bell-metal. The weight of the instrument on the Y's is relieved by live rings (ball bearings) round the axis, suspended freely by strong springs carried by the iron supports of the instrument, an arrangement which was substituted with success for the friction-rollers with upward thrust, originally supplied, as these were found to cause torsion in the axis and bearings.

Each circle is read by four microscopes. To carry the microscopes two broad wheels made of bronze are fixed to the iron supports of the instrument, the centres of the wheels being in the axis of the telescope. These wheels are screwed to the iron supports and are in addition pinned near their centres to prevent any possibility of movement.

As previously stated the instrument is reversible in its Y's. The counterpoise springs with the live rings are carried by the reversing gear during reversal so as to avoid the necessity for removal and readjustment of these springs. Another form of reversal of the instrument is obtained by turning it through 180° in azimuth, so that there are in all four essentially different positions in which it may be used.

The object glass is of 8 inches aperture and 8 feet focal length. The full aperture is used except for the Sun, when it is reduced to 6 inches. The magnification employed is 168 for stars, and 180 for the Sun.

The instrument is provided with two collimators in the meridian, each of 6 inches aperture and of 69 inches focal length. They are each mounted on two pairs of parallel arms (counterpoised) turning about centres below, so that they can be brought up into the position for observation, or lowered to be clear of the telescope and dome, when they are housed under hinged flaps.

The situation of the Altazimuth is about half-way between the Old Observatory and the New Building. Its exact position relative to the centre of the transit-circle is 141 feet ($=0^s{\cdot}15$) E. and 166 feet ($=1''{\cdot}67$) S. It is mounted on a pier of concrete, 20 feet above the ground and has a clear view all round. This pier, which is quite clear of the observing floor, rises from a large concrete foundation, 6 feet deep, on which the whole building rests. The dome is built in two halves which can be opened to a clear width of $4\frac{1}{2}$ feet, and is capable of rotation, so that the opening may be in any required azimuth.

The Chronograph used with the Altazimuth since 1900 March, was made by Sir Howard Grubb. The barrel is of the same dimensions as for the Transit-Circle Chronograph, $19\frac{3}{4}$ inches long and $11\frac{3}{4}$ inches in diameter, revolving once in 2 minutes, so that 1 second of time is represented by a space of 0·3 inch on the sheet; one sheet will take a run of about 6 hours. The registration both of clock-signals and of observations is made by means of a single stylographic pen which, through the action of an electro-magnet, taps the slowly rotating barrel lightly, and leaves a dot of ink on the paper, when the circuit is completed, whether by the observer or by the Standard Sidereal Clock. The barrel is turned smoothly by a driving-clock of the usual form, without electric control, uniform motion between the clock-taps being the essential condition in this case. Four chronograph barrels, which can readily be interchanged, are provided. The chronograph is mounted in the ground floor of the Altazimuth Pavilion.

The Reflex Zenith-Tube, constructed under the direction of Sir G. B. Airy by the late Mr. William Simms.—A detailed description of this instrument is given in *Appendix I.* to the *Greenwich Observations* for 1854; in this place the following account will suffice. The object-glass (aperture 5 inches, focal length about 9 feet 8 inches) is mounted upon a fixed tube, which is in a vertical position; upon this tube it can be turned in azimuth. To the cell of the object-glass is firmly fixed the micrometer-frame (with its plane horizontal), revolving with the object-glass when the latter is turned. The bearing of the screw of micrometer A is on the fixed micrometer-frame. The moving frame of micrometer A carries the bearing of the screw of micrometer B. Micrometer B carries the wires by which the star's image is bisected. The eyepiece is a four-glass diagonal eyepiece bent at right angles between its third lens and its fourth lens (counting from the eye), and having a diagonal-prism-reflector at the place where it is bent; and so placed that the fourth lens can receive rays of light from the direction of the nadir, and can, by means of the diagonal prism, transmit them horizontally to the eye. The fourth lens (which looks vertically downwards) and the diagonal prism are placed nearly over the centre of the object-glass, being carried by arms which are fixed to the large tube; the small horizontal tube which carries the remaining lenses of the eyepiece is supported in a slide by the large tube of the telescope, and does not project over any part of the object-glass. Below the object-glass, at a distance nearly equal to half its focal length, is a trough of mercury, which till the end of 1888 was protected from tremors, with only moderate success, by an arrangement of caoutchouc supports From 1889 February 13 an amalgamated copper trough has been used, with the result that the steadiness of the images has greatly improved. A prismatic focussing rod with scale reading to 1-200th of an inch and ivory point for contact with the surface of the mercury has been applied to the instrument in place of the former light brass rod and wooden float; the focussing rod and the micrometer-frame are both of gun-metal. The image of the star, as it passes near to the zenith, is formed in the plane of the micrometer wires. It will easily be seen that, to ensure accuracy of result, no firmness of construction is requisite in this instrument except in the connection between the micrometer and the object-glass. The instrument is mounted about 18 feet south-west of the transit-circle.

Until the end of 1908 the field of view was illuminated by an annular reflector, the brightness of the field being controlled by tilting the reflector. It was found that, owing to obstruction by the annulus, the full aperture of the object-glass was not being used for the stars furthest from the zenith; to obviate this a modified form of fixed reflector was brought into use on 1909 January 20, in conjunction with a rheostat to control the intensity of the illumination.

The Sheepshanks Equatorial.—This instrument was erected in the year 1838. The aperture of the object-glass is about 6·7 inches, and its focal length about 8 feet 2 inches. The object-glass was made by M. Cauchoix, of Paris, and was presented to the Observatory by the Rev. R. Sheepshanks. Its definition is good: a small quantity of colour from the secondary spectrum, and a diffusion of light from brilliant objects, being the principal defects. It is mounted in a dome, 19 feet east and 1½ feet north of the transit-circle. The mounting, particulars of which are given in the *Introductions* to the *Greenwich Observations* for former years, is similar in general form to that known as the "German equatorial," and was constructed by the late Mr. T. Grubb, of Dublin.

The Great Equatorial.—This instrument now carries an object-glass of 28 inches aperture and 28 feet focal length on the mounting which was originally designed for the Merz object-glass of 12·8 inches aperture and 17 ft. 10 in. focal length. This mounting was constructed by Messrs. Ransomes and Sims (as engineers), and the late Mr. William Simms (as instrument-maker), and a complete description of it, with engravings, is attached as *Appendix* to *Greenwich Observations* for 1868. The form of the instrument is the "English equatorial," the polar-axis turning on pivots at its extreme ends, and including between its two sides the telescope and declination-circle, which are mounted on a declination-axis with pivots at its opposite extremities. The object-glass of 28 inches clear aperture and 27 ft. 10 in. focal length was made by Sir Howard Grubb from discs supplied by Messrs. Chance, of Birmingham, and was brought into use at the end of 1893. It is of special form, adapted to photography as well as to eye-observation, on the plan proposed by Sir George Stokes (in a letter dated 1886 August 16) of reversing the crown lens to correct for the spherical aberration introduced by the further separation of the lenses necessary for photographic correction. Mechanical means are provided for readily effecting this reversal and separation without risk. It is found by trial that the further separation required for photographic correction is about 3·5 inches, and that the focus is thereby shortened by about 23 inches. When the crown lens is in the position for visual observation, the radii of curvature of the surfaces are:—

1st surface—146 in. convex	} Crown.		3rd surface— 138 in. concave	} Flint.	
2nd ,, 134 in. ,,			4th ,, 1000 in. convex		

and the edges of the lenses are separated by 0·4 inch, the minimum focal length being for rays about midway between D and E.

The telescope tube, made of steel and cast-iron by Sir Howard Grubb, is specially adapted to the conditions, being provided with a sliding eye-end arranged for either direct view or diagonal view by means of a silver on glass plane reflector, and permitting of observations near the zenith and the pole, when the eye-end is shortened sufficiently by the sliding motion to clear the floor and the inside of the polar frame. The Corbett telescope, of $6\frac{1}{2}$ inches aperture and 8 feet focal length, is mounted on the tube as a finder or guiding telescope. The position and transit micrometers and various eyepieces supplied for the 12·8-inch Merz refractor have been adapted to the 28-inch telescope, and have been fitted with electric illumination of the field and wires. A double-image micrometer is also used.

The instrument is driven by a Water-clock.

The dome was constructed by Messrs. T. Cooke and Sons and erected in 1893 April, replacing a cylindrical wooden dome. It is of a form specially adapted to accommodate the 28-inch refractor, the diameter being greater than that of the tower on which it is carried. A description with diagrams is given in the *Monthly Notices, R. A. S.*, vol. li., p. 436. The diameter of the dome is 36 feet at a height of 7 feet above the rail, contracting to 31 feet at the base, and the shutter-opening is 7 feet wide throughout on both sides of the zenith down to the horizon. The framework is of T-iron vertical and horizontal ribs bolted to a circular girder forming the base, the opening being framed with curved vertical girders, and the whole is covered with papier-mâché. The shutter is in two parts, with a division right down the middle, each half being a balanced shutter 3 ft. 6 in. wide, extending right over the dome from the curb, through the zenith, to the opposite part of the curb, and carried by a wheel running on a rail at the zenith. The dome rotates on a system of wheels running freely on the horizontal surface of the wall-curb.

The Thompson Equatorial, made by Sir Howard Grubb.—This instrument, carrying a 26-inch photographic refractor and a 30-inch reflector on the same mounting, was presented to the Observatory by Sir Henry Thompson, and was brought into use at the end of 1898. It is erected on the central tower of the New Observatory building under the 30-feet dome, and is approximately 350 feet south and 224 feet east of the centre of the transit-circle. The equatorial mounting, which is of the German form, modified to allow of complete circumpolar motion without reversal, carries on one end of the declination axis the 26-inch photographic refractor, the Merz $12\frac{3}{4}$-inch refractor (used as a guiding telescope), and the 9-inch photoheliograph; and on the other end the 30-inch Cassegrain reflector (made by Dr. Common), with a 6-inch refractor as a guiding telescope.

The instrument is driven by a clock with electrical control similar to that of the Astrographic Equatorial.

The 26-inch Refractor is a photographic telescope of 26 inches (0·66 metre) aperture and of 22 feet 5 inches (6·83 metres) focal length, so that its scale is double that of the Astrographic refractor, and one millimetre on the photographic plate represents 30″·2. The breech end of the instrument is arranged for a plate-carrier taking photographic plates 12 inches square, suitable adapters being inserted when smaller plates are used. The breech end is also arranged to carry a camera-box, 33 inches in length, fitted with a negative enlarging lens, 1·45 inches in diameter, and 3·3 inches in focus, and with a rapid exposing shutter, for photographing sun-spots and other objects on an enlarged scale. When used for this purpose, a diaphragm carrying a roller spring blind is placed before the object-glass, so that the sun's light may only be permitted to fall on the object-glass immediately before the exposure of the plate is to be made. The aperture is usually stopped down to 12 inches. The image of the sun in the primary focus of the telescope is 2·5 inches in diameter at mean distance, and this is enlarged 12 diameters, *i.e.* to a scale of 30 inches to the solar diameter, for the image formed on the photographic plate. The exposing shutter is of the same form as that used in the Thompson Photoheliograph (*vide infra*). The plate-carrier for the camera-box is constructed to take plates 10 inches by 12 inches or, by use of suitable adapters, of smaller sizes. The whole sun is, therefore, not photographed at one time, but only limited areas; generally a single spot-group of special size or interest.

The Merz Refractor, of 12·8 inches aperture and 17 feet 10 inches focal length, is mounted as a guiding telescope to the 26-inch, and is above it when the instrument is pointing south, and the 26-inch is on the west of the pier of the equatorial. The eye-piece of the Merz is mounted on cross-slides (parallel and perpendicular to the equator) which permit of a guiding star being observed at a distance of 45′ from the centre of the field, and are furnished with scales divided to minutes and read by verniers to 5″.

The Thompson Photoheliograph, presented to the Observatory by Sir H. Thompson in 1891, is a photographic refractor by Sir H. Grubb of 9 inches aperture and 8 feet 10 inches focal length, with a Ross enlarging doublet of 4·3 inches focus. Its tube is mounted on the 26-inch refractor on the side opposite the Merz refractor. The image of the Sun in the primary focus is 1 inch in diameter, and this is enlarged by the doublet to about 7·4 inches on the photographic plate, the whole length of the instrument being about 12 feet 4 inches. At the principal focus cross spider-lines are placed, which give facilities for determining the position angles of sun-spots on the photographs. The exposure is given (as in the Dallmeyer photoheliograph, *see* page xvi) by a shutter at the primary focus having a slit in it of adjustable width; but, whilst the shutter of the Dallmeyer photoheliograph travels in a groove, and is drawn downwards by a strong spring, in the Thompson, the shutter, which is made of aluminium for the sake of lightness, turns about a pivot 18 inches from the exposing slit, under the action of a spring placed about midway between the pivot and the slit, and giving a very rapid motion to the latter. This telescope is also provided with a 9-inch object-glass prism by Mr. Hilger.

The 30-inch Reflector.—This instrument was constructed under the supervision of Dr. Common who undertook the figuring of the mirrors. It is generally used as a simple reflecting telescope for obtaining photographs in the principal focus, but may be used as a Cassegrain. The mirrors are made of silver on glass, the concave being of 30 inches diameter, with a circular hole of 6 inches diameter. The weight of this mirror is 265 lbs., the glass of which it is composed being 4 inches thick. When not in use, it is covered by a plate-glass disc, with a hinge on one side which allows of its being turned so as to lie along the telescope tube (made D-shape to receive it) when observations are taken. The focal length of the large mirror is 3·48 metres or 11 feet 5 inches, so that 1^{mm}. at the principal focus corresponds to 59″·3. Two convex mirrors of focal lengths 24 inches and 38 inches are provided, the equivalent focal lengths of the combinations being 76 feet and 49 feet respectively.

The convex mirror, or the photographic plate-holder, is carried by an arm mounted in a slide so that it can be fixed in a convenient position, and the final adjustment for focus can be made from the eye-end by means of a rod with geared wheels actuating a screw in the boss of the arm, which gives a small motion to the mirror or plate-holder.

The Hodgson 6-inch Refractor, of 7 feet 7 inches focal length, is mounted on the reflector as a guiding telescope. It is furnished with cross-slides like the Merz and Astrographic refractors, which allow of a bright star within 40′ of the centre of the field being chosen as a guiding star. The cross-slides carry a simple position micrometer for the purpose of facilitating mechanical guiding in the photography of comets or other objects which move relatively to the stars.

The dome was constructed by Messrs. T. Cooke and Sons, of York, in 1884, and was formerly used for the Lassell reflector. It is hemispherical, of 30 feet diameter, and is covered with papier-mâché on a framework of angle-iron. It is carried by nine wheels or rollers (each 2 feet in diameter) fixed to the iron curb of the dome, and running on a flat rail, horizontal rollers being provided to prevent excessive lateral motion from the force of the wind or other cause, and it can thus be turned with great ease. The shutter-opening extends from beyond the zenith to the horizon, and is closed by a single curved shutter (3 feet 6 inches wide at the zenith, and 6 feet wide at the horizon), which turns about a point in the dome-curb opposite to the opening, and runs on guiding rails at the horizon and near the zenith, the curved shutter being continued by an open framework to complete the semicircle. The dome was erected on the central tower of the New Observatory building in 1896 September.

The Astrographic Telescope, of 13 inches aperture with 10-inch guiding telescope, mounted in a dome over the upper computing room.—This instrument was constructed by Sir Howard Grubb, F.R.S., on the lines laid down by the *Congrès Astrophotographique International pour le Levé de la Carte du Ciel* in 1887, and was brought into use at the end of 1890. The 13-inch photographic telescope and a 10-inch visual telescope are firmly connected, the tubes being of iron. The apertures of the object-glasses are $0^{m\cdot}33$, or $13^{in\cdot}0$, and $10^{in\cdot}0$ respectively, and the focal lengths of both telescopes $3^{m\cdot}43$ or $135^{in\cdot}1$, so that $1^{mm\cdot}0$ on the plate corresponds to $1'\cdot0$. [The focal length of the photographic telescope is more exactly $3^{m\cdot}441$ or $135^{in\cdot}4$, so that $1^{mm\cdot}$ represents $0'\cdot9990$.] The photographic telescope is corrected, as regards spherical and chromatic aberration, for rays near Fraunhofer's line G. It is arranged to carry a plate $16^{cm\cdot}$ square, with special provision for exact focussing and orientation. The eyepiece of the 10-inch visual telescope is mounted on cross-slides (parallel and perpendicular respectively to the equator) which are furnished with scales reading to 1-12th of a millimetre or 5″, and permit of the observation of a guiding star up to a distance of about 45′ from the centre of the field. The mounting is of the German form, so arranged as to allow a range of 1½ hours' motion on each side of the meridian without reversing the telescope. A large counterpoise is thus necessary, both because of the double weight, and of the distance from the polar axis of the two telescopes; but the movement in right ascension is very easy, owing to the arrangement adopted to relieve the friction of the polar axis. The greater part of both the transverse and end thrusts of the polar axis is received on a single anti-friction bearing, carried by a separate vertical column, disposed directly under the centre of gravity of the instrument. The rollers of the bearing turn round horizontal axes, and a bevelled collar on the polar axis rests on them. The column transmits the weight to counterweight levers. The driving clock is placed inside the stand and is controlled electrically by a seconds pendulum. The detector of the control is similar in principle to that used in Sir David Gill's form; and the system of correctors by differential wheels was devised by Sir Howard Grubb (vide *Proceedings, Institute of Mechanical Engineers*, 1888 July 31, page 311). The telescope is also provided with an electric hand control, by means of which the observer can accelerate or retard the motion in right ascension and thus keep the guiding star bisected in the guiding telescope.

The Dallmeyer Photoheliograph has an object-glass of 4 inches aperture and 5 feet focal length, forming an image of the Sun half an inch in diameter; this image is enlarged by a secondary magnifier to 8 inches on the camera screen, where the sensitive plate is inserted, the whole length of the instrument being about 11 feet

2 inches. The exposure is given by a shutter having a slit of adjustable width, which is carried by a spring across the primary image. The instrument is equatorially mounted and provided with a driving clock.

The Sidereal Standard Clock, constructed by Messrs. E. Dent and Co., is fixed to the north wall of the Magnet-house basement, as in this apartment the temperature is kept nearly uniform. The escapement will be found described in vol. iii. of the *Transactions of the Cambridge Philosophical Society*: it is a detached escapement very closely analogous to the ordinary chronometer-escapement, the pendulum receiving impulse only at each alternate vibration; consequently, the escape wheel and seconds hand move only at alternate seconds (the even seconds). The pendulum is compensated in the following way. A central steel rod is encircled by a zinc tube, which rests on the rating nut on the steel rod; the zinc tube is in its turn encircled by another steel tube, which rests at its upper end on the zinc tube, and carries at its lower end the cylindrical leaden pendulum bob attached at its centre. Slots are cut in the outer steel tube, and holes made in the intermediate zinc tube, with the object of exposing equally all parts of the compound pendulum rod to the action of temperature. For final adjustment of the rate there is placed on the crutch rod a sliding weight, which can be raised or lowered by a nut at the level of the crutch-axis without disturbing the pendulum. The rate of the clock is so steady that, when first mounted, the barometric inequality was indicated with the greatest regularity, the daily losing rate of the clock being increased by $0^{s}\cdot3$ for an increase of 1 inch of barometer reading.

In the autumn of 1873 an apparatus for correction of this inequality was applied to the clock by Messrs. E. Dent and Co., and has been in action regularly since that time. This compensating apparatus of the Sidereal Standard is founded on the magnetic principle, long previously in use for daily adjustment of the Mean Solar clock. Two bar magnets, each about six inches long, are fixed vertically to the bob of the clock pendulum, one in front, the other at the back, their lower ends being nearly level with the bottom of the pendulum bob. The lower pole of the front magnet is a north pole, and the lower pole of the back magnet a south pole. Below these a horseshoe magnet, having its poles precisely under those of the pendulum magnets, is carried transversely at the end of a lever, the opposite arm of which is attached by a connecting rod to a float in the lower leg of a syphon barometer, placed in one corner of the clock-case. The area of the cistern in which the float rests is four times as great as that of the upper tube. For change of one inch of barometer reading the horseshoe magnet is thus shifted two-tenths of an inch; and as the average distance between its poles and those of the pendulum magnets is about $3\frac{3}{4}$ inches, the change of rate produced by increase or decrease of the magnetic action is sensibly uniform. As the clock gained with low barometer reading, it was necessary to place the horseshoe magnet so that there should be attraction between its poles and the adjacent poles of the pendulum magnets. The action of this apparatus is found to be quite successful.

Galvanic contact for registration of the clock-beats is made by a wheel of 30 teeth on the escape-wheel arbor, a tooth of which at every beat of the clock presses together two light springs. Another pair of springs is also pressed together at the beginning of each minute by an arm on the same arbor, and a supplementary signal is thus sent through a galvanometer as a check on the numeration of seconds. This arrangement was substituted in the latter part of 1881 for that formerly employed (in which a pin on the pendulum was used to press together the contact springs) in order to avoid any effect on the pendulum, contact being made in the part of the beat when the pendulum is quite detached from the clock-train, after the impulse has been given. The currents obtained from the Sidereal Standard at every alternate second are used to drive a relay, from which independent circuits are derived. One of these is appropriated to the seconds-magnet of the altazimuth chronograph; another drives a relay placed, in the computing room, on the desk of the Superintendent of the Time Department. From this relay are derived several circuits, one for driving a galvanic chronometer in the Time Department, another for use with the transit-circle chronograph, and a third for use in the Transit Pavilion. No practical difficulty is found in sub-dividing the interval of two seconds between the clock-beats on the chronograph. The numeration of seconds on the chronograph is readily obtained from an automatic signal from the Sidereal Standard clock on an independent circuit, or from occasional comparisons with the clock Hardy.

The Mean Solar Clock, "Dent 2012," is placed in the lobby at the foot of the Octagon room staircase, near to the trigger of the ball-apparatus. This clock (which has been substituted for the electrical clock "Shepherd" formerly in use) has a zinc and steel pendulum, and is fitted with springs for sending out hourly signals to the Post Office and for working the mean solar dials distributed throughout the Observatory. On the escape-wheel-arbor are two wheels, each containing 30 teeth, which close contact-springs alternately, one wheel at the even, the other at the odd seconds. The currents thus set up actuate two relays, by means of which various electro-magnetic clocks in different parts of the Observatory are driven synchronously with the Mean Solar clock. Arrangements are made so that in the case of failure of the clock "Dent 2012," the circuit can be readily switched on to the electrical clock "Shepherd."

One of the synchronous clocks has a large dial exposed to public view on the east boundary wall of the Observatory; four are in the chronometer rooms, and are used in the daily comparisons of chronometers; one is in the upper computing room; one (of the dimensions of a chronometer) is upon the desk of the Superintendent of the Time Department; one is in the hall of the Astronomer Royal's dwelling-house and four are in the office rooms of the New Observatory building. A comparison of the mean time chronometer with the chronometer on the same desk synchronous with the sidereal standard clock (as mentioned in a preceding paragraph) is, in fact, a comparison of the mean solar clock with the sidereal standard. The time shown by the sidereal standard at comparison being corrected for its error (as ascertained from star-transits), the true sidereal time at the comparison is found; and this is converted, by calculation, into true mean solar time at the comparison. The difference between this and the time shown by the mean solar clock is the error of the latter. Then, by means of a commutator on the same desk, the circuit of a galvanic current, passing through a coil (with no iron core) in the clock-case, can be made either to attract or to repel a magnet attached to the pendulum, and thus to accelerate or retard the mean solar clock as long as may be necessary for its correction. The clocks connected with the mean solar clock necessarily receive the same correction. The arrangement for giving hourly signals is as follows. The mean solar clock closes a circuit precisely at each hour: that at 13^h, by the intervention of electro-magnets, pulls automatically the ball-trigger and drops the time-ball at Greenwich. Until 1885 October 27 there was an automatic arrangement for reversing the direction of the current through this apparatus; but, as this sometimes caused failure in the signal and was found to be unnecessary, it was removed on that day. At every hour also the primary clock-current by relay-action causes a galvanic current to pass on a line of wire to the central station of the Post Office Telegraphs, St. Martin's-le-Grand, London, where it is distributed by automatic action of the "Chronopher," on some of the principal lines of railway and to important provincial towns. The hourly current passes also to the clock tower of Westminster Palace for the guidance of the superintendent of the clock. This clock is not regulated or corrected by any direct galvanic action, but signals are received at definite times from the clock, which show daily at Greenwich the deviation of the clock from true time. The 13^h current drops a time-ball at Deal, the property of the Admiralty; and a return signal is automatically sent to Greenwich by the ball in its descent closing a galvanic circuit. At Devonport, Portsmouth and Portland, local clocks, giving hourly time signals, are corrected daily by the help of the current at 10^h. This time signal automatically starts an auxiliary seconds' pendulum, suspended freely just behind the clock pendulum, which is brought into coincidence of beat with the free pendulum by an attendant (by means of electro-magnetic action as in the Greenwich mean solar clock). The Devonport clock sends a return signal to Greenwich daily at $13^{h}.\ 0^{m}.\ 39^{s}\cdot0$, the Portsmouth clock at $13^{h}.\ 0^{m}.\ 20^{s}\cdot0$, and the Portland clock at $13^{h}.\ 0^{m}.\ 30^{s}\cdot0$, to serve as a test of the accuracy with which the local clocks have been corrected.

The following clocks are in use as Sidereal Clocks:—The clock Hardy, fitted with contact springs and a zinc and steel pendulum, is placed in the Transit-Circle room. The clock "Dent 2" has been fitted with springs and placed in the Record Room for use when the Sidereal Standard is under repair. There is also a clock marked "Arnold 1," having contact apparatus similar to that in the clock Hardy, in order that the clock may, if required, be temporarily used in the place of Hardy; one in the Sheepshanks dome, marked "Earnshaw," with a zinc and steel compensation pendulum; one in the New Altazimuth dome, marked "Graham 1," with a mercurial pendulum; in the Thompson Equatorial dome, one marked "Dent 2016," with a zinc and steel pendulum and seconds' contact, and one marked "Graham 2," fitted with contact springs and with a zinc and steel pendulum, which is available for use in longitude determinations; one in the Astrographic dome, marked "Dent 2017," with a zinc and steel pendulum; one marked "Dent 2009," with a wooden-rod pendulum in the Great Equatorial dome; one marked "Molyneux," with a wooden-rod pendulum in the Reflex Zenith-Tube room.

The following clocks are also in use in the Observatory as Mean Solar Clocks:— "Mudge and Dutton," with a gridiron pendulum, in the upper chronometer room; "Dent 2014," with a wooden-rod pendulum, in the lower chronometer room; "Graham 3," with a mercurial pendulum, in the ball lobby, occasionally used for facilitating the regulation of the Mean Solar Clock (described above). Several chronometers are also kept in the lower computing room for occasional use. Besides these there are two journeymen or assistant clocks; an electric clock by Shepherd, formerly used at Ashford; and a watchman's clock.

The following clocks are on loan:—"Dent 1916" and "Dent 2013" at the Cape Observatory; "Dent 2011" at the Kew Observatory; "Arnold 2" at the Oxford Observatory; and "Dent 2010" at Devonport, where it is employed to drop the Time Ball.

III. *Explanation of the Printed Observations.*

§ 1. *Transits observed with the Transit-Circle, and Computations of Apparent Right Ascension.*

The observations here printed in detail are those of the Sun, Moon, planets, fundamental and adjustment stars. Commencing with the year 1897, the printing of the details of observations of other stars has been discontinued, the daily results only being given in the *Ledgers of Mean Right Ascensions and Mean North Polar Distances of Stars.*

The *first* column on each page contains the day, which is always supposed to commence with the transit of the Sun.

The *second* column contains the numbers for convenience of reference.

The *third* column contains the name of the object observed. With respect to the Sun, Moon, and planets, the limb whose transit is observed is always mentioned, and if the limb is defective the requisite correction for defect of illumination is given in the notes. If no limb is mentioned, it is to be understood that the estimated centre was observed. The centre is observed only when the planet's disc is so small and so round as to make it easier to estimate the centre than to determine with accuracy the place of the limb. In the case of Mercury (and more rarely of Venus), whose limbs are sometimes very badly defined, a correction for defective illumination is applied when the estimated centre of the illuminated portion is observed, to reduce to the centre of the disc, see p. xxiii. In the case of the Moon, observations of the crater Mösting A have been made as well as of the limbs whenever observable. With regard to the stars, the proper names which have commonly been used in the *Greenwich Observations* are adopted in preference to other names. For other stars, the names have been taken in the following order of preference :—

1. Flamsteed's constellation-No. and constellation, with Bayer's letter, taken from Baily's edition of Flamsteed or the British Association Catalogue.
2. The No. in Auwers' edition of Bradley's Catalogue.
3. The No. in Auwers' edition of Mayer's Catalogue.
4. The hour and No. in Piazzi's Catalogue, edition 1814.
5. The No. in Groombridge's Catalogue.
6. The No. in Baily's edition of Flamsteed's Catalogue, referred to as "B.F."
7. The hour and No. in Weisse's two Catalogues of the Stars in Bessel's Zones, referred to as "W.B." and "W.B. (2)" respectively.
8. The No. in Lalande's Catalogue, published by the British Association, or in that edited by Fedorenko, or in the Supplement, referred to as Lalande, Lalande F., and Lalande F. (2) respectively.
9. The No. in Lacaille's Catalogue of Southern Stars, published by the British Association.
10. The No. in Oeltzen's two Catalogues of Argelander's Zone Observations, referred to as "Oeltz. Arg. (N.)" or "(S.)" respectively.
11. The No. in the First Radcliffe Catalogue (1845).
12. The No. in Carrington's Red Hill Catalogue.
13. The Zone and No. in Argelander's Bonn *Durchmusterung* or in Schönfeld's continuation of the *Durchmusterung* (Bonn Catalogue, Sections I., II., III., and IV.; Bonn Observations, Vols. III., IV., V., and VIII.), referred to as "B.D."
14. The No. in the Greenwich Catalogues; in the Cape Catalogue for 1880; or in the Catalogues of the *Astronomische Gesellschaft* (1875).

In observing a double star, the brighter star (if it is not otherwise expressed) is always observed.

When no mark is attached to the name of the object observed, it is to be understood that the observations were made by the galvanic or chronographic method, which was generally in use throughout the year. In any exceptional case where the eye-and-ear method is employed, the observation is distinguished by having the letters (E & E) affixed to it. The letter R denotes that the object was observed by reflexion in the trough of mercury.

The *fourth* column contains the initials of the observer's name.

The next *ten* columns contain the clock-times (seconds and decimals of a second only) at which the object was observed to pass each of the wires. For eye-and-ear transits, the wires used are denoted by the letters M, N, O, T, X, Y, Z. The wires used for galvanic transits are denoted by the letters O, P, Q, R, S, T, U, V, W, X, O, T, and X being wires of the eye-and-ear system.

The adopted equatorial intervals of the wires used are given in the *Transit-Circle Tables* at the end of this *Introduction.* These have been determined from observations of close polar stars.

For stars above the pole, the designations of Wires I., II., III., &c., at the heads of the columns correspond to O, P, Q, &c. (or to M, N, O, &c., when the object is observed by eye-and-ear), in all cases excepting Polaris, &c. For stars below the pole, the designations I., II., III., &c., correspond to X, W, V, &c., or to Z, Y, X, &c.

The nine azimuth stars are generally observed by turning the R.A. micrometer-screw with the right hand until the star is bisected by the middle wire T (or sometimes one of the other wires), the instant of accurate bisection being recorded on the chronograph with the left hand. The reading of the micrometer is then recorded, and the operation repeated until ten observations are obtained. The readings of the R.A. micrometer are always mentioned in the notes. As the "reduction to the centre wire" in this case depends on the value of successive revolutions of the micrometer-screw, the errors of this screw have been investigated. The results of the most recent investigation of these errors are given in the *Transit-Circle Tables* for 1906. It is considered that the errors are too small to necessitate correction.

For stars within 15° (but not less than 3°) of the pole, it has been the practice since 1899 to observe transits over one of the wires at various settings of the transit-micrometer which are stated in the footnotes. Stars within 3° of the pole (except the nine azimuth stars) are observed by eye-and-ear. All other stars are observed chronographically over the vertical wires in the ordinary way.

Transits of stars registered on the chronograph are usually referred to the Sidereal Standard clock; for stars observed by eye-and-ear, the clock Hardy is used. The times printed in the columns "Seconds of Transit over the Wires" are those of the observations as made, the letters (E & E) in the third column indicating when the clock Hardy was used. The difference between the indications of the two clocks is given in the notes.

The *fifteenth* column contains the *Concluded Transits*, giving the hour and minute of the time of meridian passage (which have not been given in the preceding columns), as well as the mean of the seconds.

For stars observed by eye-and-ear by the clock Hardy, the *Concluded Transit* includes the correction for reduction of the transit by Hardy to the Sidereal Standard clock.

For a planet, the correction to reduce to the centre wire includes the amount of the planet's increase of right-ascension for the interval between the mean of the wires and the centre wire, which is readily determined from the numbers given in the *Nautical Almanac*.

For the Moon, the equatorial intervals for the wires observed are added together, and the sum is divided by the number of wires; this quotient is then multiplied by

$$\frac{3600 + \mathrm{I}}{3600} \times \frac{\sin \text{Moon's geocentric } Z.D.}{\sin \text{Moon's apparent } Z.D.} \times \text{secant of Moon's geocentric declination},$$

where I is the increase (in seconds of time) of the Moon's R.A. for the transit over a meridian upon the Earth distant by 1^h of terrestrial longitude, as given in the section *Moon-culminating stars* in the *Nautical Almanac*.

In cases where a defective limb of a planet has been observed, a correction for defect of illumination is applied in forming the *Concluded Transit*. These corrections are computed from the tables given for this purpose in the *Nautical Almanac*.

Occasionally the limb of Mercury is so ill-defined that the observer records a transit of the "centre." This is considered to be the centre of gravity of the illuminated portion of the disc, and a correction of $\frac{4}{3\pi}$ $(=0{\cdot}424)$ × defect of illumination should be applied for reduction to the centre of the actual disc. In practice this is applied in forming the concluded transit as $0{\cdot}4$ × correction for defect of illumination in R.A., calculated as for a transit of a defective limb.

The *sixteenth* column contains the numerical values, in seconds of arc, of the errors of collimation (including diurnal aberration), level, and azimuth; the last two being distinguished from the first by a round and a square bracket respectively. The observations for the determination of these errors are given in a later section.

The error of collimation is considered positive when it implies an additive correction to the observed time of transit of a star above pole. The level error is positive when the western end of the axis is too high. The azimuth error is positive when the western end is too far south.

The *seventeenth* column contains the seconds of every transit, corrected for the three preceding errors, and is conceived to represent the clock-time at which each body passed the true astronomical meridian of Greenwich. The numbers to which a bracket is annexed are those resulting from the mean of the two limbs of the Sun or a planet.

The *eighteenth* column contains the seconds of the tabular R.A. of the stars which are used for determining clock and azimuth errors; the latter are given in order to enable the reader to judge of the general consistency of the observations, but not to assist in determining clock-errors.

From the beginning of 1906, the right ascensions are based on the *Standard Mean Right Ascensions for* 1900·0 *based on* 12-*hour groups*, printed in the Introduction to the *Second Nine-Year Catalogue for* 1900. The values of the precession and proper motions are taken from Prof. Newcomb's *Catalogue of Fundamental Stars.* The corrections necessary to bring up the stars' right ascensions to the day of observation are taken from the *Nautical Almanac.* In the *Transit-Circle Tables*, at the end of this *Introduction*, are given the adopted mean right ascensions for 1909·0 of all the stars which have been used for determining clock-errors or azimuth-errors, together with the corrections to the mean right ascensions given in the *Nautical Almanac.*

The *nineteenth* column contains the error of the clock, found by subtracting the numbers in the seventeenth column from those in the eighteenth. The error is therefore positive when the clock is slow. The apparent clock-errors given by the nine close polar stars used for azimuth-error, as has been remarked above, are not employed in determining the clock-errors available for computations of right ascensions.

The *twentieth* column contains the adopted losing rate and the adopted error of the clock at 0^h sidereal, as found by the following process. The observations are divided into groups, defined by bars across this column (in all instances the same as the limits of the observations of each observer). The mean of the clock-errors given by all the clock-stars in each group is then taken, and this is considered to be the clock-error corresponding to the mean of all the times of transit of those stars. For the determination of clock-rate, the clock errors found by each observer are corrected for that observer's personal equation, derived from the observations of the previous year. Each mean clock-error, properly modified, is now compared with that which precedes and with that which follows; a preceding rate and a following rate are thus found, and by these the Chief Assistant is guided in adopting the clock-rate to be used through the group of observations: this adopted clock-rate is set down in the twentieth column. It is to be remarked that, in the application of these errors, if the observations of small stars and planets have been made by the same person as the observations of the clock-stars, no further computation is necessary for obtaining the right ascensions of those objects than the application, to the time of transit, of the clock-error at 0^h, and of a proportional part of the clock-rate corresponding to the right ascension of the object; but, if the clock-stars are observed by one observer, and the other object by another, a correction for personal equation is required. The personal equations are *not* applied in this section.

The personal equations determined from the observations which are available in the year 1909 are given in the *Transit-Circle Tables* at the end of this *Introduction*. These personal equations have been applied to the collected results of transits for the Sun, Moon, and planets, whenever they were needed throughout the year 1909. But those used in the adoption of clock-rate have been deduced from the observations in 1908. The investigation of these is given in the *Transit-Circle Tables* for last year.

It has been the practice on favourable nights for the transit-circle observer to observe two "clock stars" by the eye-and-ear method, at the same time making a careful comparison between the clock "Hardy" (used in observing by this method) and the Sidereal Standard, which is used in chronographic transits. It is then an easy matter to compare the values of the quantity "clock slow" as found by the same observer using the different methods. The results are given in the *Transit-Circle Tables.*

In the standing footnote on each page is given the duration of passage for the semidiameter of a planet when only one limb has been observed. It is found as follows:—

For the Sun, the following corrections, depending on the respective observers, are applied to the Nautical Almanac semidiameter:—

Mr. Eddington	$-0^{s}.04_{1}$	Mr. Daniels	$+0.05_{8}$
Mr. Witchell	0.00_{20}	Mr. Shepperd	0.00_{12}
Mr. Evans	$+0.01_{21}$	Mr. Acton	-0.02_{10}
Mr. Cullen	-0.04_{22}	Mr. Cody	0.00_{9}
Mr. B. Evans	0.00_{16}		

The subscript numbers denote the number of observations on which the respective corrections depend. These corrections have been determined from the observations of the respective observers during the current year.

For the Moon and Mercury, the duration is taken without alteration from the *Nautical Almanac.*

For Mösting A the correction to reduce to the centre of the Moon has been obtained by interpolation with second differences from the *Berliner Jahrbuch.*

For Venus, a correction is applied to the Nautical Almanac semidiameter, determined from observations made with the transit-circle from 1851 to 1862. The investigation by Mr. Stone will be found in the *Monthly Notices of the Royal Astronomical Society*, vol. xxv. No. 3. The correction, which has been applied additively to the Nautical Almanac semidiameter during the year, is:—

$$+ 0^{s}.026 + 0.027 \times \text{tabular duration of passage of semidiameter.}$$

For Jupiter and Saturn, both limbs are always observed, if possible; but if, through accident or necessity, only one limb is observed, the duration of passage of the semidiameter is obtained by applying to the value given in the *Nautical Almanac* a correction derived from a few of the neighbouring observations. The elements of the computation are given in the notes.

The *twenty-first* column contains the right ascension of the centre of the body observed: it is formed by adding the time from the seventeenth column, the clock-error at 0^{h} next preceding from the twentieth column, the proportional part of the rate in the same column corresponding to the right ascension, and the duration of the passage of the semidiameter from the footnotes. No result is set down for a clock-star, unless at least six clock-stars, distributed over six hours of right ascension, have been observed: no result is set down for an azimuth star unless at least three of the nine azimuth stars have been observed above pole, and three below pole, and no result is set down for other close circumpolar stars, unless there has been a good determination of the azimuthal error on the day of observation.

Whenever the concluded result in this or other sections is obviously erroneous, it is enclosed within brackets, and is not used in subsequent computations.

§ 2. *Determinations of the Errors of Collimation, Level, and Azimuth of the Transit-Circle.*

OBSERVATIONS FOR COINCIDENCE OF COLLIMATORS.

These observations are made on every week-day. On all days the view is taken through the pierced cube of the transit-circle. On Mondays the transit-circle is raised, and observations are taken with an uninterrupted view of the S. collimator by the N. collimator as well as through the cube. There is a small systematic difference between the readings, according as the view is uninterrupted, or through the cube.

Immediately before the observations of the collimators with the transit-circle for determination of collimation-error, six readings of the micrometer of the N. collimator, for setting its wire system on the wire system of the S. collimator, are taken, and the wire is then left at a reading corresponding to the mean of the six. The observation is repeated immediately after the observations of the collimators with the transit-circle. The means of both sets of micrometer-readings are printed in the table, and will give a satisfactory idea of the firmness of the collimators.

OBSERVATIONS OF THE COLLIMATORS FOR DETERMINATION OF THE ERROR OF COLLIMATION.

The way in which these observations are made has been fully explained (page v). The means of the readings for the separate collimators are set down in the second and third columns. The mean of these gives, after the application of a correction " + 0·16 × excess of first reading over second reading of N. collimator for coincidence with S. collimator," the concluded reading set down in the fourth column. The next column gives the reading which has been adopted for the period of time (usually a week) limited by the bars above and below; and the last column gives the adopted reading for the line of collimation, a correction of $+0^{r}\cdot011$ having been applied to reduce the result to that which would have been obtained if the observation for coincidence of the collimators had been made with the instrument raised, instead of through the perforated cube. (See *Introduction* to the *Greenwich Second Nine-Year Catalogue* for 1900).

For ordinary observing, the transit-micrometer is left at the fixed reading $36^{r}\cdot000$. The algebraic excess of the reading for collimation above this is the error of collimation. To the excess, converted into arc, is then applied $-0''\cdot19$ for diurnal aberration; the result is the quantity set down in the sixteenth column of the daily results of transits, and is adopted for correction of the observed transits.

DETERMINATION OF THE LEVEL-ERROR.

This is determined by a nadir observation. By means of a Bohnenberger eye-piece the images of the wires are seen direct and by reflection in a trough of mercury. A comparison of the transit-micrometer reading for coincidence of the direct and reflected images of the central wire (printed in the second column) with the adopted reading for the line of collimation gives the error of level in terms of revolutions of the micrometer; and the numbers in the third column exhibit the errors of level in arc. The last column gives the adopted values of the error and the limits of time during which they have been used.

DETERMINATION OF THE ERROR OF AZIMUTH.

The error is determined from observations of the following stars :—Polaris, Cephei 51, Groombridge 1119, Bradley 1672, Groombridge 2283, δ Ursæ Minoris, λ Ursæ Minoris, Groombridge 3548 and Bradley 3147. The error actually investigated is the error at the pole, usually denoted by the letter n. The observations of the azimuth star and of a clock star (the nearest in R.A. that has been observed), being corrected for "reduction to centre wire" and collimation error, but not level error, are compared with the tabular places and the results set down in the third column. In the fourth column is given the value of $\frac{1}{15}$ cot N.P.D. for each polar and clock-star. The difference of the two quantities in the third column divided by the difference of the corresponding quantities in the fourth column is the value of n given in the fifth column. In the sixth column is given the adopted value, usually the mean of a number of separate determinations. The resulting error of azimuth in the seventh column is found from the adopted values of the level and n by the formula.

$$\text{Error of Azimuth} = \text{Error of level} \times \text{cot. colat.}, - n \text{ cosec colat.}$$

§ 3. *Mean Errors and Adopted Rates of the Sidereal Standard Clock.*

In this section are given the errors of the Sidereal Standard Clock for mean midnight as deduced from the observations of each observer. These errors have all been reduced to the standard observer by applying the personal equations deduced from the 1909 observations. The adopted losing rate (found as explained on p. xxv) is also given.

§ 4. *Observations of Zenith Distance with the Transit-Circle.*

The observations here printed in detail are those of the Sun, Moon, planets, fundamental and adjustment stars. Commencing with the year 1897, the printing of the details of observations of other stars has been discontinued, the daily results only being given in the *Ledgers of Mean Right Ascensions and Mean North Polar Distances of Stars.*

In order to include the whole of the reductions belonging to a single observation on one page, the elements for those reductions which are not frequently changed, and which do not require tabular arrangement, are given in footnotes or notes at the beginning of the section. These are :—correction for runs; formulæ used in computing micrometer-corrections, corrections for curvature of path, and inclination of wire; and zenith-point corrections.

The corrections for planets, including change of N.P.D. for reduction to the meridian, parallax, and semidiameter, are exhibited in tabular arrangement at the lower part of each page, opposite to the reference numbers which correspond to the observations in the upper part of the page.

DAY.—The day of observation always begins with the Sun's transit.

NO. FOR REFERENCE.—This column requires no explanation.

NAME OF OBJECT.—The nomenclature of stars follows the same general rule as in the section of *Transits observed,* &c. The letters N. L. and S. L. denote north and south limbs of planets, and N. C. and S. C. the north and south cusps of Mercury or Venus. Mösting A denotes the crater of that name on the Moon. The words Wire R indicate an observation of the image of the horizontal or zenith-distance wire as seen by reflexion in a trough of mercury. For other objects, the letter R. denotes that the object is observed by reflexion in the trough of mercury.

READINGS OF THE MICROSCOPE-MICROMETERS.—The six microscopes are arranged round the circle in order A, C, E, B, D, F. Each pair of adjacent readings, therefore, is the pair of readings at the opposite ends of a diameter. The number of integral revolutions is given in the fifth column only. Occasionally the number of revolutions expressed in this column does not apply unchanged to all the microscopes, on account of the difference of their readings; but since the readings never differ by more than three or four tenths of a revolution, this will occasion no ambiguity. On a few occasions the cross-wires have fallen on the negative side of the micrometer-zero; in such cases (which are always mentioned in the notes) the fractional part of the reading given is positive, being that taken from the micrometer-head, but the integer 9 represents -1. The value of one revolution of each microscope-micrometer is roughly $1'$. The determination of the correction for "runs," or exact measurement of the equivalent in arc of micrometer readings is given in § 5.

CORRECTIONS FOR ERROR OF DIVISION.—The corrections for errors of division are the means of the determinations made in 1856, 1871, and 1898 for every 5°, and of those made in 1851, 1856, and 1898 for every 1°. They are printed in the *Transit-Circle Tables.*

FLEXURE AND R—D DISCORDANCE.—The observations for determination of the horizontal astronomical flexure of the transit-circle telescope are given in the *Transit-Circle Tables* at the end of this *Introduction*. In making these observations, the nearly horizontal wire of the south collimator was brought upon the image of the corresponding wire of the north collimator by looking through the cube of the transit-circle; and the micrometer-head was set at the mean of 10 successive readings. After each complete set of 5 observations of the collimating wires, the observations for coincidence of these wires were repeated; and a correction has been applied, when required, to the mean circle-reading at bisection of the wire of the south collimator, for the half-difference in the two sets of observations for coincidence.

As is well-known, the flexure determined by direct observation on the collimators does not agree with that deduced from an analysis of the discordance of direct and reflexion observations of stars. The investigation of the discordance of direct and reflexion observations is given in the *Transit-Circle Tables.*

From 1906 January 1, a constant flexure term of $+0''\cdot60$ sin Z.D. has been adopted to include the effects of astronomical flexure and the discordance of direct and reflexion observations; but this correction is not applied in this section or in the *Ledgers,* being deferred until the results are collected in the *Catalogue* (§ 7).

To obtain information as to the cause of the R—D discordance, observations were made between 1893 December 3 and 1894 April 22 of the zenith-distances of stars directly and by reflexion, the direct observation being taken first. The observations were in other respects similar to the regular reflexion observations. These observations are printed in the *Transit-Circle Tables* for 1894 (pp. cxl–i), and a discussion of them is given in a paper by Prof. Turner and Mr. Thackeray in the *Memoirs of the Royal Astronomical Society*, vol. li.

During the years 1895 to 1898 a new series of observations were made with a view to obtaining further information on the cause of the R—D discordance. Pairs of stars were chosen of nearly the same zenith-distance and a few minutes apart in right ascension. One star of each pair was observed by reflexion, the other directly at the same transit; on the next night of observation the order was reversed, the star which had been observed previously by reflexion being observed directly. In this way a value of 2 (R—D) was derived. In order to test whether any change was taking place in the instrument, two readings of the circle were taken, one just before the star entered the field, and the second just after the bisections with the zenith-distance micrometer had been made. The results of the observations are given in the *Transit-Circle Tables* for the years 1895, 1896, 1897, and 1898, together with a comparison with the R—D discordance obtained in the usual way.

READINGS OF ZENITH-DISTANCE MICROMETER.—This column contains the reading of the micrometer on the eye-end of the telescope, corresponding to the several bisections of an object during its passage across the field of view. The reading of 20^r corresponds pretty nearly to the middle of the range of the screw, and the wire is then tolerably near the centre of the field of view; observations are, therefore, generally made with a position of the wire not greatly different from this.

In 1906 July a new steel screw was applied to the micrometer by Messrs. Troughton & Simms. Observations for the determination of the value of $1^{rev.}$ of this screw are given in the *Transit-Circle Tables* for 1906, the resulting value being 36″·93. The errors of the screw were also investigated and found to be insensible.

VERTICAL WIRES IN THE TELESCOPE-FIELD AT WHICH CIRCLE-OBSERVATIONS ARE TAKEN.—Omitting, in this section, all reference to the wires P, Q, R, S, U, V, W, adapted to galvanic observation of transits, the telescope contains seven vertical or transit wires M, N, O, T, X, Y, Z, placed at sensibly equal intervals of about $14^s \cdot 8$ for transit of an equatorial star; these wires are here called 1, 2, 3, 4, 5, 6, 7, in the case of a star observed above pole, the numbers being reversed for a star observed S. P. The central or 4th wire is so nearly in the meridian as to prevent the necessity of any correction to the observed circle-reading when the body is observed at the passage over that wire. In that case, the only corrections which are required to the mean of the microscope-micrometer-readings (when converted into arc and combined with the equivalent for the zenith-distance micrometer-reading) are those arising from errors of division of the graduated circle, and from astronomical flexure of the telescope.

When the object has not been observed at the central wire, corrections are required for reduction to the meridian. These consist of three, viz. :—First, for want of horizontality of the micrometer-wire; secondly, for curvature of path of the object, or for difference between the small circle described by the body and the great circle of which the horizontal wire forms a part; and thirdly, in the case of the Sun, Moon, and planets, for the change of N.P.D. in the interval between the time of observation and the meridian passage.

The correction due to inclination of wire was found by bisections of stars (by the zenith-distance micrometer) at the first and seventh, or second and sixth, vertical wires.

Its numerical value, additive before transit and subtractive after transit, for stars above the pole, is given in the notes at the beginning of the section.

The general formula for the correction for curvature is given also in the notes at the beginning of the section. In the case of stars very near the pole, when the place of observation does not coincide with a vertical wire, the correction for curvature is computed from the formula :—

Correction for curvature = number (log. = 6·43569) × sin 2 N.P.D. × t^2, t being the interval between the time of meridian passage and the time of transit expressed in seconds of time.

The formulæ for correction for motion are the following. In the case of the Moon, the correction for the change of N.P.D. in passing from one wire to the next is computed from the formula, "Change of declination for one hour of terrestrial longitude (from the section of Moon-culminating stars in the *Nautical Almanac*) × sec. declination × $\frac{\text{Sin Geoc. Z.D.}}{\text{Sin App. Z.D.}}$ × $\frac{14{\cdot}8}{3600}$ (the logarithm of the last factor being 7·61396)." In the case of the other planets, the correction for motion is deduced immediately from the hourly motion in declination given in the *Nautical Almanac.*

SECONDS OF CONCLUDED MERIDIAN CIRCLE-READING.—The numbers in this column are found by adding together the mean of the microscope-readings corrected for runs, the correction for division error, the equivalent for the mean of the zenith-distance micrometer readings, corrected for curvature and inclination of the wire, and the correction for motion in the case of the Sun, Moon, or planets.

ZENITH-POINT CORRECTION.—The observations for this purpose are those of the reflected image of the horizontal wire, and those of the direct and reflected images of stars made at the same transit.

From 1886 January 1 to 1896 December 31 no correction was applied to nadir-observations for discordance between the results of this observation and the mean of reflexion observations of north and south stars. From 1897 January 1 a correction of $-0''{\cdot}25$ has been applied to the nadir-observations in forming the adopted zenith-point, when there are no reflexion observations of north and south stars; but when the observation of nadir is combined with reflexion observations of stars no correction is applied. From observations in former years a connexion was traced between this discordance and the errors of the screws of the microscope-micrometers, and it was hoped that the application of the new steel screws (one of each pair being reversed) would remove the discordance. This appeared to be the case till 1892, the mean apparent correction to the nadir-observation as found from reflexion observations of stars since 1886 being as follows :—

		"			"			"
1886	−	0·09	1894	−	0·27	1902	−	0·20
1887	+	0·01	1895	−	0·31	1903	−	0·23
1888	−	0·12	1896	−	0·34	1904	−	0·41
1889	+	0·07	1897	−	0·27	1905	−	0·22
1890	+	0·08	1898	−	0·36	1906	−	0·40
1891	+	0·07	1899	−	0·41	1907	−	0·24
1892	−	0·26	1900	−	0·39	1908	−	0·33
1893	−	0·34	1901	−	0·29	1909	−	0·16

In consequence of the discordance shown in 1892, the errors of the microscope-micrometer-screws were re-determined in 1893. The observations on which these depend are given in the *Transit-Circle Tables* for 1894. Although signs of wear were shown, the errors arising from this cause are so nearly eliminated by the reversal of three of the screws, that it has not been considered advisable to apply any correction to the circle-reading for apparent error of the screws. Similar observations made in 1896 and 1906 confirm these results. These observations are given in the *Transit-Circle Tables* for 1896 and 1906.

With a view of obtaining information as to the cause of this discordance, observations of the nadir have been taken since 1895 July three times each day when practicable.

The following differences were found from observations since 1895 :—

	21^{h}—3^{h} G.M.T.	3^{h}—9^{h} G.M.T.	9^{h}—15^{h} G.M.T.	No. of Days.
	"	"	"	
1895	+ 0·29	0·00	+ 0·27	54
1896	+ 0·20	0·00	+ 0·16	84
1897	+ 0·11	0·00	+ 0·17	108
1898	+ 0·16	0·00	+ 0·11	104
1899	+ 0·17	0·00	+ 0·19	152
1900	+ 0·14	0·00	+ 0·05	118
1901	+ 0·17	0·00	+ 0·09	123
1902	+ 0·20	0·00	+ 0·17	97
1903	+ 0·04	0·00	+ 0·09	103
1904	+ 0·06	0·00	+ 0·15	79
1905	+ 0·13	0·00	+ 0·04	74
1906	+ 0·19	0·00	− 0·01	40
1907	+ 0·17	0·00	+ 0·14	67
1908	+ 0·11	0·00	+ 0·05	82
1909	+ 0·18	0·00	+ 0·12	69

The + sign indicates a greater circle-reading.

The details of the computation of zenith-point are given in a subsequent table. The adopted corrections for zenith-point are given in the footnotes to this section.

From an investigation made in 1903, with the observations of 1901, it appears that the probable error of a complete determination of zenith-point (four stars and three nadir observations) is about $\pm 0''\cdot 11$.

APPARENT ZENITH-DISTANCE.—The numbers in this column are found by adding the Zenith-point correction to the Concluded meridian circle-reading; when the sum exceeds 270° (denoting that the object is between the zenith and the north horizon), the difference from 360° is taken, and the negative sign is attached to it; for stars observed by reflexion, the sum is subtracted from 180°, and the remainder, with its algebraical sign, is the apparent zenith-distance.

CORRECTIONS FOR DEFECTIVE ILLUMINATION.—The corrections for defective illumination of the Moon, and tables for calculating the corrections for defective illumination of the planets are given in the *Nautical Almanac.* The corrections applied are given in the footnotes.

In cases where the "centre" of Mercury is observed, a correction of 0·4 × ordinary correction for defect of illumination in N.P.D. is applied for reduction to the actual centre of the disc.

BAROMETER.—The barometer is by Horne and Thornthwaite, marked "No. 389," with metallic scale and graduation modified for change of mercury-surface in the cistern. Its scale is divided by vernier to 0·002 inch; but it is not usually necessary to read it to a smaller quantity than 0·01 inch for the computation of refraction. This barometer was substituted in April 1879 for the barometer by Newman, which had been in use to that date. From comparisons with the Standard Barometer made between 1879 March 19 and May 6 (allowance being made for the difference of temperature of the two barometers), it appears that the correction required to the barometer "Horne and Thornthwaite, No. 389," is only −0·007 inch. No correction has been applied to the readings of this barometer.

EXTERIOR THERMOMETER.—From 1897 January 1 the thermometer Negretti and Zambra, No. 70661, has been used as the Exterior Thermometer for all observations with the Transit-circle. This thermometer was mounted in the front court in a screen allowing a free circulation of air on 1896 July 18.

The following are the results of the latest comparisons with the Standard Thermometer which agree well with previous determinations.

1906 May 16.

Temperature.	Error.
°	°
32·2	+ 0·2
50·2	+ 0·2
66·3	+ 0·3
73·9	+ 0·3
86·6	+ 0·2
95·7	+ 0·3

A correction − 0°·2 has been applied to the exterior thermometer from 1897 January 1.

INTERIOR THERMOMETER.—This thermometer is No. 12264, by Negretti and Zambra.

The following are the results of comparisons with the Standard Thermometer made on 1906 May 16.

Temperature.	Error.
°	°
32·6	+ 0·6
50·7	+ 0·7
64·1	+ 0·8
70·3	+ 0·9
87·2	+ 0·8
95·9	+ 0·5

A correction of − 0°·5 has been applied to the readings of the Interior Thermometer from 1889 March 15 to 1894 December 31, and of − 0°·6 from 1895 January 1.

Previous to its removal to the new Magnetic Pavilion the Meteorological Standard Thermometer was read at noon by the Transit-circle observer for comparison with the Exterior Thermometer. Since 1899 July 12, readings of this thermometer have been made each day at Apparent Noon as well as Mean Noon by the Meteorological observer. A comparison of the readings of the Exterior Thermometer and the Meteorological Standard is given in the *Transit-Circle Tables.*

REFRACTION.—From the beginning of 1906, Pulkowa refractions have been used. Tables of these refractions are given in an Appendix to the *Greenwich Observations*, 1898.

PARALLAX.—The corrections for parallax of the Sun, Moon, and planets actually employed are given in the lower part of the page, as previously stated; the assumed ellipticity of the Earth being $\frac{1}{300}$ and the value of the solar parallax 8″·80.

For the planets the formula is :—

$$\text{log. parallax} = \text{log. sin (Z.D.} - 11'.12'') + \text{ar. co. log. distance} + 0{\cdot}94360.$$

For the Moon, the horizontal equatorial parallaxes are interpolated, without alteration, from the *Nautical Almanac*, for the time of observation. The formula employed for the computation of the parallax to be applied to the observed zenith-distance is :—

Parallax = Hor. Equat. Par. from N.A. × Sin Dist. from Geoc. Zenith × Geocentric Radius (Log. = 9·9991136) + Corr. derived from the following table :—

Z.D.	Correction for South Limb.	Z.D.	Correction for South Limb.	Z.D.	Correction for North Limb.	Z.D.	Correction for North Limb.
°	″	°	″	°	″	°	″
30	−0·01	60	+0·10	30	−0·08	60	−0·10
35	0·00	65	+0·11	35	−0·09	65	−0·10
40	+0·02	70	+0·13	40	−0·09	70	−0·10
45	+0·03	75	+0·15	45	−0·10	75	−0·10
50	+0·05	80	+0·16	50	−0·10	80	−0·09
55	+0·07			55	−0·10		

The correction tabulated above is the sum of two corrections, of which the first is due to the difference in parallax between the limb and centre of the Moon; and the second is due to the employment of the arc of equatorial parallax instead of its sine, for which the formula is,

$$\frac{(\text{Seconds of hor. parallax})^3}{6} \times \text{Sin Z.D.} \times \text{Cos}^2\,\text{Z.D.} \times \text{Sin}^2\,1''.$$

For Mösting A the log sine horizontal equatorial parallax of the crater is obtained by interpolation from the *Berliner Jahrbuch.*

For the computation of the parallaxes of the small planets, the distances are taken from the Supplement to the *Nautical Almanac*, or from the *Berliner Jahrbuch,* for planets given in those works.

SEMIDIAMETER.—The adopted semidiameters of the Sun, Moon, and planets are given in the lower part of the page. For the Moon, Mercury, and Uranus, they are taken unchanged from the *Nautical Almanac.* For the Sun, Venus, Mars, Jupiter, and

Saturn, the semidiameters are also taken unchanged from the *Nautical Almanac*, except in cases where only one limb has been observed. In these cases, for the Sun, the following corrections have been applied to the tabular semidiameter, the subscript numbers denoting the number of observations on which they depend :—

Mr. Eddington	$-0''.23_{2}$	Mr. Daniels	$+0''.35_{7}$
Mr. Witchell	-0.03_{23}	Mr. Shepperd	$+0.39_{14}$
Mr. Evans	-0.39_{21}	Mr. Acton	$+0.57_{11}$
Mr. Cullen	-0.33_{22}	Mr. Cody	$+0.40_{9}$
Mr. B. Evans	$+0.14_{17}$		

For Venus the correction $+ 0''.392 + 0.027 \times$ tabular semidiameter, derived from an investigation mentioned at page xxvi, has been applied to the semidiameter given in the *Nautical Almanac*; and for Mars, Jupiter, and Saturn, a correction usually derived from neighbouring observations, and specified in the notes, has been similarly applied.

For Mösting A the correction to reduce to the centre of the Moon has been obtained by interpolation from the *Berliner Jahrbuch.*

GEOCENTRIC N.P.D. OF CENTRE.—The numbers in this column are found by combining the apparent zenith-distance with the refraction, parallax, semidiameter, correction for defective illumination, and assumed colatitude 38°.31′.21″·80.

§ 5. *Runs of each Microscope-Micrometer of the Transit-Circle; and Zenith-Points of the Transit-Circle.*

With regard to the *Runs of the Microscopes*, the columns under A, B, C, D, E, F contain respectively the number of revolutions of each micrometer which measures an arc of 5′ on the circle; and the next column gives the sums of these numbers for the six microscopes, and exhibits the number of revolutions which, for the mean of the six microscopes, measures an arc of 30′, on the supposition that the screws of the micrometers have sensibly equal values. In the first calculations for the reduction of the observations it is assumed that the space of 30′ corresponds approximately to $\frac{50}{51} \times 30^{r}.000$, or to $29^{r}.4118$; and the fiftieth part of the micrometer-reading for the mean of the microscopes being added to the micrometer-reading, the remaining correction, depending on the difference between the values in the last columns of the tables in question and $29^{r}.4118$, is afterwards applied.

With regard to the table of *Zenith-Points*, the following explanation will be sufficient.

Whenever observations of stars have been made by reflexion, the results for zenith-point derived from them have been combined with those derived from the observations of the reflected image of the wire, see page xxxii. The results are always divided into three groups, viz.: those resulting from north stars, those from south stars, and those from nadir-observations, and the mean of each group is taken. In combining these a weight 2 is attributed to each of the means of the two groups of star-observations, and a weight 1 to the mean of the group of nadir-observations, in order to prevent too much weight being given to those divisions of the circle which are always under the microscopes for the wire-observations. From the pains taken to equalize the number and altitude of the stars observed north and south of the zenith, no undue weight is, on the average, given to either of these positions; and, on the whole, it is presumed that, by this method of combination, the best possible average result is obtained. In the few cases where reflexion observations of only north or only south stars have been obtained, a correction is applied for the R—D discordance in obtaining the zenith-point. The value of this correction, which is given in a footnote in the tables of zenith-points, is derived from the adopted value $0''\cdot600$ sin Z.D. of the R—D discordance.

From 1897 January 1 a correction of $-0''\cdot25$ has been applied to observations of the nadir, in forming the zenith-point on those days when no reflexion observations of stars were obtained. (See p. xxxiii.)

§ 6. *Ledgers of Mean Right Ascensions and Mean North Polar Distances for* 1910·0 *of Stars observed in* 1909.

These ledgers are divided into two parts. Part I. contains Fundamental and Zodiacal stars; Part II. contains the stars of the Oxford Astrographic Zone.

The apparent right ascensions and north polar distances (obtained as explained in §§ 1 and 3) are reduced to mean place for the epoch 1910·0, with Newcomb's constants of precession. Since 1902 a further correction for latitude variation has been applied to the north polar distances. This correction is taken from provisional results sent by Professor Albrecht.

For stars in the lists of the national ephemerides, the correction to reduce to 1910·0 is found by subtracting the apparent R.A. or N.P.D. given in those ephemerides from the mean R.A. and N.P.D. for 1910·0 in the same ephemerides.

For the remaining stars of Part I. and for all the stars of Part II., star constants are formed for 1910·0, and the star corrections are computed by multiplying these by the day numbers with the help of Crelle's or Cotsworth's multiplication tables.

The logarithms of the day numbers, with Newcomb's constants, are given in the

Nautical Almanac for mean midnight of each day and it has been the practice to interpolate values of these quantities to within two hours of the time of observation. The additional correction depending on the longitude of the moon has only been taken into account for those stars for which apparent places are given in the ephemerides for every day of the year.

The places for 1910·0 are not corrected for secular variation during the interval between the date of observation and 1910·0 (except in the case of stars contained in the ephemerides, which have been reduced as explained above). It is intended ultimately to apply mean corrections for secular variation when the annual results are collected in the *Greenwich Catalogue for* 1910.

Corrections for the proper motion in the interval between the time of observation and the epoch 1910·0 are applied to the stars of Part I. but *not* to those of Part II. The proper motion adopted in the former case is given in the *Catalogue of Mean R.A. and N.P.D.* (§ 7).

The results in N.P.D., moreover, need to be corrected for the R—D discordance. This correction is applied in the catalogue only.

The corrections for personal equation have been applied in this section when the observations of stars for clock-error have been made by one observer and those of any other star requiring reduction on the same day by another observer.

Half weight has been given to a result for right ascension when the transit was observed at two or three wires only, observations at a single wire being rejected. A reflexion and direct observation at the same transit are considered as separate observations with full weight.

In Part I. the rules for the nomenclature of stars are the same as those in the section *Transits observed*, detailed on page xxi. In Part II. the Zone and No. in the *Bonn Durchmusterung* are used.

§ 7. *Catalogue of Mean R.A. and N.P.D. for* 1910·0 *of Fundamental and Zodiacal Stars observed in* 1909.

The results of observations of stars included in Part I. only of the ledgers are given in this catalogue.

The right ascensions in the catalogue are the means of the separate determinations for each star, and are identical with the means printed in the ledgers.

The north polar distances in the catalogue are obtained from the results in the ledgers by applying corrections for the discordance of direct and reflexion results, and in the case of reflexion observations for inclination of the verticals at the surface of the mercury and at the centre of the transit-circle.

For the flexure term of the R—D discordance a constant value, namely $+0''\cdot60$ sin Z.D., has been adopted. This is sensibly the same as the mean values used in the 1880, 1890 and 1900 Catalogues.

For the circumpolar stars the following weights are assigned to the observations in N.P.D. below pole:—

N.P.D. not exceeding 15°, weight 1,
N.P.D. 15° to 36°, weight $\frac{2}{3}$,
N.P.D. 36° to 41°, weight $\frac{1}{2}$.

Beyond N.P.D. 41° the observations are not combined. Direct and reflexion observations are treated as having equal weights.

As already explained Pulkowa refractions and an adopted colatitude 38° 31′ 21″·80 have been used in the reductions, Newcomb's constants of precession have been adopted, and the results have been corrected for latitude variation.

The proper motions given are generally taken from Prof. Newcomb's *Catalogue of Fundamental Stars for* 1900·0, or from the *Catalogue of Zodiacal Stars for the epoch* 1900·0 *and* 1920·0. For the stars given in the *Berliner Jahrbuch*, but not in the *Nautical Almanac* or *Connaissance de Temps*, the proper motions of Prof. Auwers are used.

§ 8. *Horizontal and Vertical Diameters, Right Ascensions, and North Polar Distances of the Sun, Moon, and Planets, deduced from the Observations, and compared with the Nautical Almanac and other Ephemerides, with the inferred Position of the Ecliptic, the Geocentric Errors of the Sun, Moon, and Planets, in Longitude and Ecliptic Polar Distance, and the Equations between the Geocentric Errors of the Planets and the Heliocentric Errors of the Earth and Planets.*

HORIZONTAL AND VERTICAL DIAMETERS OF THE SUN, MOON, AND PLANETS.

The duration of the passage of the Sun's diameter is found by subtracting the clock-time of transit of the first limb from that of the second limb in the *Transits observed*, &c., without any further correction. The tabular duration is found by doubling the time of the passage of the semidiameter given in the *Nautical Almanac*. The excess of the latter above the former is set down as the apparent error of the *Nautical Almanac*.

The Sun's vertical diameter is found by subtracting the zenith-distance of the north limb, corrected for refraction and parallax, from that of the south limb similarly corrected. The tabular diameter is found by doubling the semidiameter of the *Nautical Almanac.* The excess of the latter above the former is set down as the error of the *Nautical Almanac.*

The Moon's diameter is found in the same manner as that of the Sun (the correction for defective illumination having been already applied).

A table is also given of a comparison of the observations of Mösting A with those of the Moon's limb, from which the horizontal and vertical diameters of the Moon may be deduced.

For the planets, the duration of passage of diameter is found by subtracting the clock-time of transit of the first limb from that of the second limb in the section *Transits observed,* the correction for defect of illumination being applied where necessary. This correction is double the amount applicable to the mean of limbs which is stated in the notes to that section.

The vertical diameters of Mercury, Venus, Mars, and Jupiter are found by subtracting the N.P.D. of the north limb from that of the south limb, after the correction for defective illumination has been applied, as explained at page xxxiv. The vertical diameters of the other planets are obtained in a similar way, excepting that there is no correction for defective illumination.

RIGHT ASCENSIONS AND NORTH POLAR DISTANCES OF THE SUN, MOON, AND PLANETS.

The observed right ascensions of the Sun's centre are generally the means of those deduced from the observations of the two limbs; but when one limb only has been observed, the R.A. of the centre is deduced from that of the limb, by application of the duration of transit of semidiameter given in the *Nautical Almanac,* corrected by the quantities given on page xxvi. The right ascensions are transcribed from those in the section of *Transits observed,* without alteration, except that, when necessary, the correction for personal equation is applied.

The following are the values of the mean error of tabular right ascension of the Sun's centre (mean of two limbs) found by the different observers:—

	SE	W	E	RC	BE	SD	S	HA	GC	Other Observers.
	s	s	s	s	s	s	s	s	s	s
1909	$-0{\cdot}06_{1}$	$-0{\cdot}01_{19}$	$-0{\cdot}01_{20}$	$-0{\cdot}10_{19}$	$-0{\cdot}02_{16}$	$-0{\cdot}13_{8}$	$-0{\cdot}04_{12}$	$-0{\cdot}06_{10}$	$-0{\cdot}02_{9}$	$-0{\cdot}01_{7}$

the subscript numbers denoting in each case the number of observations.

The observed north polar distances of the Sun are taken from the section of *Zenith-Distances*, &c., the corrections for discordance of direct and reflexion results and (since 1902) for latitude variation being applied. As has been previously explained, Pulkowa refractions and assumed colatitude 38°.31′.21″·80 have been used throughout in the reductions. The tabular right ascensions and north polar distances are taken without correction from the *Nautical Almanac*.

The following are the values of the mean error of tabular N.P.D. of the Sun's centre (mean of two limbs) found by the different observers:—

	SE	W	E	RC	BE	SD	S	HA	GC	Other Observers.
1909	$+0''.30_{2}$	$+0''.13_{21}$	$+0''.22_{21}$	$-0''.52_{21}$	$-0''.34_{17}$	$+0''.02_{7}$	$+0''.16_{13}$	$-0''.14_{10}$	$+0''.10_{9}$	$+0''.20_{11}$

As the microscope-micrometers for the observations of the north polar distance of the Sun are not read by the observer but by his assistant, whereas the determination of the zenith-point depends on the readings of the observer himself, any difference, depending on personality, in the readings of the observers and of the microscope-readers for the Sun would introduce a systematic error into the north polar distances of the Sun. With a view to determining the magnitude of this error, if it exists, the microscopes for the midday nadir observation were read during 1908 both by the observer and microscope-reader. The results of this comparison are given in the *Transit-Circle Tables* for 1908.

The observed right ascensions of the Moon's centre are taken from the *Transits observed*, corrected, when necessary, for personal equation, and also for the Moon's motion in R.A. during the passage from the mean of wires to the true meridian. When both limbs of the Moon are observed, the correction for defective illumination is first applied to the defective limb, and the mean of the two is then taken without any further alteration.

The tabular right ascension of the Moon's centre is found by applying to the right ascension of the limb (given in the section, *Moon-culminating Stars*, of the *Nautical Almanac*) the sidereal duration of passage of semidiameter, which is given in the same section of the *Nautical Almanac*.

The observed north polar distances of the Moon's centre are taken from the section of *Zenith-Distances observed*, &c., corrected for discordance of direct and reflexion results and for the motion in N.P.D. during the passage from the mean of wires to the true meridian, and since 1902 for latitude variation.

The tabular north polar distances of the Moon's centre are taken from the section *Moon-culminating Stars* of the *Nautical Almanac*.

From the beginning of 1905 the lunar crater Mösting A has been observed, as well as the Moon's limbs whenever practicable, the observations of transits serving to connect the observations of the first and second limbs made before and after Full Moon respectively, while the observations of zenith distance in combination with similar observations made at the Cape Observatory serve to determine the parallax of the Moon.

For all the planets, the right ascensions are extracted from the twenty-first column of *Transits observed*, with no alteration, except for personal equation when necessary; the north polar distances are taken from the last column in the upper part of the page of the *Zenith-Distances observed*, &c., corrected for discordance of direct and reflexion results, and since 1902 for latitude variation. The tabular places are taken from the *Nautical Almanac*, for such planets as are given in that work and its appendices. For others the tabular places are taken from the *Berliner Jahrbuch*, or its Circulars; or occasionally from MS. ephemerides mentioned in the notes.

When only one limb of a planet is observed, the number I. or II., or the letter N, S, or C, in Columns 4 and 8, indicates that the first, second, north, or south limb, or the estimated centre, was observed.

ECLIPTIC INVESTIGATION.

The investigation of the position of the ecliptic has been made in the following manner. The mean of all the daily errors in each month of the R.A. and N.P.D. of the sun is taken to be the error for the day which is nearest to the mean of all the days of observation. When the same day is not found for R.A. and for N.P.D., an alteration of a unit or more has sometimes been made. From these, the error in the ecliptic polar distance is obtained by means of the factors R and S in the tables forming the second part of the *Appendix* to the *Greenwich Observations*, 1836. Supposing these errors to arise from an erroneous position of the ecliptic assumed in the *Nautical Almanac*, they may be expressed by the formula $x \cos l + y \sin l + z$, where l is the Sun's longitude. Weights are then assigned proportional to the number of observations of N.P.D., and the equations solved by the ordinary method of least squares. This method has been used since 1888, instead of the method of weighting and grouping the observations previously adopted.

It is probable that, starting with 1909, a small discontinuity has been introduced into the value of x, owing to the observation of the clock stars with the central illumination instead of the annular illumination formerly used; a comparison of the two methods is given in the *Transit-Circle Tables* 1908 and 1909.

MEAN ERRORS OF THE TABULAR PLACES OF THE SUN AND PLANETS.

For the *Mean Errors of the Tabular Geocentric Places of the Sun and Planets*, the observations have been collected into groups rarely exceeding a month in duration, and the mean of all the errors in each group, for R.A. and for N.P.D., giving half weight to observations of a single limb of the Sun in either element, is supposed to be the error for the day which is nearest to the mean of all the days of observation in the group, an alteration of a unit or more being sometimes made, in order to refer R.A. and N.P.D. to the same day. The errors in longitude and E.P.D. are formed by the use of the numbers P, Q, R, S in the *Appendix* to the *Greenwich Observations*, 1836. For any of the four small planets, Ceres, Pallas, Juno, and Vesta, whose latitude exceeds the limits of the tables, the longitude and E.P.D. are computed, 1st, from the R.A. and N.P.D. of the *Nautical Almanac*; 2nd, from these quantities affected with the errors in R.A. and N.P.D.; and the difference between these results gives the errors in longitude and E.P.D.

For the *Errors in the Tabular Heliocentric Places of the Planets*, the following formulæ are used:—

For the small planets, Ceres, Pallas, Juno, and Vesta.

Let R = radius vector of planet, L = planet's heliocentric longitude,
Δ = planet's distance from Earth, λ = planet's geocentric longitude,
r = Earth's radius vector, l = Earth's heliocentric longitude.

Then,

$$\text{Error of geoc. long.} = \frac{R \times \cos \text{hel. lat.} \times \cos(\lambda - L)}{\Delta \times \cos \text{geoc. lat.}} \times \text{error of hel. long.}$$

$$- \frac{\sin(\lambda - L)}{\Delta \times \cos \text{geoc. lat.} \times \sin 1''} \times \text{error of projection of planet's radius vector.}$$

$$\text{Error of hel. E.P.D.} = \frac{\Delta \times \cos \text{hel. lat.}}{R \times \cos \text{geoc. lat.}} \times \text{error of geocent. E.P.D.}$$

$$- \sin \text{hel. lat.} \times \cos \text{hel. lat.} \times \tan(\lambda - L) \times \text{error of geocent. long.}$$

$$- \frac{r \times \tan \text{geoc. lat.} \times \cos(L - l)}{R^2 \cos(\lambda - L) \times \sin 1''} \times \text{error of projection of planet's radius vector.}$$

For the other planets, the following are used:—

$$\text{Error of geocent. long.} = \frac{R \times \cos(\lambda - L)}{\Delta} \times \text{error of planet's heliocentric longitude,}$$

$$- \frac{\sin(\lambda - L)}{\Delta \times \sin 1''} \times \text{error of projection of planet's radius vector,}$$

$$- \frac{r \times \cos(\lambda - l)}{\Delta} \times \text{error of Earth's heliocentric longitude,}$$

$$+ \frac{\sin(\lambda - l)}{\Delta \times \sin 1''} \times \text{error of Earth's radius vector.}$$

$$\text{Error of hel. E.P.D.} = \frac{\Delta}{R} \times \text{error of geocent. E.P.D.}$$

The errors of the Earth's place are retained in the formulæ for the larger planets, as being probably comparable in magnitude with the errors of the places of the planets: but the errors of the tabular places of the small planets being in general large, in their case the Earth may be supposed to move exactly in the orbit assigned by the tables.

It is to be remarked that, in the column *Extent of Group*, the day given is, as in past years, the civil day (commencing at midnight) on which the observation was made, and that this occasionally differs by a unit from the astronomical day under which the observations may be found in the sections of *Transits observed* and *Observations of Zenith-Distance*: also in the column *Mean Day* the day given is the civil day corresponding to the time of observation, or to the mean of times of observation.

COMPARISON OF THE TABULAR ERRORS OF R.A. AND N.P.D. OF THE CENTRE OF THE MOON.

In this table are brought together the tabular errors of the centre of the moon, derived from observations of Mösting A and the limb, both with the transit-circle and the altazimuth (see below), and a mean error is deduced.

Corrections representing the Moon's motion in R.A. and N.P.D. in the interval between the observed and tabular times of transit have been applied in forming these Errors of the Moon's tabular place. The Apparent Errors of R.A. and N.P.D. in the section, "Right Ascensions and North Polar Distances of the Centre of the Moon," are formed, as in past years, by simple subtraction of the "R.A. or N.P.D. from Observation" from the "R.A. or N.P.D. in *Nautical Almanac*," without application of the above-mentioned corrections.

MEAN ERRORS OF THE TABULAR PLACES OF THE MOON.

Commencing with year 1908, the mean results from the limb and Mösting A, obtained with the transit-circle and altazimuth (given in the previous table) have been used in this discussion.

The errors of tabular longitude and ecliptic polar distance of the Moon are deduced from the errors of tabular R.A. and N.P.D. by the use of the numbers, P, Q, R, S, for all the meridian observations.

§ 9. *Meridian observations with the Altazimuth.*

The method of reduction of the transits and meridian zenith distances is similar to that for the transit-circle and no further explanation is required for the section of Transits and Meridian Zenith Distances beyond the short notes at the beginning of these sections. As in the case of the Transit-Circle, the lunar crater Mösting A has been observed with the Altazimuth whenever practicable, and a comparison of the results with those from the moon's limbs is given on pp. {*76*} and {*77*}.

In the *Altazimuth Tables* at the end of this *Introduction* are given :—

The values of $1^{\text{rev.}}$ of the micrometer-screws.
The adopted wire intervals.
The adopted division errors.

Further details of the methods by which these were obtained are given in the Tables at the end of the *Introduction* for 1901.

A discussion of the R—D discordance and of the colatitude is also given in substantially the same form as for the transit-circle. A comparison of the North Polar Distances observed in the four positions of the instrument is also given in the *Altazimuth Tables* at the end of this *Introduction.*

§ 10. *Extra-meridian observations with the Altazimuth.*

The method of observation has been already described on page ix, the essential point being that the means of the times of observation in azimuth and zenith distance should be as nearly as possible the same, so that the azimuth and zenith distance can be readily referred to the same instant of time.

The following explanation refers to the observations and reductions as printed in this section.

The first twelve columns of this section require no explanation. The Apparent Error of Tabular Z.D. in the thirteenth column is the excess above the concluded Zenith Distance of the Tabular Zenith Distance, which is taken from tables constructed for each azimuth with argument N.P.D. according to the formula

$$\cos(Z+\theta) = \sec\gamma_0 \cos\Delta$$

where

$$\sin\gamma_0 = \sin\gamma \sin A$$

$$\tan\theta = \tan\gamma \cos A$$

Z being the tabular zenith distance, or the zenith distance on crossing the standard azimuth corresponding to the tabular N.P.D. which is denoted by Δ. The colatitude is denoted by γ and the azimuth reckoned from the south by A.

The tabular places are taken, whenever possible, from the Greenwich Clock Star List or recent Greenwich Catalogues, or from Newcomb's Fundamental Catalogue, in this order of preference.

The fourteenth column is derived from the thirteenth by converting arc into time at the rate $15'' \sin \gamma \sin A = 15\ m$ to a second of time. This is the rate of motion in zenith distance and is constant throughout the same azimuth.

The second column of the right hand page is the mean of the separate taps over the horizontal wires registered on the chronograph reduced to the centre wire by a process analogous to the completion of transits in the meridian. In this case, however, the reduction to the centre wire is simpler, because the transits are usually symmetrical, and also because the motion in zenith distance is constant throughout the azimuth. The observed time of transit over the centre wire includes the correction for curvature of the star's path, when sensible.

The fourth column gives the tabular time T of transit over the standard azimuth, computed with the help of tables from the formulæ :—

$$\cos (T - \alpha + \phi) = \tan \gamma_0 \cot \Delta$$

where

$$\tan \phi = \sec \gamma \cot A$$

α being the tabular right ascension.

The clock error is the excess of this latter quantity over the quantity in the second column corrected by the application of the quantity in the last column of the left hand page. The clock rate is taken from the transit-circle observations, and the clock error reduced to 0^h sidereal with this rate is exhibited in the fifth column. Means are taken in this column for each group observed by the same observer on the same side of the zenith.

The sixth column gives the adopted clock error, which is the mean of the two groups observed, east and west of the zenith.

The observed time of transit over the centre vertical wire given in the seventh column is corrected for curvature of the star's path, when sensible. The errors of collimation and level given in the ninth column are converted into time by the divisors $15\ m \cot S$ and $15\ m \cot S \sec Z$ respectively, S being the parallactic angle. The seconds corrected are given in the tenth column. The result in the tenth column is corrected for the clock error and rate given in the sixth column, and the excess of the tabular transit T over the quantity thus derived is set down in the eleventh column, under the heading Apparent Error of Tabular Time of Transit. From this apparent error is deduced the Apparent Error of Azimuth, the quantity set down in the twelfth column being the determination of this error from the particular star, derived by multiplying the quantity in eleventh column by $15\ m \cot S \operatorname{cosec} Z$.

In the thirteenth column is given the adopted error of azimuth, the weighted mean of the quantities in the preceding column, the weight assigned being the nearest integer to 10 $\sin^2 Z$. The Apparent Errors of Tabular Place in Azimuth and Zenith Distance given in the fourteenth and fifteenth columns are derived by multiplying the excess of the azimuth error and clock error as determined from the particular star, over their adopted values by $\sin Z$ and 15 m respectively.

The remaining columns require no explanation.

At the foot of the page are given details of the reductions for the Sun, Moon and Planets.

The second column of the left hand page gives the quantity in the seventh column of the right hand page above corrected for clock error, rate, collimation, level, and azimuth. The clock error used for Azimuth observations is derived from stars on both sides of the Zenith; that for Zenith Distance observations from stars on the same side of the Zenith as the object observed. Correction is still required on account of semidiameter, parallax, and orbital motion. This correction is calculated as a fraction $\frac{A}{B}$ whose numerator and denominator are approximately equal to the semidiameter and 15 $m \cot S$, a quantity called the collimation divisor. The numerator of this fraction, A, requires to be corrected for parallax and curvature. The former correction is the same fraction of the semidiameter that the perpendicular from the centre of the Earth upon the standard azimuth is of the linear semidiameter of the object observed. The correction for curvature is $\frac{1}{2} \times \frac{(15\,t)^2}{206265} \sin \Delta \cos \Delta$ in seconds of arc applicable to N.P.D. Its horizontal component is found by multiplication by $\sin S$. It will be observed that $\sin \Delta \sin S$ is a constant for the azimuth and that $\cos \Delta$ varies between small limits and is never far different from unity. A sufficient approximation to the value of t in the numerator is obtained by dividing the semidiameter by the collimation divisor.

For the denominator B, of the fraction, the collimation divisor requires correction for the contribution of the object's orbital motion to the apparent motion across the azimuth of the instrument.

The contribution arising from the orbital motion in R.A. is the same fraction of the collimation divisor that the orbital motion in R.A. is of the diurnal motion, 15 $\sin \Delta$. In the case of the Moon, however, the mean orbital motion is considered as coalescing with the diurnal motion, and the inequalities of its motion are alone attributed to orbital motion. As a consequence, the fraction whose value is exhibited in the ninth column of the printed results is expressed in lunar seconds in the case of the moon and sidereal seconds for the sun and planets. A lunar second denotes the $\frac{1}{86,400}$ part of a lunar day, which is the mean interval between consecutive transits. The contribution to the collimation divisor of a motion in N.P.D. of one second of arc in a second of time is clearly sin *S.*, and for a greater or less motion in N.P.D., the effect is in proportion.

This suffices for the explanation of the third to the ninth columns inclusive. The tenth column is the result of the application of the ninth column (which must be reduced to sidereal seconds when necessary) to the second column.

The eleventh column is taken from the second column of the right hand page above corrected for clock-error and rate. The clock-error employed is derived from the stars on the same side of the zenith only, and is that set down in brackets in the fifth column of the right hand page above.

The difference $T-t_2$, the excess of the tenth column over the eleventh is always small: the twelfth column exhibits this difference converted into arc by the factor $15m$ corrected for orbital motion in R.A. and N.P.D. The method of correction is analogous to the correction of the collimation divisor.

The thirteenth column exhibits the semidiameter, interpolated from the *Nautical Almanac.*

The fourteenth column exhibits the horizontal parallax, reduced to the geocentric distance of the instrument, and multiplied by sin $(z - \zeta)$ where ζ is the angle of the vertical projected upon the plane of the instrument ($11' \; 12''$ cos A), the ellipticity of the Earth being assumed to be 1/300 and the height of the instrument above sea level being taken as 170 feet.

The fifteenth column exhibits the excess of the true correction for semidiameter and parallax.

$$\sin^{-1} [(\rho \sin (z - \zeta) \pm \mu) \sin p]$$

over the sum of the preceding corrections. In this formula, ρ denotes the geocentric distance of the instrument, μ the linear diameter of the planet, and p its equatorial horizontal parallax.

On the right hand page the second column gives the application of the corrections in the four last columns to the zenith distance in the twelfth column of the left hand page above.

The third and fourth columns contain the N.P.D. and hour angle corresponding to Z, the latter combined with T gives the R.A. in the fifth column: the remaining columns require no further explanation.

The method of reducing lunar observations is described by Mr. Cowell in the *Monthly Notices*, vol. lxii. p. 503, where full formulæ and an example are given.

§ 11. *Ledgers of Mean Right Ascensions and North Polar Distances and Catalogue.*

The star ledgers and the annual star catalogue are printed together. The position of the instrument is indicated in each case, and the Mean N.P.D. is given as obtained from each circle separately. The separate results are corrected for latitude variation, and the means of groups in each position of the instrument are corrected for the R – D discordance.

§ 12. *Results of Observations of Planets.*

The planetary results are similar to those obtained with the transit-circle and require no further explanation.

Attention may be called to the fact that the results of the observations of the Moon with the altazimuth are compared and combined with those obtained with the transit-circle in special tables given at the end of the Planetary Results of the transit-circle observations (see § 8).

§ 13. *Meridian Zenith Distances of Stars observed with the Reflex Zenith Tube.*

It was pointed out by Mr. Chandler in the *Astronomical Journal*, No. 511 (1901 November) that the anomalous results found from observations of γ Draconis with this instrument were to be explained by the variation of latitude and that the instrument was well adapted for the determination of the amount of this variation. It was decided, therefore, early in 1902, to resume without delay the observations of γ Draconis, which had been intermitted since 1899 May and to observe such other stars as passed sufficiently near the zenith and were sufficiently bright. By suitable modification of the illumination it has been found possible to observe stars down to the magnitude 7·0, and, by mounting the eyepiece in a slide, good definition at a distance of 50′ or more from the zenith (centre of the field) has been secured.

A working catalogue of suitable stars was prepared and systematic observations began in 1902 June. The daily results are given in substantially the same form as the observations of γ Draconis in volumes up to that for 1881, to which reference may here be made.

An account of the determinations of the mean value of 1 revolution of the screws, of the errors of the screws, and of the intervals of the wires is given in the *Reflex Zenith Tube Tables* for 1903.

It is to be noted, however, that there is no means of securing (with the accuracy demanded) that the value of a revolution of the screw and of the wire intervals shall remain constant for any considerable period. The value of a revolution of the screw depends on the distance between the mercury-trough and the object-glass, and this can only be roughly adjusted. Accordingly, the zenith-distances printed require correction by a scale-constant, which can only be determined by a careful discussion of the observations.

§ 14. *Eclipses, Occultations, and Transits of Jupiter's Satellites, compared with the Nautical Almanac; and Occultations of Stars by the Moon with the Equations deduced from the Occultations.*

The clocks used in these observations are in general compared with the Sidereal Standard near the time of the observation, and the mean solar time is computed in the usual way.

For the computation of the Occultations of stars by the Moon, the star's place is taken from the "Elements for facilitating the Computation of Occultations" in the *Nautical Almanac* when given there. The Moon's geocentric place and horizontal equatorial parallax are interpolated with second differences from the *Nautical Almanac*, and are used without alteration. From the beginning of 1900 a correction has been applied to the *Nautical Almanac* semidiameter, to reduce it from Hansen's bright limb value 15′ 34″·09 to Struve's dark limb value 15′ 32″·65. The correction to be applied to the parallax of the Moon's centre, in order to obtain that for the point of the limb at which the occultation takes place, is derived from a table given in the *Introduction* to the *Greenwich Observations* of 1899.

Let now δ and θ be the N.P.D. and hour-angle of the star, which are the same as the apparent N.P.D. and hour-angle of the point of the Moon's limb; δ' and θ' those of the corresponding point of the limb as seen from the Earth's centre; l the geocentric latitude of the place; and P' the corrected horizontal parallax; then, by an investigation similar to that given in the *Introductions* to the volumes, from 1843 to 1849, it may be shown that

$$\sin(\theta - \theta') = \frac{\text{Radius of parallel for Greenwich}}{\text{Moon's distance from the Earth's axis}} \times \sin\theta.$$

$$\sin(\delta - \delta') = \frac{\sin l \,.\, \sin\delta \,.\, \sin\theta \,.\, \sin P'}{\sin\frac{1}{2}(\theta + \theta') \,.\, \cos\frac{1}{2}(\theta - \theta')} - \cot\tfrac{1}{2}(\theta + \theta') \,.\, \tan\tfrac{1}{2}(\theta - \theta') \,.\, \sin(\delta + \delta').$$

For the first step of the computation the following quantities are formed :—

F = log. sin star's hour-angle + log. seconds of corrected eq. hor. parallax + 9·4942268.

G = log. sin star's N.P.D. + log. sin star's hour-angle + log. seconds of corrected eq. hor. parallax + 9·8913966.

(The former numerical constant is the logarithm of half the distance of Greenwich from the Earth's axis, and the latter is the logarithm of the distance of Greenwich from the plane of the equator; supposing the Earth's ellipticity $= \frac{1}{300}$).

The preceding formulæ are then adapted to logarithmic computation, and the equations are solved by successive trials, assuming a value for δ', in the following manner :—

$$\log. \tfrac{1}{2}(\theta - \theta') \text{ in seconds} = F - \log. \sin \delta' + \log. \tfrac{\text{sine}}{\text{arc}} \text{ for hor. parallax} + \log. \tfrac{\text{arc}}{\text{sine}} \text{ for } (\theta - \theta').$$

$$\log. 1^{\text{st}} \text{ number} = G + \log. \text{secant} \tfrac{1}{2}(\theta - \theta') + \log. \tfrac{\text{sine}}{\text{arc}} \text{ for hor. parallax} + \log. \tfrac{\text{arc}}{\text{sine}} \text{ for } (\delta - \delta') - \log. \text{sine} \tfrac{1}{2}(\theta + \theta').$$

$$\log. 2^{\text{nd}} \text{ number} = \log. \tfrac{1}{2}(\theta - \theta') \text{ in seconds} + \log. \tfrac{\tan}{\text{arc}} \text{ for } \tfrac{1}{2}(\theta - \theta') + \log. \sin(\delta + \delta' - 180^\circ) + \log. \cot \tfrac{1}{2}(\theta + \theta') + \log. \tfrac{\text{arc}}{\text{sine}} \text{ for } (\delta - \delta').$$

$$\delta - \delta' = 1^{\text{st}} \text{ number} + 2^{\text{nd}} \text{ number}.$$

In the first trials, the log. $\frac{\text{arc}}{\text{sine}}$, &c. are omitted. The convergence of these approximations is extremely rapid.

When δ' and θ' are found accurately, the distance of the corresponding point from the Moon's centre is thus found, by means of a subsidiary angle ψ :—

If log. tan ψ = log. diff. R.A. of Moon's centre and corresponding point + $\frac{1}{2}$ log. sin N.P.D. of Moon's centre + $\frac{1}{2}$ log. sin δ' − log. diff. N.P.D. of Moon's centre and corresponding point;

Then log. dist. = log. diff. N.P.D. − log. cos ψ,
or = log. diff. R.A. + $\frac{1}{2}$ log. sin N.P.D. of centre + $\frac{1}{2}$ log. sin δ' − log. sin ψ.

The coefficients of small variations of the north polar distance and of the difference of right ascension (in the expression for distance) are computed by the formulæ :—

log. 1^{st} number = 2 log. diff. R.A. + log. sine (sum of N.P.D.) − log. dist. + 4·0835.
log. 2^{nd} number = log. diff. N.P.D. − log. distance = log. cos ψ.

Coefficient of variation of greater N.P.D. = 1st number + 2nd number.
Coefficient of variation of smaller N.P.D. = 1st number − 2nd number.
Log. coefficient of variation of diff. R.A. =

log. diff. R.A. + log. sin δ' + log. sin Moon's N.P.D. − log. distance.

The variation of the R.A. of the corresponding point contains the following terms :—

1st. The alteration of the R.A. of the star by the quantity e'' will alter the R.A. of the corresponding point by very nearly the same quantity e''.

2nd. The alteration of the horizontal equatorial parallax in the proportion of $1 : 1 + \frac{m}{1000}$ will alter all the deduced parallaxes (in R.A. and in N.P.D.) in nearly the same proportion: and therefore the R.A. of the corresponding point will be altered by $\frac{m}{1000} \times$ correction for parallax in R.A.

3rd. The alteration in the position of the Moon, with regard to the meridian depending on the alteration of time t^s, will introduce an alteration in the correction for parallax. It is computed by the following formula :—

Alteration in correction of R.A. of corresponding point for parallax, depending on the alteration of time =

$$15'' \times t \times \left\{ \begin{array}{l} \sin P \,.\, \cos l \,.\, \text{cosec N.P.D. cos hour-angle} \\ + \sin^2 P \,.\, \cos^2 l \,.\, \text{cosec}^2 \text{ N.P.D. cos 2 hour-angle} \end{array} \right\}.$$

The variation of the R.A. of the Moon's centre is $x'' + t \times$ change of R.A. in 1^s.

The variation of the N.P.D. of the corresponding point contains three terms analogous to those for R.A.: namely—

1st. The alteration of the star's N.P.D. by the quantity f'' will alter the N.P.D. of the corresponding point by f'' nearly.

2nd. The correction for parallax in N.P.D. will be altered by $\frac{m}{1000} \times$ correction for parallax in N.P.D.

3rd. The increase of hour-angle (considered positive when the Moon is west of the meridian), depending on the alteration of time t^s, will alter the correction for parallax in N.P.D. by the following quantity :—

$$15'' \times t \times \left\{ \begin{array}{l} (-\sin P \,.\, \cos l \,.\, \text{cos N.P.D.} - \sin^2 P \,.\, \sin l \,.\, \cos l \,.\, \text{cos 2 N.P.D.}) \times \sin \\ \qquad \text{hour-angle.} \\ + \left(-\tfrac{3}{2} \sin^2 P \,.\, \cos^2 l \,.\, \text{cot N.P.D.} + \sin^2 P \,.\, \cos^2 l \,.\, \text{cot N.P.D.} \cos^2 \text{N.P.D.}\right) \\ \qquad \times \text{ sin 2 hour-angle.} \end{array} \right\}$$

The variation of the N.P.D. of the Moon's centre is $y'' + t \times$ change of N.P.D. in 1^s.

The computed distance, with addition of the sum of the products of the preceding variations by their proper coefficients, is made equal to the semidiameter increased by the term, semidiameter $\times \frac{n}{1000}$; and thus the final equation is formed.

For a planet, the R.A. and N.P.D. of the centre are used to find those of the corresponding point of the limb; the planetary parallax is subtracted from that of the Moon; and the distance of the corresponding point is equated to the sum (or difference) of the semidiameters.

§ 15. *Micrometric Observations of Double Stars.*

These observations were made with a position-micrometer on the 28-inch refractor. The method of observation consists in turning the micrometer till its fixed wire is parallel to the line joining the stars (so that they can be simultaneously bisected by it, by moving the telescope with one of the slow-motion rods) and reading the position-circle. The two movable wires, which are perpendicular to the fixed wire, are then moved till they bisect the two stars, and the readings of the micrometer-heads are taken. This may be done in two ways, the wire moved by the right hand screw bisecting the star on the right or left, as the observer wishes, and the wire moved by the left hand screw bisecting the other star in each case. The zero of position-angle is obtained by placing the fixed wire so that the diurnal motion carries a star along it. As the values of $1^{rev.}$ of the micrometer-screws are equal, and their readings increase in opposite directions, the distance between the stars is obtained by taking the sum of the readings of the micrometer-heads and subtracting the sum of the corresponding readings when the wires coincide; or if the measure has been made with wires reversed, by subtracting the sum of the readings from the reading for coincidence. When the observation has been made both *directly* and with wires reversed, the distance is half the difference of the sum of the micrometer-readings in the two cases.

The value of one revolution of each micrometer-screw is 12″·06. It was determined in 1894 November from transits of stars near the pole. The observations are given in the volume for 1894.

The nomenclature of the stars in column 1 refers to the original observer's catalogue. Column 2 gives the name adopted for the star in the Greenwich Catalogues. Columns 3 and 4 contain the approximate R.A. and N.P.D. for 1900. Columns 5 and 6 give the measured position-angle and distance on different nights, and the means.

Column 7 gives the number of measures of each element on the separate nights. Column 8 gives the magnitudes derived from the original observers' catalogues. Column 9 gives the epoch of the observations, expressed as the fraction of the year In column 10 the magnifying power used is given, and in column 11 such remarks as appear necessary.

§ 16. *Observations of Comets and Minor Planets from Photographs taken with the* 30-*inch Reflector of the Thompson Equatorial.*

The Thompson Equatorial, carrying the 26-inch photographic refractor at one end of the declination axis, and the 30-inch reflector at the other, is briefly described on page xiii. The focal length of the reflector is approximately 11 feet 5 inches, giving a scale of 1′ to the millimetre nearly.

The photographs are taken on plates 16 centimetres square, on which a *réseau* of cross lines 5 millimetres apart is printed in the same manner as for the Photographic Map of the Heavens.

The measurement of the photographs was made with the Astrographic Micrometer, which has a glass diaphragm with cross scales at the focus of the microscope. These scales are divided into 100 parts, and the micrometer is readily adjusted so that 100 divisions of the scale are equal, very nearly, to the distance between two *réseau* lines as viewed with the microscope. The intersection of the scales is made to bisect the object, and the positions of the *réseau* lines on each side are read off on the scales by estimation to the thousandth part of a *réseau* interval. The rectangular co-ordinates of the images are thus obtained in units of 1 *réseau* interval, which for both the 30-inch reflector and the 13-inch refractor is approximately 5′.

The plates are in all cases measured in reversed positions to eliminate personality. Where several images of the same object are obtained on a plate, they are all measured and the mean taken. The magnifying power used is 15.

The determination of Right Ascension and Declination is made by Professor Turner's method (*Monthly Notices*, *R.A.S.*, vol. liv., p. 11), as follows:—

With an assumed Right Ascension and Declination of the centre of the plate, the "Standard Co-ordinates," ξ and η, of those stars which are used as reference stars are computed by the formula—

$$\xi = \tan(\alpha - A)\cos\phi\sec(\phi - D),$$
$$\eta = \tan(\phi - D)$$
$$\text{where } \tan\phi = \tan\delta\sec(\alpha - A)$$

In this formulæ—

α is the R.A. of the star,
A ,, ,, centre of the plate
δ is the Dec. of the star
D ,, ,, centre of the plate
and ϕ is an auxiliary angle.

The "Standard Co-ordinates" of the reference stars are compared with the measured co-ordinates x, y; and from equations of the form—

$$\xi - x = ax + by + c$$
$$\eta - y = dx + ey + f$$

the constants of each plate a, b, c, d, e, f are deduced. By means of these constants, the "Standard Co-ordinates" of any object on the plate are obtained by applying corrections $ax' + by' + c$, $dx' + ey' + f$ to the measured co-ordinates x', y', from which the Right Ascension and Declination are deduced by inversion of the trigonometrical formulæ given above.

It should be noticed that the Right Ascension and Declination are referred to the equator and equinox of 1909·0, and that the position of a comet or minor planet obtained in this way is referred to this epoch and is corrected for the part of the aberration arising from the Earth's motion.

In each case the uncorrected measures of the co-ordinates of the reference stars and the comet are given, and the deduced Right Ascension and Declination for the equator and equinox of 1909·0. For the reference stars the comparison with the assumed Right Ascension and Declination is also given.

The adopted plate constants, and the Apparent Right Ascension and Declination reduced to the equator and equinox of 1909·0 are given in separate tables.

§ 17. *Observations of the Sixth, Seventh and Eighth Satellites of Jupiter, and of the Ninth Satellite of Saturn (Phœbe) from Photographs taken with the* 30-*inch Reflector, during* 1909.

The photographs were taken and measured as described in the preceding paragraph.

The method of reduction employed, in order to eliminate the optical distortion of the reflector, and the determination of the error of the Tabular Place of the planet are described in the Note at the beginning of the section itself.

F. W. DYSON.

Royal Observatory, Greenwich,
1911 *January.*

TRANSIT-CIRCLE TABLES,

1909.

ROYAL OBSERVATORY, GREENWICH.

TRANSIT-CIRCLE TABLES, 1909.

Equatorial Intervals of the Transit Wires.

The following are the intervals from the middle wire, determined from observations of close polar stars, which were in use throughout the year (adopted value of 1[rev.] of the Transit-micrometer = 36″·97):—

For Wire		s	For Wire		s
M	=	+ 44·20	T	=	0·00
N	=	+ 29·73	U	=	− 7·44
O	=	+ 14·94	V	=	− 9·89
P	=	+ 12·39	W	=	− 12·31
Q	=	+ 9·92	X	=	− 14·80
R	=	+ 4·88	Y	=	− 29·59
S	=	+ 2·41	Z	=	− 44·35

Apparent Correction to adopted Level-Errors, deduced from a Comparison of Reflexion and Direct Observations of Right Ascension, made in the Year 1909.

Name of Star.	Approx. N.P.D.	Approx. R.A.	Seconds of R.	Seconds of D.	R. − D.	Deduced Correction to Level-Error.	Number of Observations. R.	Number of Observations. D.	Weight.
	° ′	h m	s	s	s	″			
ε Cassiopeiæ S.P.	−26. 46	1. 47	54·600	54·550	+0·050	−0·40	1	1	1
53 Cassiopeiæ S.P.	−26. 2	1. 56	19·900	19·910	−0·010	+0·08	1	1	1
λ Draconis S.P.	−20. 10	11. 26	4·210	4·140	+0·070	−0·34	1	1	1
Bradley 2673 S.P.	−17. 46	20. 30	24·360	24·030	+0·330	−1·34	1	1	1
Bradley 1508	11. 44	10. 52	46·980	47·110	−0·130	−0·22	1	1	2
ψ Bootis	62. 42	15. 0	35·300	35·262	+0·038	+0·27	1	5	3
α Coronæ	62. 58	15. 30	52·600	52·575	+0·025	+0·18	1	4	3
γ Herculis	70. 38	16. 17	57·000	56·950	+0·050	+0·41	1	6	3
α Pegasi	75. 16	23. 0	16·680	16·615	+0·065	+0·58	1	6	2
α Equulei	85. 7	21. 11	19·570	19·576	−0·006	−0·06	1	5	2
λ Aquarii	98. 3	22. 47	55·260	55·210	+0·050	+0·72	1	3	2
δ Crateris	104. 17	11. 14	50·360	50·455	−0·095	−1·68	1	2	1

The weights used have been determined as follows :—

Putting m and n for the number of reflexion and direct observations respectively, the weight to be given to each star, in deducing the mean correction to level-error, is $\frac{4mn}{m + n + \frac{1}{5}mn}$ cos Z.D., which has been adopted for use to the nearest integer.

Combining these results with the weights attached to them, we have :—

From 7 South Stars, Mean Correction to Level-Error + 0″·21, Weight 16.
„ 5 North Stars, „ „ „ − 0″·41, „ 6.

Factors for Instrumental-Errors.

N.P.D.	Collimation.	Level.	Azimuth.	N.P.D.	Collimation.	Level.	Azimuth.
	$\frac{1}{15 \sin \text{N.P.D.}}$	$\frac{\cos \text{Z.D.}}{15 \sin \text{N.P.D.}}$	$\frac{\sin \text{Z.D.}}{15 \sin \text{N.P.D.}}$		$\frac{1}{15 \sin \text{N.P.D.}}$	$\frac{\cos \text{Z.D.}}{15 \sin \text{N.P.D.}}$	$\frac{\sin \text{Z.D.}}{15 \sin \text{N.P.D.}}$
° ′				° ′			
−45. 0	−0·094	−0·011	+0·094	−17. 30	−0·222	−0·124	+0·184
−44. 0	−0·096	−0·013	+0·095	−17. 0	−0·228	−0·129	+0·188
−43. 0	−0·098	−0·014	+0·096	−16. 30	−0·235	−0·134	+0·192
−42. 0	−0·100	−0·016	+0·098	−16. 0	−0·242	−0·140	+0·197
−41. 0	−0·102	−0·018	+0·100	−15. 30	−0·249	−0·146	+0·202
−40. 0	−0·104	−0·021	+0·102	−15. 0	−0·257	−0·153	+0·207
−39. 0	−0·106	−0·023	+0·104	−14. 30	−0·266	−0·160	+0·213
−38. 0	−0·108	−0·025	+0·105	−14. 0	−0·276	−0·168	+0·219
−37. 0	−0·111	−0·027	+0·107	−13. 30	−0·286	−0·176	+0·225
−36. 0	−0·113	−0·030	+0·109	−13. 0	−0·296	−0·184	+0·232
−35. 0	−0·116	−0·033	+0·111	−12. 30	−0·308	−0·194	+0·240
−34. 0	−0·119	−0·036	+0·114	−12. 0	−0·321	−0·204	+0·248
−33. 0	−0·122	−0·039	+0·116	−11. 30	−0·334	−0·214	+0·256
−32. 0	−0·126	−0·042	+0·119	−11. 0	−0·349	−0·227	+0·266
−31. 0	−0·129	−0·045	+0·121	−10. 30	−0·366	−0·240	+0·276
−30. 0	−0·133	−0·049	+0·124	−10. 0	−0·384	−0·254	+0·288
−29. 0	−0·138	−0·053	+0·127	− 9. 30	−0·404	−0·270	+0·300
−28. 0	−0·142	−0·057	+0·130	− 9. 0	−0·426	−0·288	+0·314
−27. 0	−0·147	−0·061	+0·133	− 8. 30	−0·451	−0·308	+0·330
−26. 0	−0·152	−0·065	+0·137	− 8. 0	−0·479	−0·330	+0·348
−25. 0	−0·158	−0·070	+0·141	− 7. 30	−0·511	−0·355	+0·368
−24. 0	−0·164	−0·076	+0·145	− 7. 0	−0·547	−0·383	+0·390
−23. 0	−0·171	−0·082	+0·150	− 6. 30	−0·589	−0·416	+0·417
−22. 0	−0·178	−0·088	+0·155	− 6. 0	−0·638	−0·455	+0·447
−21. 0	−0·186	−0·094	+0·160				
−20. 0	−0·195	−0·102	+0·166	6. 0	+0·638	+0·538	−0·343
−19. 30	−0·200	−0·106	+0·170	6. 30	+0·589	+0·499	−0·312
−19. 0	−0·205	−0·110	+0·173	7. 0	+0·547	+0·466	−0·286
−18. 30	−0·210	−0·114	+0·176	7. 30	+0·511	+0·438	−0·263
−18. 0	−0·216	−0·119	+0·180	8. 0	+0·479	+0·413	−0·243
−17. 30	−0·222	−0·124	+0·184	8. 30	+0·451	+0·391	−0·226

Factors for Instrumental-Errors—continued.

N.P.D.	Collimation.	Level.	Azimuth.	N.P.D.	Collimation.	Level.	Azimuth.
	$\frac{1}{15 \text{ Sin N.P.D.}}$	$\frac{\text{Cos Z.D.}}{15 \text{ Sin N.P.D.}}$	$\frac{\text{Sin Z.D.}}{15 \text{ Sin N.P.D.}}$		$\frac{1}{15 \text{ Sin N.P.D.}}$	$\frac{\text{Cos Z.D.}}{15 \text{ Sin N.P.D.}}$	$\frac{\text{Sin Z.D.}}{15 \text{ Sin N.P.D.}}$
8° 30′	+0·451	+0·391	−0·226	44° 0′	+0·096	+0·096	+0·009
9. 0	+0·426	+0·371	−0·210	45. 0	+0·094	+0·094	+0·011
9. 30	+0·404	+0·353	−0·196	46. 0	+0·093	+0·092	+0·012
10. 0	+0·384	+0·337	−0·183	47. 0	+0·091	+0·090	+0·013
10. 30	+0·366	+0·323	−0·172	48. 0	+0·090	+0·088	+0·015
11. 0	+0·349	+0·310	−0·161	49. 0	+0·088	+0·087	+0·016
11. 30	+0·334	+0·298	−0·152	50. 0	+0·087	+0·085	+0·017
12. 0	+0·321	+0·287	−0·143	51. 0	+0·086	+0·084	+0·018
12. 30	+0·308	+0·277	−0·135	52. 0	+0·085	+0·082	+0·020
13. 0	+0·296	+0·267	−0·128	53. 0	+0·083	+0·081	+0·021
13. 30	+0·286	+0·259	−0·122	54. 0	+0·082	+0·080	+0·022
14. 0	+0·276	+0·251	−0·116	55. 0	+0·081	+0·078	+0·023
14. 30	+0·266	+0·244	−0·111	56. 0	+0·080	+0·077	+0·024
15. 0	+0·257	+0·236	−0·105	57. 0	+0·080	+0·075	+0·025
15. 30	+0·249	+0·230	−0·099	58. 0	+0·079	+0·074	+0·026
16. 0	+0·242	+0·224	−0·093	59. 0	+0·078	+0·073	+0·027
16. 30	+0·235	+0·218	−0·088	60. 0	+0·077	+0·072	+0·028
17. 0	+0·228	+0·212	−0·084	61. 0	+0·076	+0·070	+0·029
17. 30	+0·222	+0·207	−0·080	62. 0	+0·076	+0·069	+0·030
18. 0	+0·216	+0·202	−0·076	63. 0	+0·075	+0·068	+0·031
18. 30	+0·210	+0·197	−0·072	64. 0	+0·074	+0·067	+0·032
19. 0	+0·205	+0·193	−0·068	65. 0	+0·073	+0·066	+0·033
19. 30	+0·200	+0·189	−0·065	66. 0	+0·073	+0·065	+0·034
20. 0	+0·195	+0·185	−0·062	67. 0	+0·072	+0·064	+0·035
21. 0	+0·186	+0·177	−0·056	68. 0	+0·072	+0·063	+0·035
22. 0	+0·178	+0·171	−0·051	69. 0	+0·071	+0·061	+0·036
23. 0	+0·171	+0·164	−0·046	70. 0	+0·071	+0·060	+0·037
24. 0	+0·164	+0·159	−0·041	71. 0	+0·071	+0·059	+0·038
25. 0	+0·158	+0·153	−0·037	72. 0	+0·070	+0·058	+0·039
26. 0	+0·152	+0·148	−0·033	73. 0	+0·070	+0·057	+0·039
27. 0	+0·147	+0·144	−0·029	74. 0	+0·069	+0·056	+0·040
28. 0	+0·142	+0·140	−0·026	75. 0	+0·069	+0·055	+0·041
29. 0	+0·138	+0·136	−0·023	76. 0	+0·069	+0·054	+0·042
30. 0	+0·133	+0·131	−0·020	77. 0	+0·068	+0·053	+0·043
31. 0	+0·129	+0·128	−0·017	78. 0	+0·068	+0·053	+0·043
32. 0	+0·126	+0·125	−0·014	79. 0	+0·068	+0·052	+0·044
33. 0	+0·122	+0·122	−0·012	80. 0	+0·068	+0·051	+0·045
34. 0	+0·119	+0·119	−0·009	81. 0	+0·067	+0·050	+0·045
35. 0	+0·116	+0·116	−0·007	82. 0	+0·067	+0·049	+0·046
36. 0	+0·113	+0·113	−0·005	83. 0	+0·067	+0·048	+0·047
37. 0	+0·111	+0·111	−0·003	84. 0	+0·067	+0·047	+0·048
38. 0	+0·108	+0·108	−0·001	85. 0	+0·067	+0·046	+0·048
39. 0	+0·106	+0·106	+0·001	86. 0	+0·067	+0·045	+0·049
40. 0	+0·104	+0·104	+0·003	87. 0	+0·067	+0·044	+0·050
41. 0	+0·102	+0·101	+0·004	88. 0	+0·067	+0·043	+0·051
42. 0	+0·100	+0·099	+0·006	89. 0	+0·067	+0·042	+0·052
43. 0	+0·098	+0·097	+0·007	90. 0	+0·067	+0·041	+0·052
44. 0	+0·096	+0·096	+0·009	91. 0	+0·067	+0·040	+0·053

Factors for Instrumental-Errors—continued.

N.P.D.	Collimation.	Level.	Azimuth.	N.P.D.	Collimation.	Level.	Azimuth.
	$\frac{1}{15 \sin N.P.D.}$	$\frac{\cos Z.D.}{15 \sin N.P.D.}$	$\frac{\sin Z.D.}{15 \sin N.P.D.}$		$\frac{1}{15 \sin N.P.D.}$	$\frac{\cos Z.D.}{15 \sin N.P.D.}$	$\frac{\sin Z.D.}{15 \sin N.P.D.}$
° ′				° ′			
91. 0	+0·067	+0·040	+0·053	109. 0	+0·071	+0·024	+0·066
92. 0	+0·067	+0·040	+0·054	110. 0	+0·071	+0·023	+0·067
93. 0	+0·067	+0·039	+0·054	111. 0	+0·072	+0·022	+0·068
94. 0	+0·067	+0·038	+0·055	112. 0	+0·072	+0·021	+0·069
95. 0	+0·067	+0·037	+0·056	113. 0	+0·073	+0·020	+0·070
96. 0	+0·067	+0·036	+0·057	114. 0	+0·073	+0·018	+0·071
97. 0	+0·067	+0·035	+0·057	115. 0	+0·074	+0·017	+0·072
98. 0	+0·067	+0·034	+0·058	116. 0	+0·075	+0·016	+0·072
99. 0	+0·067	+0·033	+0·059	117. 0	+0·075	+0·015	+0·073
100. 0	+0·068	+0·032	+0·060	118. 0	+0·076	+0·014	+0·074
101. 0	+0·068	+0·031	+0·060	119. 0	+0·076	+0·013	+0·075
102. 0	+0·068	+0·030	+0·061	120. 0	+0·077	+0·012	+0·076
103. 0	+0·068	+0·029	+0·062	121. 0	+0·078	+0·011	+0·077
104. 0	+0·069	+0·028	+0·063	122. 0	+0·079	+0·009	+0·078
105. 0	+0·069	+0·027	+0·063	123. 0	+0·080	+0·008	+0·079
106. 0	+0·069	+0·027	+0·064	124. 0	+0·080	+0·007	+0·080
107. 0	+0·070	+0·026	+0·065	125. 0	+0·081	+0·005	+0·081
108. 0	+0·070	+0·025	+0·066	126. 0	+0·082	+0·004	+0·082
109. 0	+0·071	+0·024	+0·066				

Assumed Mean Right Ascensions of Clock Stars and Circumpolar Stars, with the Corrections to the R.A. of the Nautical Almanac, for 1909·0.

Star's Name.	Mag.	Assumed Mean R.A. 1909·0.	Correction to N.A.	Approx. N.P.D.	Star's Name.	Mag.	Assumed Mean R.A. 1909·0.	Correction to N.A.	Approx. N.P.D.
		h m s	s	° ′			h m s	s	° ′
α Andromedæ...	2·1	0. 3. 40·863	− 0·014	61. 25	o Piscium.........	4·4	1. 40. 35·190	− 0·008	81. 18
γ Pegasi..........	3·0	0. 8. 32·898	− 0·006	75. 19	β Arietis.........	2·8	1. 49. 36·621	+ 0·027	69. 38
ι Ceti..............	3·6	0. 14. 47·496	− 0·007	99. 20	α Arietis..........	2·0	2. 2. 2·430	+ 0·007	66. 58
44 Piscium.......	5·8	0. 20. 44·239	− 0·003	88. 34	ξ^{1} Ceti............	4·4	2. 8. 10·480	− 0·016	81. 35
12 Ceti	6·2	0. 25. 23·688	− 0·011	94. 28	67 Ceti............	5·5	2. 12. 26·619	+ 0·010	96. 50
ε Andromedæ ...	4·6	0. 33. 44·610	− 0·031	61. 11	ξ^{2} Ceti............	4·4	2. 23. 19·131	+ 0·003	81. 57
β Ceti	2·1	0. 39. 1·349	+ 0·006	108. 29	ν Ceti	4·9	2. 31. 5·829	+ 0·022	84. 48
δ Piscium.........	4·6	0. 43. 57·581	− 0·011	82. 55	δ Ceti	4·1	2. 34. 49·001	− 0·022	90. 4
20 Ceti............	5·0	0. 48. 21·399	+ 0·037	91. 38	γ^{2} Ceti............	3·0	2. 38. 35·046	+ 0·016	87. 9
μ Andromedæ...	3·9	0. 51. 41·851	− 0·045	52. 0	σ Arietis	5·5	2. 46. 27·965	− 0·001	75. 18
ε Piscium	4·5	0. 58. 13·143	+ 0·001	82. 36	ε Arietis..........	4·6	2. 54. 0·335	0·000	69. 1
β Andromedæ...	2·2	1. 4. 37·963	+ 0·002	54. 52	α Ceti	2·7	2. 57. 31·260	+ 0·001	86. 16
ζ^{1} Piscium........	5·4	1. 8. 58·511	− 0·033	82. 54	δ Arietis..........	4·5	3. 6. 25·359	− 0·023	70. 37
θ Ceti.............	3·8	1. 19. 28·465	+ 0·003	98. 39	τ^{1} Arietis.........	5·2	3. 15. 58·243	− 0·014	69. 11
Polaris	2·2	1. 26. 28·757	+ 0·147	1. 11	o Tauri............	3·8	3. 19. 54·860	− 0·002	81. 17
η Piscium.........	3·7	1. 26. 36·687	− 0·004	75. 7	f Tauri............	4·3	3. 25. 50·802	− 0·032	77. 22
ν Piscium.........	4·7	1. 36. 41·642	− 0·019	84. 58	ε Eridani.........	3·7	3. 28. 38·526	− 0·015	99. 46

Assumed Mean Right Ascensions of Clock Stars and Circumpolar Stars, with the Corrections to the R.A. of the Nautical Almanac, for 1909·0—continued.

Star's Name.	Mag.	Assumed Mean R. A. 1909·0.	Correction to N.A.	Approx. N.P.D.	Star's Name.	Mag.	Assumed Mean R. A. 1909·0.	Correction to N.A.	Approx. N.P.D.
		h m s	s	° ′			h m s	s	° ′
11 Tauri	6·5	3. 35. 20·028	− 0·014	64. 58	ε Hydræ	3·8	8. 41. 57·493	− 0·008	83. 15
δ Eridani	3·7	3. 38. 53·275	− 0·036	100. 4	α Cancri	4·3	8. 53. 30·702	− 0·013	77. 47
η Tauri	3·0	3. 42. 4·355	+ 0·002	66. 11	κ Cancri	5·0	9. 2. 49·179	− 0·022	78. 58
γ^1 Eridani	3·0	3. 53. 46·982	− 0·021	103. 46	83 Cancri	6·6	9. 13. 54·266	− 0·035	71. 55
A^1 Tauri	4·4	3. 59. 18·772	− 0·023	68. 10	α Hydræ	2·0	9. 23. 6·963	+ 0·002	98. 16
ω^1 Tauri	5·8	4. 3. 51·714	− 0·051	70. 38	ξ Leonis	5·2	9. 27. 2·551	+ 0·001	78. 18
o^1 Eridani	4·1	4. 7. 25·328	− 0·043	97. 4	o Leonis	3·8	9. 36. 17·720	− 0·008	79. 42
γ Tauri	3·9	4. 14. 36·771	− 0·015	74. 35	ε Leonis	3·1	9. 40. 41·311	+ 0·008	65. 48
ε Tauri	3·7	4. 23. 18·065	− 0·017	71. 1	μ Leonis	4·1	9. 47. 35·467	+ 0·052	63. 34
Aldebaran	1·0	4. 30. 41·854	+ 0·014	73. 40	π Leonis	5·0	9. 55. 24·341	0·000	81. 31
τ Tauri	4·4	4. 36. 46·890	− 0·015	67. 13	Regulus	1·4	10. 3. 31·654	+ 0·020	77. 35
μ Eridani	4·3	4. 40. 57·065	− 0·037	93. 25	γ^1 Leonis	2·0	10. 14. 57·471	+ 0·028	69. 42
ι Aurigæ	2·7	4. 51. 3·912	− 0·015	56. 59	μ Hydræ	4·1	10. 21. 41·311	− 0·022	106. 22
ε Leporis	3·3	5. 1. 36·493	− 0·012	112. 30	ρ Leonis	4·0	10. 28. 1·261	− 0·004	80. 13
Rigel	0·3	5. 10. 9·844	+ 0·010	98. 18	34 Sextantis	6·9	10. 37. 55·585	− 0·013	85. 56
β Tauri	1·9	5. 20. 32·303	− 0·003	61. 28	*l* Leonis	5·3	10. 44. 28·522	− 0·011	78. 58
δ Orionis	2·4	5. 27. 21·425	+ 0·001	90. 22	*d* Leonis	5·0	10. 55. 51·708	+ 0·022	85. 54
α Leporis	2·7	5. 28. 42·940	− 0·051	107. 53	χ Leonis	4·7	11. 0. 19·427	− 0·008	82. 10
ε Orionis	1·8	5. 31. 35·718	− 0·010	91. 16	δ Leonis	2·8	11. 9. 16·245	− 0·015	68. 59
α Columbæ	2·7	5. 36. 21·200	− 0·030	124. 7	δ Crateris	3·9	11. 14. 47·409	+ 0·012	104. 17
κ Orionis	2·2	5. 43. 26·414	− 0·014	99. 42	τ Leonis	5·1	11. 23. 15·470	0·000	86. 39
α Orionis	1·4	5. 50. 14·708	+ 0·008	82. 37	υ Leonis	4·5	11. 32. 17·365	− 0·004	90. 19
1 Geminorum	4·3	5. 58. 35·311	− 0·015	66. 44	β Leonis	2·2	11. 44. 25·149	− 0·003	74. 55
ν Orionis	4·4	6. 2. 22·551	− 0·048	75. 13	β Virginis	3·7	11. 45. 57·312	+ 0·003	87. 43
η Geminorum	3·2	6. 9. 23·078	− 0·039	67. 28	π Virginis	4·4	11. 56. 12·612	+ 0·026	82. 53
μ Geminorum	3·2	6. 17. 27·322	− 0·018	67. 26	o Virginis	4·3	12. 0. 34·462	+ 0·011	80. 46
β Canis Majoris	2·0	6. 18. 41·511	− 0·012	107. 55	ε Corvi	3·1	12. 5. 26·557	− 0·002	112. 7
ν Geminorum	4·0	6. 23. 33·609	+ 0·008	69. 44	Bradley 1672	6·3	12. 14. 26·101	+ 0·460	1. 48
γ Geminorum	2·0	6. 32. 27·329	+ 0·002	73. 31	η Virginis	4·0	12. 15. 14·999	− 0·014	90. 10
ξ Geminorum	3·4	6. 40. 10·935	− 0·014	77. 0	δ^2 Corvi	3·0	12. 25. 9·223	− 0·034	106. 1
θ Canis Majoris	4·2	6. 49. 57·701	− 0·043	101. 55	β Corvi	2·8	12. 29. 36·271	+ 0·027	112. 54
ε Canis Majoris	1·5	6. 55. 2·943	− 0·015	118. 51	ρ Virginis	5·1	12. 37. 16·736	− 0·015	79. 16
Cephei 51	5·3	6. 58. 10·130	+ 0·394	2. 48	35 Virginis	6·9	12. 43. 13·393	− 0·004	85. 56
ζ Geminorum	3·7	6. 58. 42·734	− 0·028	69. 18	31 Comæ	5·0	12. 47. 16·038	+ 0·024	61. 58
γ Canis Majoris	4·1	6. 59. 38·471	− 0·031	105. 30	δ Virginis	3·7	12. 51. 1·155	+ 0·012	86. 6
51 Geminorum	5·4	7. 8. 8·799	− 0·033	73. 41	ε Virginis	3·0	12. 57. 38·835	+ 0·013	78. 33
δ Geminorum	3·2	7. 14. 41·357	− 0·035	67. 51	θ Virginis	4·4	13. 5. 14·210	− 0·001	95. 3
β Canis Minoris	3·1	7. 22. 12·996	− 0·009	81. 32	Spica	1·2	13. 20. 23·847	+ 0·012	100. 41
Castor	2·7	7. 28. 47·756	+ 0·021	57. 55	ζ Virginis	3·5	13. 30. 3·317	+ 0·017	90. 8
Procyon	0·5	7. 34. 32·322	+ 0·021	84. 32	*m* Virginis	5·3	13. 36. 50·053	+ 0·012	98. 15
Pollux	1·1	7. 39. 44·970	+ 0·009	61. 45	τ Boötis	4·5	13. 42. 56·286	+ 0·022	72. 5
ξ Argûs	3·4	7. 45. 28·000	− 0·026	114. 38	η Boötis	2·9	13. 50. 21·110	− 0·004	71. 9
6 Cancri	5·0	7. 57. 55·868	− 0·046	61. 57	τ Virginis	4·4	13. 57. 0·852	− 0·007	88. 1
ρ Argûs	2·9	8. 3. 40·101	+ 0·001	114. 2	94 Virginis	6·8	14. 1. 28·536	+ 0·016	98. 27
Groomb. 1119	7·1	8. 7. 38·453	− 0·213	1. 6	κ Virginis	4·3	14. 8. 2·372	− 0·011	99. 51
β Cancri	3·8	8. 11. 34·881	+ 0·012	80. 32	Arcturus	0·0	14. 11. 30·629	+ 0·012	70. 21
d^1 Cancri	5·9	8. 18. 9·296	− 0·006	71. 23	*f* Boötis	5·4	14. 22. 13·383	+ 0·001	70. 22
η Cancri	5·5	8. 27. 26·903	− 0·009	69. 15	ρ Boötis	3·6	14. 27. 54·515	− 0·001	59. 14
γ Cancri	4·8	8. 38. 1·331	− 0·006	68. 12	ϵ^2 Boötis	3·0	14. 41. 0·790	+ 0·018	62. 33

Assumed Mean Right Ascensions of Clock Stars and Circumpolar Stars, with the Corrections to the R.A. of the Nautical Almanac, for 1909·0—continued.

Star's Name.	Mag.	Assumed Mean R.A. 1909·0.	Correction to N.A.	Approx. N.P.D.	Star's Name.	Mag.	Assumed Mean R.A. 1909·0.	Correction to N.A.	Approx. N.P.D.
		h m s	s	° ′			h m s	s	° ′
α Libræ	3·0	14. 45. 50·494	− 0·006	105. 40	μ Aquilæ	4·7	19. 29. 38·654	− 0·010	82. 49
ξ^2 Libræ	5·8	14. 51. 49·695	+ 0·016	101. 3	h^2 Sagittarii	4·6	19. 31. 10·273	+ 0·040	115. 5
ψ Boötis	4·5	15. 0. 32·782	+ 0·010	62. 42	e^1 Sagittarii	5·6	19. 35. 30·659	+ 0·003	106. 30
Groomb. 2283	7·1	15. 6. 18·428	− 0·075	2. 25	γ Aquilæ	2·8	19. 41. 56·020	+ 0·018	79. 37
ι^1 Libræ	4·9	15 7. 1·875	− 0·007	109. 27	α Aquilæ	1·0	19. 46. 20·618	+ 0·011	81. 22
β Libræ	2·7	15. 12. 6·488	− 0·008	99. 3	β Aquilæ	4·0	19. 50. 50·611	+ 0·010	83. 49
o^2 Libræ	6·3	15. 17. 57·113	− 0·001	104. 49	c Sagittarii	4·7	19. 57. 3·885	+ 0·024	117. 58
ζ^1 Libræ	6·2	15. 23. 7·318	− 0·008	106. 24	θ Aquilæ	3·4	20. 6. 36·619	+ 0·016	91. 6
α Coronæ	2·4	15. 30. 50·090	+ 0·013	62. 59	α^2 Capricorni	3·8	20. 13. 0·407	+ 0·006	102. 50
α Serpentis	2·7	15. 39. 47·099	+ 0·020	83. 17	β Capricorni	3·4	20. 15. 53·998	− 0·013	105. 4
ε Serpentis	3·7	15. 46. 16·727	+ 0·008	85. 15	ρ Capricorni	5·0	20. 23. 40·303	+ 0·012	108. 7
γ Serpentis	4·0	15. 52. 14·941	− 0·009	74. 3	ε Delphini	4·1	20. 28. 51·938	− 0·008	79. 0
β^1 Scorpii	2·0	16. 0. 8·595	+ 0·021	109. 33	α Delphini	4·0	20. 35. 24·680	− 0·013	74. 25
δ Ophiuchi	2·8	16. 9. 34·518	− 0·008	93. 28	ε Aquarii	3·8	20. 42. 45·079	+ 0·021	99. 50
γ Herculis	3·8	16. 17. 54·317	+ 0·004	70. 38	μ Aquarii	4·8	20. 47. 44·812	+ 0·009	99. 20
Antares	1·1	16. 23. 49·525	− 0·007	116. 14	32 Vulpeculæ	5·1	20. 50. 40·891	+ 0·003	62. 17
λ Ophiuchi	4·0	16. 26. 19·351	− 0·013	87. 49	θ Capricorni	4·3	21. 0. 50·002	+ 0·005	107. 36
ζ Ophiuchi	2·8	16. 32. 8·784	− 0·005	100. 23	ζ Cygni	3·5	21. 9. 3·774	+ 0·014	60. 9
ζ Herculis	3·1	16. 37. 51·354	+ 0·026	58. 14	α Equulei	4·1	21. 11. 16·519	+ 0·007	85. 8
κ Ophiuchi	3·4	16. 53. 21·618	+ 0·008	80. 29	ι Capricorni	4·4	21. 17. 10·875	− 0·021	107. 13
ε Herculis	4·0	16. 56. 48·453	+ 0·004	58. 56	Groomb. 3548	7·4	21. 17. 50·449	+ 0·259	3. 20
η Ophiuchi	2·6	17. 5. 9·469	+ 0·017	105. 37	β Aquarii	3·1	21. 26. 46·172	+ 0·010	95. 58
α^1 Herculis	3·1	17. 10. 29·854	− 0·001	75. 30	ξ Aquarii	4·8	21. 32. 54·514	− 0·009	98. 16
θ Ophiuchi	3·4	17. 16. 25·183	+ 0·015	114. 55	ε Pegasi	2·4	21. 39. 43·007	+ 0·023	80. 33
σ Ophiuchi	4·4	17. 21. 59·949	+ 0·001	85. 47	δ Capricorni	3·0	21. 42. 1·193	+ 0·010	106. 32
α Ophiuchi	2·2	17. 30. 42·593	+ 0·005	77. 22	16 Pegasi	5·0	21. 48. 55·255	− 0·001	64. 30
β Ophiuchi	2·9	17. 38. 58·605	− 0·005	85. 24	α Aquarii	3·2	22. 1. 6·648	+ 0·010	90. 46
μ Herculis	3·5	17. 42. 53·784	− 0·013	62. 14	ι Pegasi	4·0	22. 2. 46·439	− 0·007	65. 6
89 Herculis	5·6	17. 51. 44·904	− 0·041	63. 56	θ Aquarii	4·3	22. 12. 1·980	+ 0·024	98. 14
δ Ursæ Minoris	4·3	18. 1. 37·685	+ 0·396	3. 23	γ Aquarii	4·1	22. 16. 57·400	+ 0·008	91. 51
72 Ophiuchi	3·8	18. 3. 2·125	+ 0·023	80. 27	σ Aquarii	4·8	22. 25. 49·937	− 0·035	101. 9
μ Sagittarii	4·1	18. 8. 19·268	+ 0·021	111. 5	η Aquarii	4·2	22. 30. 40·844	+ 0·006	90. 35
η Serpentis	3·4	18. 16. 36·051	+ 0·025	92. 55	ζ Pegasi	3·6	22. 36. 55·387	− 0·008	79. 39
λ Sagittarii	3·1	18. 22. 21·271	− 0·019	115. 28	μ Pegasi	3·7	22. 45. 36·595	− 0·010	65. 53
α Lyræ	0·2	18. 33. 51·425	− 0·019	51. 18	λ Aquarii	3·8	22. 47. 52·075	+ 0·011	98. 4
2 Aquilæ	4·8	18. 37. 17·493	− 0·031	99. 8	Fomalhaut	1·3	22. 52. 37·514	+ 0·036	120. 6
β^1 Lyræ	3·4	18. 46. 43·214	+ 0·013	56. 45	α Pegasi	2·6	23. 0. 13·624	+ 0·011	75. 17
ε Aquilæ	4·1	18. 55. 29·544	+ 0·019	75. 3	γ Piscium	3·8	23. 12. 26·867	+ 0·011	87. 13
ζ Aquilæ	3·1	19. 1. 13·668	+ 0·025	76. 16	κ Piscium	5·0	23. 22. 16·045	− 0·013	89. 15
ψ Sagittarii	5·2	19. 9. 57·716	+ 0·030	115. 25	Bradley 3147	5·6	23. 27. 47·036	+ 0·950	3. 12
λ Ursæ Minoris	6·5	19. 12. 9·001	+ 0·434	1. 0	ι Piscium	4·3	23. 35. 16·161	+ 0·010	84. 52
ω Aquilæ	5·1	19. 13. 32·720	+ 0·011	78. 34	δ Sculptoris	4·6	23. 44. 11·298	+ 0·082	118. 38
δ Aquilæ	3·5	19. 20. 54·634	+ 0·015	87. 4	ω Piscium	4·2	23. 54. 38·262	0·000	83. 38
α Vulpeculæ	4·7	19. 24. 55·136	+ 0·025	65. 31	2 Ceti	4·6	23. 59. 4·749	+ 0·013	107. 51

NOTE.—The Right Ascensions are deduced from the "Standard Mean Right Ascensions of Clock Stars for 1900·0 based on Twelve-hour Groups," printed at the end of the *Introduction to the Second Nine-Year Catalogue for* 1900. The values of the Precession and Proper Motions are taken from Prof. Newcomb's *Catalogue of Fundamental Stars.*

The correction to the R.A. of Procyon for the effect of orbital motion from 1900 (the epoch of the *Nine-Year Catalogue*) to 1909·0 is −0s·091. This correction is derived from Prof. Auwers' "Elements" (*Astronomische Nachrichten*, Nos. 1371, 1372, 1373).

The Right Ascensions of the *Nautical Almanac* for 1909·0 are derived from Prof. Newcomb's *Catalogue of Fundamental Stars.*

The following table gives the personal equations for chronographic transits derived from observations made in 1909 :—

W − S E = + $0^s \cdot 06$	W − H F = + $0^s \cdot 04$	W − B E = − $0^s \cdot 15$	W − G C = + $0^s \cdot 16$
W − A C = + 0·03	W − W S = − 0·04	W − S D = − 0·03	W − A W = + 0·13
W − B = + 0·05	W − E = − 0·06	W − S = − 0·01	W − R = + 0·04
W − W B = + 0·15	W − R C = − 0·15	W − H A = + 0·25	W − J = + 0·02

The following table gives the comparison of the clock errors deduced from eye-and-ear transits with those deduced from the chronographic transits by the same observer, these latter being referred to the Standard Observer, Mr. Witchell (W_0), by applying the personal equations for chronographic transits found from the observations of 1909 :—

W_0 − W = −$0^s \cdot 04$	W_0 − E = −$0^s \cdot 03$	W_0 − S D = +$0^s \cdot 06$	W_0 − G C = +$0^s \cdot 02$
W_0 − W S = −0·07	W_0 − R C = −0·15	W_0 − H A = +0·11	

Comparisons of Clock Errors at 0^h Sidereal referred to the Standard Observer, from Observations with the Transit-Circle with Central and with Annular Illumination.

Date.		Observer.	Clock Error. Central Illumination.	Clock Error. Annular Illumination.	Central. — Annular.	Date.		Observer.	Clock Error. Central Illumination.	Clock Error. Annular Illumination.	Central. — Annular.
1909.			s	s	s	1909.			s	s	s
Jan.	8	R C	−62·30	−62·30	0·00	Apr.	23	R C	−22·67	−22·65	− 0·02
	11	S D	− 2·70	− 2·72	+ 0·02	May	4	R C	−24·84	−24·77	− 0·07
	11	R C	− 2·72	− 2·71	− 0·01		29	W	−30·26	−30·20	− 0·06
	13	G C	− 3·12	− 3·09	− 0·03	June	30	W	−39·58	−39·53	− 0·05
	16	R C	− 3·42	− 3·42	0·00	July	1	B E	−39·85	−39·85	0·00
	18	G C	− 3·86	− 3·89	+ 0·03		12	W	−43·86	−43·85	− 0·01
	19	E	− 3·88	− 3·86	− 0·02		19	R C	−46·37	−46·35	− 0·02
	25	W	− 5·43	− 5·44	+ 0·01		20	W	−46·80	−46·75	− 0·05
Feb.	1	R C	− 7·34	− 7·30	− 0·04	Aug.	3	E	−52·39	−52·44	+ 0·05
	5	R C	− 7·86	− 7·84	− 0·02		21	W	−59·43	−59·37	− 0·06
	6	W	− 8·14	− 8·09	− 0·05		28	R C	− 4·35	− 4·30	− 0·05
	8	G C	− 8·58	− 8·56	− 0·02		31	E	− 5·46	− 5·46	0·00
	8	R C	− 8·40	− 8·39	− 0·01	Sept.	1	R C	− 6·94	− 6·84	− 0·10
	12	G C	− 9·32	− 9·25	− 0·07		9	R C	−11·93	−11·90	− 0·03
	12	R C	− 9·19	− 9·20	+ 0·01		18	W	−17·71	−17·68	− 0·03
	13	S D	− 9·48	− 9·53	+ 0·05		23	W	−21·34	−21·35	+ 0·01
	17	R C	−10·29	−10·22	− 0·07	Oct.	19	R C	−38·91	−38·89	− 0·02
	18	H A	−10·61	−10·61	0·00		21	B E	−41·11	−41·12	+ 0·01
	19	W	−10·66	−10·64	− 0·02	Nov.	5	B E	−49·40	−49·33	− 0·07
	20	E	−10·93	−10·89	− 0·04		8	R C	−48·01	−47·99	− 0·02
Mar.	4	E	−13·45	−13·45	0·00		13	W	−45·68	−45·66	− 0·02
	8	E	−14·20	−14·16	− 0·04		15	E	−45·20	−45·16	− 0·04
Apr.	1	E	−18·27	−18·21	− 0·06		22	B E	−42·10	−42·10	0·00
	2	R C	−18·35	−18·35	0·00	Dec.	3	S E	−38·18	−38·16	− 0·02
	6	R C	−19·24	−19·23	− 0·01						
	9	R C	−19·86	−19·82	− 0·04						

The central illumination with compound corrected lens inserted on 1908 September 17 has been in use throughout the year. The correction to the clock error with the annular illumination from the mean of 50 observations is $-^s \cdot 022$.

Errors of Division.

In use from 1897.

The following table contains the adopted result for errors of division for every degree. The errors are always considered in the nature of reading too much. $1^r = 61''\cdot4$ nearly.

Degree.	Excess of Reading.	Degree.	Excess of Reading.	Degree.	Excess of Reading.	Degree.	Excess of Reading.	Degree.	Excess of Reading.	Degree.	Excess of Reading.	Degree.	Excess of Reading.	Degree.	Excess of Reading.	Degree.	Excess of Reading.	Degree.	Excess of Reading.
°	r	°	r	°	r	°	r	°	r	°	r	°	r	°	r	°	r	°	r
0	0·051	36	0·054	72	0·053	108	0·059	144	0·087	180	0·067	216	0·064	252	0·075	288	0·073	324	0·081
1	·049	37	·050	73	·049	109	·065	145	·084	181	·069	217	·064	253	·078	289	·078	325	·082
2	·047	38	·047	74	·048	110	·059	146	·079	182	·069	218	·064	254	·082	290	·077	326	·082
3	·051	39	·050	75	·053	111	·056	147	·089	183	·067	219	·064	255	·085	291	·080	327	·077
4	·051	40	·051	76	·056	112	·059	148	·089	184	·067	220	·063	256	·089	292	·081	328	·081
5	·049	41	·051	77	·052	113	·060	149	·089	185	·061	221	·062	257	·088	293	·079	329	·085
6	·053	42	·056	78	·053	114	·067	150	·084	186	·056	222	·063	258	·090	294	·088	330	·080
7	·052	43	·055	79	·054	115	·066	151	·083	187	·059	223	·064	259	·089	295	·092	331	·077
8	·055	44	·049	80	·060	116	·071	152	·086	188	·063	224	·063	260	·096	296	·087	332	·078
9	·056	45	·045	81	·063	117	·071	153	·090	189	·063	225	·062	261	·103	297	·085	333	·083
10	·052	46	·050	82	·067	118	·070	154	·096	190	·053	226	·065	262	·099	298	·081	334	·091
11	·052	47	·057	83	·068	119	·074	155	·100	191	·049	227	·071	263	·106	299	·085	335	·082
12	·053	48	·060	84	·070	120	·082	156	·096	192	·056	228	·069	264	·108	300	·096	336	·082
13	·052	49	·058	85	·069	121	·088	157	·082	193	·061	229	·071	265	·105	301	·097	337	·075
14	·057	50	·052	86	·070	122	·090	158	·075	194	·058	230	·071	266	·107	302	·093	338	·072
15	·047	51	·050	87	·073	123	·095	159	·078	195	·057	231	·071	267	·108	303	·096	339	·071
16	·046	52	·055	88	·072	124	·099	160	·080	196	·058	232	·078	268	·104	304	·101	340	·075
17	·044	53	·065	89	·069	125	·092	161	·078	197	·054	233	·082	269	·099	305	·097	341	·069
18	·050	54	·065	90	·068	126	·095	162	·075	198	·057	234	·081	270	·098	306	·102	342	·075
19	·050	55	·071	91	·067	127	·095	163	·075	199	·064	235	·080	271	·094	307	·102	343	·069
20	·052	56	·071	92	·072	128	·093	164	·082	200	·060	236	·076	272	·085	308	·099	344	·062
21	·043	57	·069	93	·069	129	·091	165	·088	201	·061	237	·080	273	·085	309	·093	345	·068
22	·043	58	·072	94	·071	130	·088	166	·088	202	·062	238	·085	274	·083	310	·092	346	·064
23	·046	59	·071	95	·069	131	·094	167	·079	203	·064	239	·093	275	·092	311	·099	347	·062
24	·044	60	·067	96	·067	132	·089	168	·070	204	·063	240	·091	276	·090	312	·098	348	·062
25	·045	61	·063	97	·064	133	·085	169	·063	205	·063	241	·089	277	·095	313	·097	349	·058
26	·050	62	·061	98	·071	134	·085	170	·062	206	·062	242	·084	278	·105	314	·097	350	·052
27	·048	63	·060	99	·077	135	·084	171	·065	207	·063	243	·093	279	·098	315	·090	351	·054
28	·045	64	·065	100	·074	136	·087	172	·058	208	·061	244	·095	280	·092	316	·090	352	·052
29	·049	65	·061	101	·071	137	·092	173	·055	209	·063	245	·092	281	·090	317	·090	353	·052
30	·059	66	·059	102	·071	138	·087	174	·053	210	·072	246	·089	282	·093	318	·091	354	·047
31	·064	67	·054	103	·070	139	·082	175	·056	211	·075	247	·082	283	·095	319	·083	355	·045
32	·061	68	·052	104	·069	140	·081	176	·066	212	·070	248	·071	284	·092	320	·087	356	·048
33	·063	69	·057	105	·062	141	·082	177	·070	213	·067	249	·075	285	·086	321	·079	357	·055
34	·059	70	·058	106	·063	142	·085	178	·071	214	·063	250	·082	286	·084	322	·078	358	·052
35	·052	71	·056	107	·058	143	·090	179	·067	215	·060	251	·078	287	·076	323	·087	359	·050

Division-Correction.

Applicable to Observations made with the six Microscopes.

(*Always Additive.*)

In use from 1897.

The corrections recur after every 60° of pointer reading.

Pointer Reading.	Corr.	Pointer Reading.	Corr.	Pointer Reading.	Corr.	Pointer Reading.	Corr.	Pointer Reading.	Corr.	Pointer Reading.	Corr.
° °	″	° °	″	° °	″	° °	″	° °	″	° °	″
0– 1	0·25	10–11	0·56	20–21	1·06	30–31	0·31	40–41	0·57	50–51	0·50
1– 2	0·28	11–12	0·54	21–22	0·99	31–32	0·32	41–42	0·59	51–52	0·43
2– 3	0·26	12–13	0·57	22–23	0·91	32–33	0·22	42–43	0·59	52–53	0·31
3– 4	0·24	13–14	0·65	23–24	0·82	33–34	0·16	43–44	0·60	53–54	0·29
4– 5	0·28	14–15	0·72	24–25	0·73	34–35	0·31	44–45	0·67	54–55	0·35
5– 6	0·35	15–16	0·73	25–26	0·64	35–36	0·32	45–46	0·61	55–56	0·32
6– 7	0·46	16–17	0·80	26–27	0·56	36–37	0·39	46–47	0·60	56–57	0·29
7– 8	0·49	17–18	0·88	27–28	0·50	37–38	0·47	47–48	0·59	57–58	0·29
8– 9	0·47	18–19	0·95	28–29	0·42	38–39	0·51	48–49	0·56	58–59	0·28
9–10	0·48	19–20	1·10	29–30	0·29	39–40	0·58	49–50	0·47	59–60	0·22

When the Pointer reads 0°.30′ the division under Microscope A is 271° ; under Microscope C, 211° ; under Microscope E, 151° ; under Microscope B, 91° ; under Microscope D, 31° ; and under Microscope F, 331°.

The above table of division-errors is a slight modification of that published and used in the second *Ten Year Catalogue*, 1890, owing to the incorporation at a later date of the results of a special examination of the single degree divisions for five degrees on either side of the pole corresponding to pointer readings 14°–24°.

The corrections for division-errors with the transit-circle have been changed four times since its erection ; from 1851 to 1856 the values were derived from the observations made in 1851 ; from 1857 to 1867 the values were derived from the observations made in 1856 ; from 1868 to 1879 the values were derived by taking the mean of the observations made in 1851 and 1856 ; from 1880 to 1896 the last values were still used, but in order to allow for the distance between Microscope A and the pointer being 89°.30′ instead of 90°, as it had till then been assumed to be, what had been taken as the correction for 1°—that was, for all pointer readings between 0°.30′ and 1°.30′—was considered to be the correction for all pointer readings between 0° and 1°, and so on. An account of the determination of the errors is given in the *Introduction* for 1897, and also tables of the differences of the values now used (resulting from the determinations in 1851, 1856, and 1898) and the values adopted in previous years.

Table of Corrections for 5′ Divisions.

FOR NADIR.

Pointer Reading ...	179° 30′	35′	40′	45′	50′	55′	180° 0′	5′	10′	15′	20′	25′	30′	No. of Sets.
Division-Correction	0″·22	0″·30	0″·35	0″·38	0″·40	0″·45	0″·45	0″·41	0″·38	0″·32	0″·29	0″·26	0″·25	10

FOR COLLIMATORS.

Pointer Reading	89° 30′ or 269·30	35′	40′	45′	50′	55′	90° 0′ or 270·0	5′	10′	15′	20′	25′	30′	No. of Sets.
Division-Correction	0″·29	0″·28	0″·38	0″·40	0″·41	0″·43	0″·46	0″·50	0″·43	0″·34	0″·26	0″·19	0″·24	10

FOR POLAR STARS.

Pointer Reading ...	317° 30′	35′	40′	45′	50′	55′	318° 0′	5′	10′	15′	20′	25′	30′	No. of Sets.
Division-Correction	0″·88	0″·98	1″·03	1″·04	1″·07	1″·12	1″·14	1″·11	1″·03	0″·94	0″·91	0″·92	0″·95	9

Pointer Reading ...	319° 30′	35′	40′	45′	50′	55′	320° 0′	5′	10′	15′	20′	25′	30′	No. of Sets.
Division-Correction	1″·10	1″·09	1″·14	1″·13	1″·09	1″·05	1″·03	1″·06	1″·09	1″·11	1″·15	1″·15	1″·06	14

Pointer Reading ...	321° 30′	35′	40′	45′	50′	55′	322° 0′	5′	10′	15′	20′	25′	30′	No. of Sets.
Division-Correction	0″·99	1″·06	1″·02	0″·99	1″·01	1″·02	1″·02	1″·03	1″·02	0″·99	0″·94	0″·92	0″·91	18

Pointer Reading ...	322° 30′	35′	40′	45′	50′	55′	323° 0′	5′	10′	15′	20′	25′	30′	No. of Sets.
Division-Correction	0″·91	0″·98	0″·97	0″·90	0″·87	0″·92	0″·98	1″·00	1″·02	0″·99	0″·92	0″·86	0″·82	4

Pointer Reading ...	323° 30′	35′	40′	45′	50′	55′	324° 0′	5′	10′	15′	20′	25′	30′	No. of Sets.
Division-Correction	0″·82	0″·74	0″·77	0″·82	0″·82	0″·81	0″·83	0″·83	0″·77	0″·73	0″·73	0″·76	0″·73	9

Observations to determine the Astronomical Flexure of the Transit-Circle, 1909.

Date.	Observer.	Reader of Micro-scopes.	Mean Concluded Circle-Reading.		Resulting Correction for Astronomical Horizontal Flexure.	Temperature.
			North Collimator.	South Collimator.		
1909. d h						
July 21. 4	B E	B E	269° 37′ 16″·97	89° 37′ 16″·94	+ ″·02	66°·3
November 11. 4	B E	B E	16·83	17·78	− ·48	45·3

The mean of these observations gives the value of $-0''\cdot23$ for the Astronomical flexure.

The observations for coincidence of the north and south collimator wires were in every case made through the openings in the central cube of the transit-circle.

The observations for flexure were made by bringing the zenith distance micrometer wire into contact above and below with the single horizontal wires of the collimators.

No correction for flexure has been applied since April 1879.

Excess of Reflexion Results above Direct Results, for Observations of Zenith-Distances with the Transit-Circle, 1909.

In this table the reflexion observations are not corrected for inclination of the vertical at the surface of the mercury to that at the centre of the instrument.

Star's Name.	Approximate R.A.	Approximate N.P.D.	R—D.	No. of Obs. R. and D.	Weight.	Star's Name.	Approximate R.A.	Approximate N.P.D.	R—D.	No. of Obs. R. and D.	Weight.
	h m	°	″				h m	°	″		
o Ursæ Majoris S.P.	8. 23	− 29. 0	−0·74	2	2	ι Cephei S.P.	22. 46	− 24. 3	−0·97	2	2
η Cephei S.P.	20. 43	− 28. 5	+0·08	1	1	Bradley 1429 S.P.	10. 18	− 24. 0	−0·71	1	1
α Ursæ Majoris S.P.	10. 58	− 27. 8	−1·50	1	1	α Camelopardi S.P.	4. 45	− 23. 8	−1·55	4	3
20 Cephei S.P.	22. 2	− 27. 6	−2·21	1	1	Bradley 366 S.P.	2. 37	− 22. 6	−0·87	1	1
θ Cephei S.P.	20. 28	− 27. 3	−0·45	1	1	ω Cassiopeiæ S.P.	13. 36	− 22. 4	−1·55	2	2
Groombridge 716 S.P.	3. 34	− 27. 1	−1·41	2	2	Groombridge 2214 S.P.	15. 14	− 22. 3	−1·49	2	2
30 Cephei S.P.	20. 35	− 26. 9	−1·08	3	3						
ε Cassiopeiæ S.P.	13. 48	− 26. 8	−0·60	3	3	ω Draconis S.P.	17. 38	− 21. 2	−0·19	1	1
53 Cassiopeiæ S.P.	13. 56	− 26. 0	−1·43	1	1	Piazzi V. 335 S.P.	6. 9	− 20. 6	−1·33	1	1
19 Camelopardi S.P.	5. 29	− 25. 9	−1·96	1	1	Piazzi X. 126 S.P.	10. 37	− 20. 4	−2·54	1	1
36 Draconis S.P.	18. 13	− 25. 6	−3·24	1	1	Groombridge 1564 S.P.	9. 35	− 20. 3	+0·13	1	1
						λ Draconis S.P.	11. 26	− 20. 2	−1·26	1	1
α Draconis S.P.	14. 2	− 25. 2	−0·18	1	1	ε Draconis S.P.	19. 48	− 20. 0	+0·40	1	1
i Draconis S.P.	13. 49	− 24. 8	−0·63	1	1	11 Cephei S.P.	21. 41	− 19. 1	−1·58	2	2
Bradley 448 S.P.	3. 12	− 24. 7	−1·28	1	1	Bradley 2854 S.P.	21. 38	− 19. 1	−1·24	1	1
32 Ursæ Majoris S.P.	10. 12	− 24. 4	−2·52	1	1	γ Camelopardi S.P.	3. 41	− 18. 9	−2·24	1	1

Excess of Reflexion Results above Direct Results, for Observations of Zenith-Distances with the Transit-Circle, 1909—continued.

Star's Name.	Approximate R.A.	Approximate N.P.D.	R—D.	No. of Obs. R. and D.	Weight.	Star's Name.	Approximate R.A.	Approximate N.P.D.	R—D.	No. of Obs. R. and D.	Weight.
	h m	°	″				h m	°	″		
24 Cephei S.P.	22. 8	− 18. 1	+0·02	1	1	Lalande F. 693	5. 0	4. 1	−0·15	1	1
50 Cassiopeiæ S.P.	13. 56	− 18. 0	−0·66	1	1	2 Ursæ Minoris	0. 56	4. 2	+0·48	1	1
Bradley 2673 S.P.	20. 30	− 17. 8	+0·11	2	2	Groombridge 944	5. 33	4. 8	+0·28	2	2
						Bradley 1399	10. 17	5. 3	−0·10	3	3
16 Cephei S.P.	21. 58	− 17. 3	−1·06	1	1	Bradley 3058	22. 55	6. 1	−0·40	1	1
τ Draconis S.P.	19. 17	− 16. 8	−1·26	1	1						
79 Draconis S.P.	21. 52	− 16. 7	−0·03	2	2	Piazzi X. 22	10. 22	7. 0	+0·91	1	1
Piazzi IX. 187 S.P.	9. 50	− 16. 7	−1·09	2	2	ε Ursæ Minoris	16. 55	7. 8	−0·30	2	2
Piazzi IV. 207 S.P.	4. 53	− 16. 1	−0·17	2	2	76 Draconis	20. 49	7. 8	−0·81	1	1
Groombridge 1446 S.P.	8. 30	− 16. 0	−0·59	2	2	Bradley 344	2. 35	8. 9	−0·07	1	1
50 Draconis S.P.	18. 49	− 14. 7	−1·82	1	1						
5 Ursæ Minoris S.P.	14. 28	− 13. 9	−3·76	1	1	Piazzi IV. 269	5. 8	10. 9	+0·44	1	1
						Bradley 1508	10. 53	11. 7	−0·47	1	1
γ Cephei S.P.	23. 36	− 12. 9	+0·38	1	1	77 Draconis	21. 7	12. 2	+0·03	2	2
κ Cephei S.P.	20. 12	− 12. 6	−0·02	2	2	Piazzi XVI. 195	16. 35	12. 4	−0·93	1	1
Bradley 431 S.P.	3. 9	− 12. 6	+0·01	1	1	Bradley 431	3. 9	12. 6	−0·85	1	1
Groombridge 1852 S.P.	12. 1	− 12. 6	−1·86	1	1	Bradley 6	0. 11	13. 5	+0·52	1	1
77 Draconis S.P.	21. 7	− 12. 3	+0·59	1	1	Bradley 1446	10. 27	13. 8	−0·51	1	1
θ Ursæ Minoris S.P.	15. 34	− 12. 3	−0·45	1	1	19 Ursæ Minoris	16. 13	13. 9	−0·68	1	1
4 Ursæ Minoris S.P.	14. 9	− 12. 0	+0·47	2	2	Groombridge 3834	22. 31	14. 2	−2·28	1	1
Piazzi IV. 269 S.P.	5. 8	− 10. 9	−0·22	2	2						
Bradley 117 S.P.	1. 4	− 10. 8	+0·42	1	1	Groombridge 966	5. 28	15. 0	−0·57	1	1
						73 Draconis	20. 33	15. 3	+0·05	1	1
Piazzi IX. 37 S.P.	9. 24	− 8. 3	+0·01	1	1	16 Cephei	21. 58	17. 2	−0·44	1	1
76 Draconis S.P.	20. 49	− 7. 8	−1·81	1	1	χ Draconis	18. 23	17. 3	−0·20	1	1
ε Ursæ Minoris S.P.	16 55	− 7. 8	−0·32	1	1	γ Ursæ Minoris	15. 21	17. 8	+0·27	1	1
						50 Cassiopeiæ	1. 56	18. 0	+0·79	1	1
Groombridge 1418 S.P.	8. 28	− 4. 6	+0·22	1	1	24 Cephei	19. 50	18. 1	−0·39	2	2
2 Ursæ Minoris S.P.	0. 56	− 4. 2	+0·01	1	1						
Lalande F. 693 S.P.	5. 0	− 4. 2	−0·35	1	1	14 Pegasi	21. 46	60. 2	+0·76	1	1
Groombridge 3548 S.P.	21. 18	− 3. 4	+0·26	1	1	ξ Herculis	17. 54	60. 7	+0·39	1	1
δ Ursæ Minoris S.P.	18. 1	− 3. 4	−0·57	1	1	α Trianguli	1. 48	60. 8	+0·31	1	1
Bradley 3147 S.P.	23. 28	− 3. 2	−0·27	1	1	W. B. (2) V. 207	5. 12	61. 2	+0·81	1	1
Cephei 51 S.P.	6. 59	− 2. 8	−0·68	3	3	α Andromedæ	0. 4	61. 4	−0·10	1	1
Groombridge 2283 S.P.	15. 6	− 2. 4	−1·11	2	2	β Tauri	5. 21	61. 4	+0·59	1	1
						Pollux	7. 40	61. 7	+0·26	2	2
Polaris S.P.	1. 27	− 1. 2	−1·01	2	2	μ Herculis	17. 43	62. 2	+0·32	1	1
Groombridge 1119 S.P.	8. 9	− 1. 1	−0·72	1	1	32 Vulpeculæ	20. 51	62. 3	−0·13	1	1
λ Ursæ Minoris S.P.	19. 11	− 1. 0	+0·15	1	1						
λ Ursæ Minoris	19. 11	1. 0	+0·38	4	3						
Groombridge 1119	8. 9	1. 1	−0·47	3	3	ψ Boötis	15. 1	62. 7	−0·79	1	1
Polaris	1. 27	1. 2	+0·43	1	1	α Coronæ	15. 31	62. 9	+0·25	1	1
Bradley 1672	12. 14	1. 8	+0·02	1	1	μ Leonis	9. 48	63. 5	+0·72	1	1
Groombridge 2283	15. 6	2. 4	−0·43	2	2	89 Herculis	17. 52	63. 9	+0·75	1	1
						87 Herculis	17. 45	64. 3	+0·20	1	1
Cephei 51	6. 59	2. 8	−0·76	3	3	16 Pegasi	21. 49	64. 5	+1·61	1	1
Bradley 3147	23. 28	3. 2	−0·39	1	1	κ Pegasi	21. 41	64. 7	+0·21	1	1
Groombridge 3548	21. 18	3. 3	+0·27	3	3	ι Pegasi	22. 3	65. 1	−0·37	1	1
δ Ursæ Minoris	18. 1	3. 4	−0·73	1	1	α Vulpeculæ	19. 25	65. 5	+0·05	1	1

Excess of Reflexion Results above Direct Results, for Observations of Zenith-Distances with the Transit-Circle, 1909—continued.

Star's Name.	Approximate R.A.	Approximate N.P.D.	R—D.	No. of Obs. R. and D.	Weight.
	h m	°	″		
62 Tauri	4. 19	65. 9	+0·51	1	1
η Tauri	3. 42	66. 1	−0·34	1	1
41 Leonis Minoris	10. 39	66. 3	+0·42	1	1
α Arietis	2. 2	66. 9	+0·79	1	1
μ Geminorum	6. 18	67. 4	+1·95	1	1
γ Cancri	8. 38	68. 2	+0·23	2	2
β Herculis	16. 26	68. 3	−0·17	2	2
δ Leonis	11. 9	68. 9	+0·05	2	2
28 Pegasi	22. 6	69. 4	−0·09	1	1
ι Serpentis	15. 38	70. 0	−0·84	1	1
1 Pegasi	21. 18	70. 5	−0·03	3	3
γ Herculis	16. 18	70. 6	+0·07	1	1
15 Arietis	2. 6	70. 9	+1·38	1	1
θ Cancri	8. 26	71. 6	−0·50	1	1
τ Boötis	13. 43	72. 1	−0·15	1	1
130 Tauri	5. 42	72. 3	+0·89	1	1
κ Herculis	16. 4	72. 7	−1·71	1	1
51 Geminorum	7. 8	73. 7	+0·24	1	1
τ Serpentis	15. 22	74. 2	+1·44	2	2
α Pegasi	23. 0	75. 2	+2·39	1	1
29 Cancri	8. 24	75. 5	+0·68	1	1
α¹ Herculis	17. 11	75. 5	+0·89	3	3
20 Pegasi	21. 57	77. 3	+1·43	1	1
α Ophiuchi	17. 31	77. 3	+1·79	1	1
f Tauri	3. 26	77. 3	+1·18	1	1
Regulus	10. 4	77. 6	+0·39	1	1
31 Pegasi	22. 17	78. 2	+1·17	1	1
o Leonis	9. 36	79. 7	−0·77	1	1
S Monocerotis	6. 36	80. 0	+1·07	1	1
ε Pegasi	21. 40	80. 5	+0·58	2	2
β Canis Minoris	7. 22	81. 5	+0·27	2	2
π Leonis	9. 55	81. 5	+1·04	2	2
13 Monocerotis	6. 28	82. 6	+0·56	1	1
10 Leonis	9. 32	82. 7	+0·97	1	1
μ Aquilæ	19. 30	82. 8	+0·21	1	1
τ Aquilæ	20. 0	82. 9	+0·85	1	1
ε Hydræ	8. 42	83. 2	+0·85	1	1
ζ Hydræ	8. 51	83. 7	−0·73	1	1
σ Virginis	13. 13	84. 0	+0·66	1	1
Procyon	7. 35	84. 5	+1·06	2	2
ν Ceti	2. 31	84. 8	+1·37	2	2
α Equulei	21. 11	85. 1	+0·67	2	2
ε Serpentis	15. 46	85. 2	+1·09	1	1
β Ophiuchi	17. 39	85. 4	+0·96	2	2
σ Ophiuchi	17. 22	85. 7	+0·74	1	1
σ Hydræ	8. 34	86. 3	+1·32	1	1
α Piscium	1. 57	87. 6	+0·21	1	1
44 Piscium	0. 21	88. 5	+0·52	1	1
10 Tauri	3. 32	89. 8	+1·71	1	1
o Orionis	5. 17	90. 4	+0·32	1	1
θ Aquilæ	20. 7	91. 0	+0·14	1	1
29 Sextantis	10. 25	92. 2	+0·14	1	1
e Leonis	11. 26	92. 5	−0·20	1	1
e Aquilæ	19. 26	92. 9	+0·80	1	1
o Ceti	2. 15	93. 3	+3·09	1	1
μ Eridani	4. 41	93. 4	−0·31	1	1
6 Sextantis	9. 47	93. 8	+0·05	1	1
25 Monocerotis	7. 33	93. 9	+0·98	1	1
13 Ceti	0. 31	94. 0	+0·65	1	1
27 Piscium	23. 54	94. 0	+1·56	1	1
ε Ophiuchi	16. 14	94. 4	+3·63	1	1
θ Virginis	13. 5	95. 0	+0·71	1	1
Piazzi XXII. 250	22. 51	95. 4	+0·98	1	1
33 Hydræ	9. 30	95. 5	+0·48	1	1
β Aquarii	21. 27	95. 9	+2·31	1	1
φ Aquarii	23. 10	96. 5	+1·55	1	1
67 Ceti	2. 12	96. 8	−0·63	1	1
τ Orionis	5. 13	96. 9	+0·26	1	1
22 Sextantis	10. 13	97. 6	+1·58	1	1
λ Aquarii	22. 48	98. 0	+1·26	1	1
ξ Aquarii	21. 33	98. 2	+1·92	2	2
1 Aquilæ	18. 30	98. 3	+1·37	1	1
94 Virginis	14. 2	98. 4	+1·81	1	1
η Eridani	2. 52	99. 2	+1·21	1	1
ε Aquarii	20. 43	99. 8	+0·83	2	2
δ Eridani	3. 39	100. 0	−0·18	1	1
ζ Ophiuchi	16. 32	100. 3	+2·49	2	2
20 Ophiuchi	16. 45	100. 6	+0·94	2	2
Spica	13. 20	100. 6	+1·13	1	1
ξ² Libræ	14. 52	101. 0	+1·44	1	1
2 Libræ	14. 19	101. 2	+0·72	1	1
λ Hydræ	10. 6	101. 8	+1·08	1	1
Mayer 616	15. 19	102. 0	+2·43	2	2
6 Hydræ	8. 36	102. 1	+1·06	2	2
i Virginis	13. 22	102. 2	+1·27	1	1
ρ Ceti	2. 22	102. 6	−0·47	1	1
λ Virginis	14. 14	102. 9	+0·69	3	3
τ² Aquarii	22. 45	104. 0	+1·71	1	1
δ Crateris	11. 15	104. 2	+1·26	3	3
γ Libræ	15. 30	104. 4	+0·93	2	2

The weights used have been determined as follows:—Putting m and n for the number of reflexion and direct observations respectively, e for the probable error of one observation, e_0 for the probable systematic error affecting all observations of the same, the weight to be given to that star is proportional to $\frac{m}{me^2 + ne^2 + 2\,mne_0^2}$; or assuming $e_0^2 = \frac{1}{10}e^2$, which would make $e_0 = 0''\cdot16$, the weight becomes $\frac{4\,m}{m + n + \frac{1}{5}\,mn}$, which has been adopted. When $m = n$, the weight is proportional to $\frac{m}{10 + n}$, and $\frac{11\,m}{10 + m}$, the most convenient multiple of this, has been adopted.

Excess of Reflexion Results above Direct Results from Groups of Stars observed with the Transit-Circle.

Extent of Group, 1909.	Weight.	Mean N.P.D.	Mean Z.D. South.	Mean Value of R—D, corrected for Inclination of Verticals.	R—D computed by the Formula + 0″·080 + 1″·199 × sin Z.D.	Apparent Error of Formula.
		°	°	″	″	″
ο Ursæ Majoris S.P. to 36 Draconis S.P.	17	−27.2	−65.7	− 1·33	− 1·01	+ 0·32
α Draconis S.P. to Groombridge 2214 S.P.	15	−23.7	−62.2	− 1·40	− 0·98	+ 0·42
ω Draconis S.P. to Bradley 2673 S.P.	14	−19.3	−57.8	− 0·99	− 0·93	+ 0·06
16 Cephei S.P. to 5 Ursæ Minoris S.P.	12	−16.1	−54.6	− 1·10	− 0·90	+ 0·20
γ Cephei S.P. to Bradley 117 S.P.	12	−12.0	−50.5	− 0·16	− 0·85	− 0·69
Piazzi IX. 37 S.P. to ε Ursæ Minoris S.P.	3	− 8.0	−46.5	− 0·83	− 0·79	+ 0·04
Groomb. 1418 S.P. to Groomb. 2283 S.P.	11	− 3.3	−41.8	− 0·56	− 0·72	− 0·16
Polaris S.P. to Groombridge 2283	14	0.7	−37.8	− 0·50	− 0·66	− 0·16
Cephei 51 to Bradley 3058	16	4.0	−34.5	− 0·24	− 0·60	− 0·36
Piazzi X. 22 to Bradley 344	5	7.9	−30.6	− 0·19	− 0·53	− 0·34
Piazzi IV. 269 to Groombridge 3834	10	12.7	−25.8	− 0·54	− 0·44	+ 0·10
Groombridge 966 to 24 Cephei	8	17.1	−21.4	− 0·17	− 0·36	− 0·19
14 Pegasi to 32 Vulpeculæ	10	61.4	22.9	+ 0·41	+ 0·55	+ 0·14
ψ Boötis to 41 Leonis Minoris	12	64.6	26.1	+ 0·34	+ 0·61	+ 0·27
α Arietis to ι Serpentis	10	68.4	29.9	+ 0·28	+ 0·68	+ 0·40
1 Pegasi to τ Serpentis	12	72.0	33.5	+ 0·34	+ 0·74	+ 0·40
α Pegasi to 31 Pegasi	10	76.5	38.0	+ 1·27	+ 0·82	− 0·45
ο Leonis to π Leonis	8	80.8	42.3	+ 0·62	+ 0·89	+ 0·27
13 Monocerotis to σ Hydræ	18	84.4	45.9	+ 0·92	+ 0·94	+ 0·02
α Piscium to ο Orionis	4	89.1	50.6	+ 0·81	+ 1·01	+ 0·20
θ Aquilæ to ε Ophiuchi	11	93.2	54.7	+ 1·09	+ 1·06	− 0·03
θ Virginis to 94 Virginis	13	97.0	58.5	+ 1·32	+ 1·10	− 0·22
η Eridani to ι Virginis	17	100.9	62.4	+ 1·44	+ 1·14	− 0·30
ρ Ceti to γ Libræ	10	103.7	65.2	+ 1·04	+ 1·17	+ 0·13

In forming the mean values of R—D for groups in the last column but two of the above table, a correction of $+0''\cdot16$ sin Z.D. has been applied to the mean of each group for inclination of the vertical at the surface of the mercury used in reflexion observations to that at the centre of the transit-circle, the mercury trough being mounted so as to describe a circle of 8 feet radius.

Assuming that the R—D correction can be represented by

$$x + y \sin \text{Z.D. south},$$

it is found by calculation that the following expressions, when tabulated, will give the values which best agree with the errors in the above, namely :—

For direct observations,

$$+ 0''\cdot040 + 0''\cdot600 \sin \text{Z.D.}$$

For reflexion observations,

$$- 0''\cdot040 - 0''\cdot600 \sin \text{Z.D.} + 0''\cdot16 \sin \text{Z.D.}$$

or $$- 0''\cdot040 - 0''\cdot440 \sin \text{Z.D.}$$

Beginning with 1906, the corrections for the R—D discordance have been found by using the value of x from the observations made during the year, and by assuming a constant value of $+0''\cdot600$ for y (practically the value adopted for the 1880, 1890, and 1900 Catalogues), giving :—

For direct observations,

$$+ 0''\cdot040 + 0''\cdot600 \sin \text{Z.D.}$$

For reflexion observations,

$$- 0''\cdot040 - 0''\cdot440 \sin \text{Z.D.}$$

For use, these formulæ have been tabulated as follows, and the corrections have been applied to the mean results for N.P.D. of the Sun, Moon, and Planets in the section of planetary results throughout the year :—

N.P.D.	Corrections to Results of Direct Observations.	Corrections to Results of Reflexion Observations.
°	"	"
− 45	− 0·56	+ 0·40
40	− 0·55	+ 0·39
30	− 0·52	+ 0·37
20	− 0·47	+ 0·34
− 10	− 0·41	+ 0·29
0	− 0·33	+ 0·23
+ 10	− 0·25	+ 0·17
20	− 0·15	+ 0·10
30	− 0·05	+ 0·03
40	+ 0·06	− 0·05
50	+ 0·16	− 0·13
60	+ 0·26	− 0·20
70	+ 0·35	− 0·27
80	+ 0·44	− 0·33
90	+ 0·51	− 0·38
100	+ 0·57	− 0·43
110	+ 0·61	− 0·46
120	+ 0·63	− 0·48
+ 125	+ 0·64	− 0·49

No correction for flexure has been applied since April 1879.

Simultaneous Readings at Apparent Noon of the Transit-Circle Exterior Thermometer and the Meteorological Standard Thermometer.

Date, 1909.	Meteorological Standard Thermom.	Excess of Transit-Circle Exterior Thermometer.
d h	°	°
Jan. 7.0	43·8	0·0
9.0	39·9	− 0·3
14.0	45·8	0·0
16.0	38·3	+ 0·5
20.0	39·6	− 0·7
25.0	37·2	+ 0·3
26.0	38·4	− 0·9
30.0	36·7	− 1·0
Feb. 7.0	41·7	− 0·1
8.0	37·8	− 0·1
12.0	35·4	− 0·7
15.0	48·0	− 0·2
16.0	40·9	− 1·0
17.0	42·9	+ 0·6
19.0	41·1	− 0·2
20.0	45·7	+ 0·1
22.0	39·7	− 0·3
23.0	32·6	+ 2·2
24.0	37·7	− 1·3
28.0	33·6	0·0
Mar. 5.0	37·4	− 0·2
8.0	46·6	+ 0·3
16.0	38·3	+ 0·2
17.0	43·7	− 0·1
25.0	53·6	− 1·6
27.0	48·6	+ 0·4
Apr. 3.0	49·5	− 1·9
5.0	49·1	− 1·5
6.0	57·1	− 2·1
7.0	58·4	− 1·1
8.0	62·2	− 1·2
9.0	68·3	+ 0·3
10.0	60·7	− 0·1
11.0	69·3	+ 0·5
15.0	58·6	+ 0·9
19.0	65·4	− 1·0
20.0	58·6	+ 0·2
22.0	61·1	− 0·5
24.0	61·3	+ 0·2
26.0	64·2	+ 0·3
28.0	57·5	+ 0·5
29.0	56·8	− 0·1

Date, 1909.	Meteorological Standard Thermom.	Excess of Transit-Circle Exterior Thermometer.
d h	°	°
May 4.0	61·7	+ 0·1
5.0	59·6	− 1·3
6.0	62·1	− 0·3
7.0	60·1	− 1·6
8.0	58·9	+ 0·4
9.0	56·8	− 0·2
10.0	55·6	+ 0·4
12.0	69·4	0·0
19.0	64·1	+ 1·6
20.0	73·1	+ 1·7
21.0	78·3	+ 0·2
22.0	79·7	− 0·1
24.0	71·1	+ 1·8
28.0	62·6	+ 1·9
31.0	73·0	− 0·1
June 8.0	62·6	+ 1·7
14.0	64·6	+ 2·0
16.0	60·3	+ 0·5
17.0	60·4	+ 1·2
19.0	67·6	+ 0·3
21.0	68·5	0·0
22.0	62·5	− 1·3
23.0	61·4	+ 0·5
28.0	63·0	+ 0·6
July 2.0	64·9	+ 1·1
3.0	71·7	+ 0·1
4.0	69·3	− 1·2
14.0	68·3	− 0·5
18.0	71·9	− 0·3
19.0	68·5	+ 0·3
20.0	70·2	+ 1·4
23.0	68·6	+ 0·4
24.0	58·9	− 0·4
28.0	66·1	− 1·3
Aug. 4.0	69·6	− 0·3
5.0	70·6	− 0·7
6.0	75·1	− 0·3
7.0	76·7	+ 0·1
9.0	76·5	− 1·4
10.0	75·8	+ 0·8
11.0	75·7	+ 1·9

Date, 1909.	Meteorological Standard Thermom.	Excess of Transit-Circle Exterior Thermometer.
d h	°	°
Aug. 12.0	82·4	+ 0·7
13.0	77·9	+ 1·4
19.0	69·8	− 0·2
21.0	65·1	+ 0·9
22.0	63·0	− 1·9
28.0	67·3	+ 1·3
30.0	59·0	+ 0·7
Sept. 1.0	57·0	+ 0·8
2.0	61·5	+ 0·3
3.0	66·3	− 0·1
11.0	62·9	+ 0·1
17.0	67·2	+ 0·3
21.0	56·1	− 0·1
22.0	65·6	+ 0·8
24.0	65·6	+ 0·1
25.0	62·7	− 0·2
Oct. 8.0	62·8	+ 0·3
11.0	63·6	+ 0·9
12.0	63·1	− 0·7
Nov. 2.0	52·8	− 4·0
5.0	50·2	− 1·5
6.0	54·2	+ 0·7
8.0	47·3	− 0·5
9.0	46·0	− 0·1
11.0	44·6	− 0·8
15.0	40·7	− 0·4
18.0	45·6	− 0·3
19.0	42·0	− 0·2
20.0	36·8	+ 2·0
22.0	37·9	− 0·5
30.0	46·7	− 0·4
Dec. 3.0	42·7	+ 0·1
6.0	40·3	− 0·6
8.0	38·6	− 0·8
20.0	35·3	− 0·5
21.0	35·0	− 0·6
25.0	43·9	− 0·1
29.0	43·8	− 0·8
30.0	38·6	+ 2·0
31.0	50·0	− 0·3

Means of Simultaneous Readings at Apparent Noon of the Meteorological Standard Thermometer and Transit-Circle Exterior Thermometer.

1909.	January.	February.	March.	April.	May.	June.	Mean of Year.
Meteorological Standard..	$40^{\circ}{\cdot}0_{8}$	$39^{\circ}{\cdot}8_{12}$	$44^{\circ}{\cdot}7_{6}$	$59^{\circ}{\cdot}9_{16}$	$65^{\circ}{\cdot}7_{15}$	$63^{\circ}{\cdot}4_{9}$	
Excess of Exterior.	− 0·3	− 0·1	− 0·2	− 0·4	+ 0·3	+ 0·6	
1909.	July.	August.	September.	October.	November.	December.	
Meteorological Standard..	$67^{\circ}{\cdot}8_{10}$	$71^{\circ}{\cdot}8_{14}$	$62^{\circ}{\cdot}8_{9}$	$63^{\circ}{\cdot}2_{3}$	$45^{\circ}{\cdot}4_{12}$	$40^{\circ}{\cdot}9_{9}$	$56^{\circ}{\cdot}3_{123}$
Excess of Exterior.	0·0	+ 0·2	+ 0·2	+ 0·2	− 0·5	− 0·2	0·0

Correction to Assumed Colatitude, 38° 31′ 21″·80, *from Observations in the Year* 1909.

(Using Pulkowa Refractions.)

Corrections for Variation of Latitude supplied by Prof. Albrecht have been applied in forming this Table (see p. {2} of the section "Ledgers of Mean Right Ascensions and North Polar Distances").

Star's Name.	Approximate R.A.	Approximate N.P.D.	Excess of R.A. above Pole.	Excess of N.P.D. above Pole.	No. of Observations. Above Pole.	No. of Observations. Below Pole.	Weight.
	h m	° ′	s	″			
λ Ursæ Minoris..............	19. 11	1. 0	+0·24	−0·17	17	9	20
Groombridge 1119...........	8. 9	1. 6	+0·75	−0·20	14	15	22
Polaris	1. 27	1. 10	−1·12	+0·17	31	33	29
Bradley 1672.................	12. 14	1. 48	−0·33	−0·08	19	11	21
Groombridge 2283...........	15. 6	2. 25	−1·09	−0·19	12	6	16
Cephei 51	6. 59	2. 48	+0·08	−0·23	14	15	21
Bradley 3147.................	23. 28	3. 11	−0·29	−0·03	15	16	22
Groombridge 3548...........	21. 18	3. 20	+0·26	−0·19	13	11	20
δ Ursæ Minoris..............	18. 1	3. 23	+0·50	−0·33	19	10	20
Lalande F. 693...............	5. 0	4. 9		−0·51	2	2	6
2 Ursæ Minoris	0. 56	4. 13		0·00	3	2	7
Bradley 1399.................	10. 17	5. 17	+0·36	−0·31	7	1	5
76 Draconis...................	20. 49	7. 48		+0·38	3	2	6
ε Ursæ Minoris..............	16. 55	7. 49		−0·09	4	2	7
Piazzi IX. 37.................	9. 24	8. 16	−0·12	−0·15	3	3	8
Piazzi IV. 269...............	5. 8	10. 52		+0·76	2	5	8

Correction to Assumed Colatitude, 38° 31′ 21″80, *from Observations in the Year* 1909—continued.

Star's Name.	Approximate R.A.	Approximate N.P.D.	Excess of R.A. above Pole.	Excess of N.P.D. above Pole.	No. of Observations.		Weight.
					Above Pole.	Below Pole.	
	h m	° ′	s	″			
77 Draconis	21. 7	12. 14	−0·08	+0·59	5	3	8
Bradley 431	3. 9	12. 36		−0·40	2	2	5
Groombridge 966	5. 28	15. 1		−0·03	2	1	3
τ Draconis	19. 17	16. 49		+0·48	1	2	4
16 Cephei	21. 58	17. 15	−0·38	+0·03	3	3	6
γ Ursæ Minoris	15. 21	17. 51		+0·88	2	1	3
50 Cassiopeiæ	1. 56	18. 1	−0·36	−0·90	2	2	5
24 Cephei	22. 8	18. 6		+0·91	5	2	6
ι Cephei	22. 46	24. 16		−1·05	1	4	5
36 Draconis	18. 13	25. 38		−0·20	1	2	3
30 Cephei	22. 35	26. 53		+0·36	1	6	5
γ Draconis	17. 55	38. 30	−0·02	+0·05	5	1	2
o Andromedæ	22. 58	48. 9	+0·07	(+1·45)	2	1	

The weights used in the above tables are determined by use of the "Probable Errors of the Greenwich Observations in Zenith-Distance," given by Mr. Stone in the *Monthly Notices of the Royal Astronomical Society* for 1869 June, page 234. Putting n for the number of observations of a star above the pole; e for the probable error of one observation; n_1 and e_1 the similar quantities for the observations below the pole; e_0 the probable systematic error affecting all observations of the same star, and depending on outstanding division-error, uncertainty in the constant of refraction, &c.,—the formula employed to determine the weight to be given to that star is $\frac{2nn_1}{n_1e^2 + ne_1^2 + 2nn_1e_0^2}$; or, assuming $e_0^2 = \frac{1}{10} e_1^2$, which would make $e_0 = 0''\cdot16$, the weight becomes $\frac{2nn_1}{n_1e^2 + ne_1^2 + \frac{1}{5} nn_1e^2}$, which has been adopted in the investigation.

If z be the correction to the assumed colatitude 38° 31′ 21″·80, $2z$ + the algebraic sum of determinations ought to be equal to 0. Combining the whole with the weights above attached to them, $z = +0''\cdot030$.

The colatitude determined from the observations of 1909 is therefore 38° 31′ 21″·83.

Pivot Errors.

The table p. iv. shows the changes of direction of a certain line in the axis of the pivots of the transit-circle as the telescope is rotated.

Treating the Y's as plane bearings, an analysis of these results gives for the form of the pivots the curve

$$r = a\{-''\cdot05 \sin 2\theta + ''\cdot03 \cos 2\theta + ''\cdot05 \sin 3\theta + ''\cdot00 \cos 3\theta - ''\cdot05 \sin 4\theta + ''\cdot00 \cos 4\theta + \ldots\}$$

The coefficients are probably not greater than their accidental errors, and the accuracy of form of the pivots appears to be perfectly satisfactory.

The quantities in the table cannot be interpreted as errors in the form of the pivots, but seem to be mainly due to changes in the way the pivots settle in the Y's. As the telescope rotates, the extremity of the axis, instead of remaining at rest, describes an ellipse or straight line.

The following table shows the correction which must be applied to the Right Ascensions, if the errors given on p. iv. are taken into account (including the effect of the corrections to the collimation, level, azimuth and clock errors):—

N.P.D. Pointer.	Correction to R.A.	N.P.D. Pointer.	Correction to R.A.	N.P.D. Pointer.	Correction to R.A.	N.P.D. Pointer.	Correction to R.A.
°	s	°	s	°	s	°	s
5	+ ·038	95	·000	185	+ ·035	275	− ·003
15	+ ·022	105	− ·001	195	+ ·032	285	− ·001
25	+ ·026	115	+ ·004	205	+ ·031	295	− ·003
35	+ ·010	125	+ ·007	215	+ ·039	305	+ ·007
45	+ ·007	135	+ ·006	225	+ ·037	315	+ ·007
55	+ ·001	145	+ ·020	235	+ ·029	325	+ ·012
65	·000	155	+ ·023	245	+ ·036	335	+ ·012
75	− ·003	165	+ ·029	255	...	345	+ ·011
85	·000	175	+ ·030	265	− ·004	355	+ ·047

The corrections to the direct observations are extremely small, and as they do not help to explain discordances between Greenwich places and those of the Fundamental Catalogues, or between above and below pole observations, it does not seem worth while to apply them. But in any case it is unsafe to assume that these errors are permanent and invariable; because, being due not to errors in the form of the pivots but to the mode of resting on the Y's, they are likely to change through wear or whenever the adjustment of the Y's is disturbed.

ALTAZIMUTH TABLES, 1909.

ROYAL OBSERVATORY, GREENWICH.

ALTAZIMUTH TABLES, 1909.

Equivalents of the Transit-Micrometer Screw and Equatorial Intervals of the Transit Wires.

The following are the intervals from the middle wire determined from measures with the transit-micrometer and the position micrometer, combined with star transits. A star transits the wires in the order of numeration of the wires in position 0°, d or 180°, r; in the reverse order in position 0°, r or 180°, d. In each case, the order is reversed below the pole.

One revolution of transit-micrometer = 21″·584.

Equatorial Intervals of the Transit Wires.

Wire.	1909.	Wire.	1909.	Wire.	1909.
	s		s		s
1	+ 43·314	10	+ 7·212	19	− 8·570
2	+ 33·153	11	+ 5·828	20	− 11·702
3	+ 30·244	12	+ 4·319	21	− 14·407
4	+ 27·441	13	+ 2·812	22	− 21·623
5	+ 24·440	14	0·000	23	− 24·508
6	+ 21·636	15	− 2·867	24	− 27·472
7	+ 14·495	16	− 4·283	25	− 30·249
8	+ 11·469	17	− 5·728	26	− 33·271
9	+ 8·656	18	− 6·968	27	− 43·379

Equivalents of the Zenith Distance Micrometer-Screw and Intervals of the Zenith Distance Wires.

The following are the intervals from the middle wire, determined from measures with the telescope-micrometer and the position-micrometer, combined with star transits.

A star transits the wires in the order of numeration of the wires when the Fixed Circle is south, *i.e.*, in positions 0°, d, to 180°, d, or 180°, r, to 360°, r.

One revolution of telescope-micrometer = 21″·635.

Intervals of the Zenith Distance Wires.

Wire.	1909.	Wire.	1909.	Wire.	1909.
	″		″		″
I.	+ 347·56	VIII.	+ 88·95	XV.	(− 107·81)
II.	+ 326·46	IX.	+ 67·20	XVI.	− 128·27
III.	+ 304·60	X.	+ 43·69	XVII.	− 259·37
IV.	+ 282·54	XI.	0·00	XVIII.	− 280·74
V.	+ 260·24	XII.	− 43·59	XIX.	− 302·71
VI.	+ 132·54	XIII.	− 65·21	XX.	(− 323·25)
VII.	+ 109·81	XIV.	− 86·89	XXI.	− 345·54

Apparent Correction to adopted Level-Errors, deduced from a Comparison of Reflexion and Direct Observations of Right Ascension, made in the Year 1909.

Name of Star.	Approx. N.P.D.	Approx. R.A.	Seconds of R.A. R.	Seconds of R.A. D.	R. − D.	Deduced Correction to Level-Error.	Number of Observations. R.	Number of Observations. D.	Weight.
	° ′	h m	s	s	s	″			
Piazzi VI. 42	10. 20	6. 25	38·880	39·240	−0·360	−0·54	1	1	2
Bradley 117	10. 49	1. 4	22·340	22·525	−0·185	−0·29	½	2	1
Bradley 1634	11. 53	12. 8	57·040	57·200	−0·160	−0·27	1	1	2
ζ Ursæ Minoris	11. 56	15. 47	17·000	17·250	−0·250	−0·43	1	1	2
Lalande F. 1855–6	12. 8	11. 17	33·080	33·260	−0·180	−0·31	1	1	2
Groombridge 1852	12. 35	12. 1	38·680	38·460	+0·220	+0·39	1	1	2
Bradley 1147	13. 58	8. 8	8·820	8·500	+0·320	+0·63	1	1	2
Bradley 2897	15. 25	21. 57	59·210	59·350	−0·140	−0·30	1	1	2
Groombridge 710	15. 45	3. 35	30·860	30·900	−0·040	−0·09	1	1	2
Groombridge 2775	16. 0	19. 1	49·590	49·400	+0·190	+0·42	1	1	2
Groombridge 2719	16. 1	18. 48	3·420	3·270	+0·150	+0·33	1	1	2
Groombridge 1446	16. 3	8. 30	36·670	37·070	−0·400	−0·89	1	1	2
B. D. + 73° 210	16. 15	3. 56	25·270	25·070	+0·200	+0·45	½	1	1
Lalande F. 2747	16. 37	16. 5	15·480	15·970	−0·490	−1·13	1	1	2
Lalande 21235	17. 33	11. 2	11·430	11·790	−0·360	−0·86	1	1	2
ρ Ursæ Majoris	22. 1	8. 54	21·240	21·350	−0·110	−0·32	1	1	2
ψ Cassiopeiæ	22. 21	1. 19	29·050	29·620	−0·570	−1·67	½	1	1
α Lyræ	51. 18	18. 34	51·480	51·395	+0·085	+0·51	1	2	2
54 Persei	55. 39	4. 14	29·920	30·100	−0·180	−1·15	1	1	2
θ Geminorum	55. 56	6. 47	47·410	47·495	−0·085	−0·55	1	2	2
ι Aurigæ	56. 59	4. 51	3·890	3·917	−0·027	−0·17	1	3	3
53 Herculis	58. 9	16. 50	30·780	30·960	−0·180	−1·19	1	1	2
β Tauri	61. 28	5. 21	32·300	32·307	−0·007	−0·06	2	4	4
α Coronæ	62. 59	15. 31	49·860	50·097	−0·237	−1·72	1	3	3
12 Comæ	63. 39	12. 18	55·900	56·030	−0·130	−0·95	1	1	2
α Arietis	66. 58	2. 2	2·280	2·430	−0·150	−1·16	1	1	2
δ Geminorum	67. 51	7. 15	41·210	41·330	−0·120	−0·94	1	½	1
β Arietis	69. 38	1. 50	36·750	36·596	+0·154	+1·25	1	2½	2
γ¹ Leonis	69. 42	10. 15	57·550	57·470	+0·080	+0·65	1	1½	1
f Boötis	70. 22	14. 22	13·140	13·390	−0·250	−2·05	1	½	1
ε Tauri	71. 1	4. 23	18·040	18·140	−0·100	−0·83	1	1	2
δ Tauri	72. 40	4. 18	41·050	41·200	−0·150	−1·28	1	1	2
Regulus	77. 35	10. 4	31·680	31·650	+0·030	+0·28	1	1½	2
o Virginis	80. 46	12. 1	34·390	34·463	−0·073	−0·72	1	3	2
π Virginis	82. 53	11. 56	12·390	12·490	−0·100	−1·02	1	1	1

From 17 North Stars, Mean Correction to Level-Error = − 0″·27.

„ 18 South Stars, „ „ „ = − 0″·58.

Excess of Reflexion Results above Direct Results for Observations of Zenith-Distance with the Altazimuth, 1909.

Star's Name.	R.A.	N.P.D.	R.—D.	No. of Obs. R. and D.	Weight.	Star's Name.	R.A.	N.P.D.	R.—D.	No. of Obs. R. and D.	Weight.
Position 0°, r. January, February.											
	h m	° ′	″				h m	° ′	″		
ψ^1 Draconis S.P.	17. 44	−17. 49	− 2·19	1	1	θ Geminorum	6. 47	55. 56	− 1·20	1	1
Piazzi XVI. 195 S.P.	16. 35	−12. 23	− 1·35	1	1	β Tauri	5. 21	61. 28	+ 0·47	1	1
ε Ursæ Minoris S.P.	16. 55	− 7. 49	− 0·94	1	1	δ Geminorum	7. 15	67. 51	(−4·84)	1	1
						ε Tauri	4. 23	71. 1	− 1·31	1	1
						130 Tauri	5. 42	72. 18	+ 1·95	1	1
						δ Tauri	4. 18	72. 40	+ 0·44	1	1
Cephei 51	6. 58	2. 48	− 0·82	1	1						
Piazzi VI. 42	6. 25	10. 20	+ 0·26	1	1	ζ Hydræ	8. 50	83. 42	− 1·49	1	1
						δ Orionis	5. 27	90. 22	− 0·97	1	1
						ζ Orionis	5. 36	92. 0	+ 0·23	1	1
Groombridge 1446	8. 30	16. 3	+ 0·15	1	1	30 Monocerotis	8. 21	93. 37	− 1·24	1	1
ρ Ursæ Majoris	8. 54	22. 1	+ 0·06	1	1	Rigel	5. 10	98. 18	− 1·68	2	2
Position 0°, d. March, April.											
δ Cassiopeiæ S.P.	1. 19	−30. 14	− 0·48	1	1	12 Comæ	12. 18	63. 39	− 0·77	1	1
γ Cassiopeiæ S.P.	0. 51	−29. 47	− 0·37	1	1	ζ Leonis	10. 11	66. 8	+ 1·42	1	1
						γ^1 Leonis	10. 15	69. 42	− 0·72	2	2
						Arcturus	14. 11	70. 21	− 0·09	1	1
ψ^1 Draconis S.P.	17. 44	−17. 49	− 0·69	1	1	Regulus	10. 4	77. 35	− 0·91	1	1
35 Draconis S.P.	17. 53	−13. 2	− 0·29	1	1	ε Virginis	12. 58	78. 33	− 3·59	1	1
						ο Virginis	12. 1	80. 46	− 3·66	1	1
Bradley 1634	12. 8	11. 53	+ 0·11	1	1	π Leonis	9. 55	81. 31	+ 0·67	1	1
Lalande F. 1855–6	11. 17	12. 7	+ 0·42	1	1	σ Virginis	13. 13	84. 3	+ 0·26	1	1
Groombridge 1852	12. 1	12. 35	+ 0·08	1	1						
Bradley 1147	8. 8	13. 58	+ 2·26	1	1	η Orionis	5. 20	92. 29	+ 0·52	1	1
Lalande 21235	11. 2	17. 33	+ 0·41	1	1	Rigel	5. 10	98. 19	+ 1·12	1	1
Position 180°, d. May, June.											
ι Cephei S.P.	22. 46	−24. 3	+ 0·63	1	1	53 Herculis	16. 50	58. 9	− 0·51	1	1
ω Cassiopeiæ S.P.	1. 36	−22. 25	− 3·26	1	1	α Coronæ	15. 31	62. 59	− 1·10	1	1
ψ Cassiopeiæ S.P.	1. 19	−22. 21	+ 2·05	1	1	ε Leonis	9. 41	65. 48	+ 0·97	1	1
						γ^1 Leonis	10. 15	69. 42	+ 0·37	1	1
						f Boötis	14. 22	70. 22	− 0·31	1	1
Bradley 1672	12. 14	1. 48	+ 0·36	1	1	24 Comæ	12. 30	71. 7	+ 0·27	1	1

Excess of Reflexion Results above Direct Results from Observations of Zenith-Distance with the Altazimuth, 1909—contd.

Star's Name.	R.A.	N.P.D.	R.—D.	No. of Obs. R. and D.	Weight.	Star's Name.	R.A.	N.P.D.	R.—D.	No. of Obs. R. and D.	Weight.
			Position 180°, d. May, June—*continued.*								
	h m	° ′	″				h m	° ′	″		
Lalande F. 2537	14. 41	9. 49	− 0·01	1	1	π Boötis	14. 36	73. 12	− 1·99	1	1
Piazzi XVI. 182	16. 31	10. 50	+ 0·08	2	2	γ Serpentis	15. 52	74. 2	− 2·31	2	2
Bradley 1508	10. 52	11. 45	+ 0·64	1	1	β Serpentis	15. 42	74. 18	− 1·81	1	1
Bradley 1634	12. 7	11. 53	− 1·09	1	1	Regulus	10. 4	77. 35	+ 0·39	1	1
ζ Ursæ Minoris	15. 47	11. 56	− 1·90	1	1	ε Virginis	12. 58	78. 33	+ 0·06	1	1
η Ursæ Minoris	16. 20	14. 2	− 0·42	2	2	π Virginis	11. 56	82. 53	− 1·58	1	1
β Ursæ Minoris	14. 50	15. 28	− 0·74	1	1	σ Virginis	13. 13	84. 3	+ 0·79	1	1
Lalande F. 2747	16. 5	16. 37	− 1·06	1	1						
						δ Ophiuchi	16. 9	93. 28	+ 2·32	1	1
						α Hydræ	9. 23	98. 16	+ 1·33	1	1
			Position 180°, r. July, August.								
Groombridge 2719	18. 48	16. 1	+ 0·92	1	1	α Lyræ	18. 34	51. 18	− 0·47	1	1
Groombridge 2775	19. 1	16. 0	+ 1·18	1	1	Bradley 2308	18. 18	66. 46	+ 1·36	1	1
			Position 0°, r. September, October.								
Bradley 117	1. 4	10. 49	+ 0·65	1	1						
Bradley 2897	21. 57	15. 25	+ 1·66	1	1						
ψ Cassiopeiæ	1. 19	22. 21	+ 0·52	1	1						
			Position 0°, d. November, December.								
Groombridge 710	3. 35	15. 45	+ 0·89	1	1	54 Persei	4. 14	55. 39	− 0·40	1	1
						ι Aurigæ	4. 51	56. 59	+ 0·62	1	1
B. D. + 73° 210	3. 56	16. 15	− 1·91	1	1						
						β Tauri	5. 21	61. 28	+ 0·76	1	1
						α Arietis	2. 2	66. 58	+ 0·19	1	1
						β Arietis	1. 50	69. 38	− 2·06	1	1

Excess of Reflexion Results above Direct Results from Groups of Stars observed with the Altazimuth, 1909.

Extent of Group 1909.	Weight.	Mean N.P.D.	Mean Z.D. South.	Mean Value of R.—D., corrected for Inclination of Verticals.	R.—D. computed by the Formula.	Apparent Error of the Formula.
			Position 0°, r. January, February.			
		° ′	° ′	″	″	″
ψ^1 Draconis S.P. to ε Ursæ Minoris S.P.	3	− 12. 40	− 51. 11	− 1·58	− 0·04	+ 1·54
Cephei 51 to Piazzi VI. 42	2	6. 34	− 31. 57	− 0·34	− 0·02	+ 0·32
Groombridge 1446 to ρ Ursæ Majoris	2	19. 2	− 19. 29	+ 0·06	0·00	− 0·06
θ Geminorum to δ Tauri	5	66. 41	28. 10	+ 0·13	+ 0·05	− 0·08
ζ Hydræ to δ Orionis	2	87. 2	48. 31	− 1·14	+ 0·08	+ 1·22
ζ Orionis to Rigel	4	95. 33	57. 2	− 0·99	+ 0·09	+ 1·08
			Position 0°, d. March, April.			
δ Cassiopeiæ S.P. to γ Cassiopeiæ S.P.	2	− 30. 0	− 68. 31	− 0·55	− 0·09	+ 0·46
ψ Draconis S.P. to 35 Draconis S.P.	2	− 15. 26	− 53. 57	− 0·59	− 0·08	+ 0·51
Bradley 1634 to Lalande 21235	5	13. 37	− 24. 54	+ 0·61	− 0·05	− 0·66
12 Comæ to Arcturus	5	67. 54	29. 23	− 0·11	+ 0·01	+ 0·12
Regulus to σ Virginis	5	80. 26	41. 55	− 1·37	+ 0·03	+ 1·40
η Orionis to Rigel	2	95. 24	56. 53	+ 0·92	+ 0·05	− 0·87
			Position 180°, d. May, June.			
ι Cephei S.P. to ψ Cassiopeiæ S.P.	3	− 23. 0	− 61. 31	− 0·30	− 0·05	+ 0·25
Bradley 1672	1	1. 48	− 36. 43	+ 0·29	− 0·02	− 0·31
Lalande F. 2537 to Lalande F. 2747	10	12. 42	− 25. 49	− 0·53	− 0·01	+ 0·52
53 Herculis to ε Leonis	3	62. 18	23. 47	− 0·16	+ 0·05	+ 0·21
γ^1 Leonis to σ Virginis	11	75. 24	36. 53	− 0·70	+ 0·07	+ 0·77
δ Ophiuchi to α Hydræ	2	95. 54	57. 23	+ 1·92	+ 0·09	− 1·83
			Position 180°, r. July, August.			
Groomb. 2719 to Groomb. 2775	2	16. 0	− 22. 31	+ 1·00	− 0·05	− 1·05
α Lyræ	1	51. 18	12. 47	− 0·44	0·00	+ 0·44
Bradley 2308	1	66. 48	28. 17	+ 1·42	+ 0·02	− 1·40
			Position 0°, r. September, October.			
Bradley 117 to ψ Cassiopeiæ	3	16. 12	− 22. 19	+ 0·89	− 0·01	− 0·90

Excess of Reflexion Results above Direct Results from Groups of Stars observed with the Altazimuth—contd.

Extent of Group 1909.	Weight.	Mean N.P.D.	Mean Z.D. South.	Mean Value of R.—D. corrected for Inclination of Verticals.	R.—D. computed by the Formula.	Apparent Error of the Formula.
Position 0°, d. November, December.						
		° ′	° ′	″	″	″
Groombridge 710	1	15. 42	− 22. 49	+ 0·84	− 0·05	− 0·89
B. D. + 73° 210	1	16. 12	− 22. 19	− 1·95	− 0·05	+ 1·90
54 Persei	1	55. 36	17. 15	− 0·37	0·00	+ 0·37
ι Aurigæ	1	57. 0	18. 29	+ 0·66	0·00	− 0·66
β Tauri	1	61. 30	22. 59	+ 0·81	+ 0·01	− 0·80
α Arietis	1	67. 0	28. 29	+ 0·25	+ 0·01	− 0·24
β Arietis	1	69. 36	31. 5	− 2·00	+ 0·02	+ 2·02

In forming the mean values of R−D for groups in the fifth column of the above table, a correction of $+0''\cdot12$ sin Z.D. has been applied to the mean of each group, for inclination of the vertical at the surface of the mercury used in reflexion observations to that at the centre of the instrument, the centre of the mercury trough being assumed to describe a circle of 6 feet radius.

Assuming that the R−D discordance can be represented by

$$x + y \sin \text{Z.D. south},$$

it is found by calculation that the following expressions, when tabulated, will give the values which best agree with the errors in the above, namely :—

Observed R−D Discordance for Different Positions of the Altazimuth, in the Year 1909.

Position of Instrument.	R−D Discordance.	
	″	″
0°, r (Jan., Feb.).	−0·64	+0·20 sin Z.
0°, d (Mar., Apr.).	−0·18	−0·44 sin Z.
180°, d (May, June).	−0·34	+0·14 sin Z.
180°, r (July, Aug.).	+0·74	−0·70 sin Z.
0°, r (Sept., Oct.).	+0·92	+0·06 sin Z.
0°, d (Nov., Dec.).	−0·34	+0·54 sin Z.

Assuming the formulæ for the four positions as

$$+ a + b \sin \text{Z.D.} \text{ for the positions } 0°, \text{ d, and } 180°, \text{ r},$$

and

$$- a + b \sin \text{Z.D.} \quad ,, \quad ,, \quad 0°, \text{ r, and } 180°, \text{ d},$$

the correction for the R − D discordance in the four positions of the instrument has been taken as

$$\mp 0''{\cdot}01 + 0''{\cdot}04 \sin \text{Z.D.}$$

Comparison of North Polar Distances observed with the Altazimuth in 1909, *with Newcomb's Fundamental Catalogue, for each* 10° *of N.P.D.*

Mean N.P.D. of Group.	Mean Tabular —Observed.	Weight.	Mean N.P.D. of Group.	Mean Tabular —Observed.	Weight.	Mean N.P.D. of Group.	Mean Tabular —Observed.	Weight.
Position 0°, r. Jan., Feb.			Position 180°, d. May, June.			Position 0°, r. Sept., Oct.		
°	"		°	"		°	"	
− 35·8	− 1·07	2	− 34·0	− 0·18	1	− 35·5	− 0·25	7
− 25·6	− 0·69	2	− 23·0	− 0·31	4	− 24·2	− 0·55	4
− 15·5	+ 0·04	4	− 14·1	− 0·04	4	− 13·8	− 0·90	9
− 3·4	+ 0·10	6	− 1·2	− 0·29	1	− 3·4	− 0·50	7
2·6	+ 0·04	4	1·9	− 0·50	5	2·6	− 0·74	9
12·2	+ 0·41	3	13·9	− 0·23	8	15·1	− 0·44	6
22·0	− 0·19	1	23·5	+ 0·60	5	26·2	− 0·36	13
46·4	− 0·09	2	34·4	+ 0·08	6	33·1	− 0·42	7
54·9	+ 0·23	7	45·6	+ 0·28	9	43·6	+ 0·44	5
66·4	− 0·18	14	55·3	− 0·10	11	56·5	− 0·05	3
74·6	− 0·09	24	64·7	+ 0·21	11	64·1	− 0·87	7
83·2	+ 0·09	16	74·1	+ 0·05	24	74·7	− 0·83	5
96·7	− 0·54	13	84·6	+ 0·17	12	85·2	− 0·66	5
102·7	− 0·95	3	95·3	+ 0·26	16	95·1	− 0·92	12
112·4	+ 1·39	2	104·0	− 0·29	17	104·9	− 0·48	8
			113·5	+ 0·54	7	111·7	− 0·86	1
Position 0°, d. March, April.			Position 180°, r. July, August.			Position 0°, d. Nov., Dec.		
− 31·5	+ 1·03	5	− 31·0	+ 1·46	1	− 33·6	+ 0·85	5
− 28·2	+ 0·95	5	− 29·7	+ 0·46	1	− 24·3	+ 0·89	3
− 15·1	− 0·52	4	− 11·6	− 0·12	4	− 14·2	+ 0·96	3
− 3·3	+ 0·33	8	− 2·8	+ 1·10	1	− 3·3	+ 1·24	7
3·1	− 0·26	4	4·5	+ 0·04	4	2·1	+ 1·28	7
12·0	+ 0·25	5	14·7	+ 0·58	3	13·6	+ 0·83	3
24·7	− 0·08	5	24·4	− 0·15	5	23·9	+ 1·86	4
32·4	+ 0·45	4	34·9	+ 0·46	5	32·8	+ 0·64	7
46·5	+ 0·53	12	46·2	+ 0·09	7	45·7	+ 0·95	6
55·0	0·00	6	53·2	0·00	15	55·6	+ 1·08	8
66·2	+ 0·74	15	64·0	+ 0·60	7	64·3	+ 1·15	10
75·3	− 0·03	21	76·0	+ 0·41	13	75·6	+ 0·68	10
83·5	+ 0·03	32	86·2	+ 0·71	15	83·6	+ 0·61	13
95·9	− 0·02	13	94·2	+ 0·39	10	94·6	− 0·13	14
104·5	+ 0·39	18	103·9	+ 0·84	9	108·5	+ 0·41	2
114·2	+ 0·88	8	116·3	+ 0·63	10	115·6	+ 0·60	2

Assuming the differences "Tabular—Observed" to be represented by the formula

$$a+b \sin \text{Z.D.},$$

a solution by the method of least squares gave the results :—

Newcomb – Altazimuth.

Position of Altazimuth.			Position of Altazimuth.		
0°, r (Jan., Feb.).	−0″·12	+0″·02 sin Z.D.	180°, r (July, Aug.).	+0″·33	+0″·19 sin Z.
0°, d (Mar., Apr.).	+0·32	−0·10 sin Z.D.	0°, r (Sept., Oct.).	−0·56	−0·07 sin Z.
180°, d (May, June).	−0·01	+0·16 sin Z.D.	0°, d (Nov., Dec.).	+0·86	−0·39 sin Z.

Taking the coefficient of sin Z.D. from the results of the reflexion observations as +0″·04, the values found for the a term in the different positions are given below.

Position of Instrument.	Difference of N.P.D. Newcomb – Altazimuth. Value of a.	Weight.	Position of Instrument.	Difference of N.P.D. Newcomb – Altazimuth. Value of a.	Weight.
0°, r (Jan., Feb.).	−0″·13	103	180°, r (July, Aug.).	+0″·39	110
0°, d (Mar., Apr.).	+0·27	165	0°, r (Sept., Oct.).	−0·56	107
180°, d (May, June).	+0·04	141	0°, d (Nov., Dec.).	+0·77	104

The weighted mean is ±0″·32, and the resulting formula would be ±0″·32 +0″·04 sin Z.D., the upper sign applying to positions 0°, d, 180°, r.

Adopted Corrections to North Polar Distances of the Altazimuth, 1909.

N.P.D.	Corrections to Results of Direct Observations.		Corrections to Results of Reflexion Observations.	
	0°, d. 180°, r.	0°, r. 180°, d.	0°, d. 180°, r.	0°, r. 180°, d.
° −40	″ −0·05	″ −0·03	″ −0·07	″ −0·09
−30	−0·05	−0·03	−0·06	−0·08
−20	−0·04	−0·02	−0·06	−0·08
−10	−0·04	−0·02	−0·05	−0·07
0	−0·03	−0·01	−0·04	−0·06
+10	−0·03	−0·01	−0·03	−0·05
20	−0·02	0·00	−0·02	−0·04
30	−0·02	0·00	0·00	−0·02
40	−0·01	+0·01	+0·01	−0·01
50	0·00	+0·02	+0·03	+0·01
60	0·00	+0·02	+0·04	+0·02
70	+0·01	+0·03	+0·05	+0·03
80	+0·02	+0·04	+0·06	+0·04
90	+0·02	+0·04	+0·07	+0·05
100	+0·03	+0·05	+0·08	+0·06
110	+0·03	+0·05	+0·09	+0·07
120	+0·03	+0·05	+0·09	+0·07

Altazimuth Colatitude Investigation.

Correction to Assumed Colatitude 38° 31′ 23″·42 from observations in the Year 1909.

(Using Pulkowa Refractions, computed from the tables given in the Appendix to the *Greenwich Observations for* 1898.)

Corrections for Variation of Latitude supplied by Prof. Albrecht have been applied in forming this table (see p. {*28*} of the section "Ledgers of Mean Right Ascensions and North Polar Distances of Stars observed with the Altazimuth"):—

Star's Name.	Approximate R.A.	Approximate N.P.D.	Excess of N.P.D. above Pole.	No. of Observations: Above Pole.	No. of Observations: Below Pole.	Weight.	Star's Name.	Approximate R.A.	Approximate N.P.D.	Excess of N.P.D. above Pole.	No. of Observations: Above Pole.	No. of Observations: Below Pole.	Weight.
	h m	° ′	″					h m	° ′	″			
Polaris	1 26	1 11	− 2·02	3	2	7	φ Draconis	18 22	18 43	− 0·28	2	1	3
Bradley 1672	12 14	1 48	− 0·21	5	7	13	ψ Cassiopeiæ	1 19	22 21	+ 1·19	2	2	5
Groomb. 2283	15 6	2 25	+ 2·88	3	1	4	ω Cassiopeiæ	1 36	22 25	− 0·92	1	2	4
Cephei 51	6 58	2 48	− 1·71	5	1	5	Bradley 3166	23 44	22 42	− 0·36	4	1	3
Bradley 3147	23 28	3 12	+ 0·37	5	5	12	Bradley 1429	10 18	23 58	+ 1·33	1	1	2
δ Ursæ Minoris	18 2	3 23	− 0·27	3	4	9	8 Draconis	12 52	24 4	− 0·87	1	2	4
Groomb. 944	5 33	4 51	− 1·99	1	1	3	ι Cephei	22 46	24 17	+ 1·11	2	2	5
Bradley 1399	10 17	5 17	− 0·30	1	1	3	32 Ursæ Majoris	10 11	24 26	+ 1·04	1	1	2
ε Ursæ Minoris	16 55	7 49	− 0·24	1	2	4	Piazzi XI. 43	11 17	25 10	− 0·35	1	2	3
Piazzi VI. 42	6 25	10 20	− 0·39	2	1	3	36 Draconis	18 13	25 38	+ 1·67	4	2	5
Piazzi VI. 75	6 31	10 20	− 0·16	2	2	5	30 Cephei	22 35	26 53	− 1·04	1	2	3
Bradley 117	1 4	10 49	+ 0·19	3	1	4	26 Draconis	17 34	28 3	− 0·35	1	1	2
Bradley 1508	10 53	11 45	+ 0·37	4	2	6	ν Cephei	21 43	29 19	− 0·64	2	1	3
Bradley 1634	12 8	11 53	+ 2·06	4	2	6	β Camelopardi	4 55	29 41	+ 0·12	1	1	2
Lal. F. 1855–6	11 17	12 8	+ 0·06	2	2	5	γ Cassiopeiæ	0 51	29 47	− 1·34	2	2	4
Piazzi XVI. 195	16 35	12 22	− 0·35	1	3	5	Piazzi XXI. 51	21 9	30 23	+ 0·94	2	1	2
Groomb. 1852	12 1	12 35	+ 0·61	2	1	3	ν Ursæ Majoris	9 45	30 32	+ 0·07	1	2	3
γ Cephei	23 36	12 53	− 0·69	2	2	5	β Cassiopeiæ	0 4	31 21	− 2·51	3	1	2
35 Draconis	17 54	13 1	− 1·17	1	3	5	δ² Cephei	22 26	32 3	+ 1·66	1	1	2
Bradley 1147	8 8	13 58	− 0·38	2	1	3	Groomb. 2377	16 44	33 3	+ 0·77	1	1	2
η Ursæ Minoris	16 20	14 2	+ 0·79	4	1	4	β Ursæ Majoris	10 56	33 8	+ 1·17	2	1	2
π Cephei	23 5	15 6	− 1·36	1	1	3	α Cassiopeiæ	0 35	33 58	− 0·52	3	1	2
Groomb. 1446	8 30	16 3	+ 0·35	2	2	5	81 Ursæ Majoris	13 31	34 11	+ 0·37	1	2	3
Lalande F. 2747	16 5	16 37	− 1·81	2	1	3	Groomb. 2343	16 22	34 35	− 1·19	1	1	2
31 Cephei	22 34	16 50	+ 1·27	3	1	4	γ Draconis	17 54	38 30	+ 0·42	1	1	2
Lalande 21235	11 2	17 33	+ 0·83	2	2	5	Piazzi XI. 19	11 12	40 2	− 0·04	1	1	1
Groomb. 2029	13 35	18 18	+ 2·51	1	2	4	η Ursæ Majoris	13 44	40 14	− 0·95	1	2	2

The weights used in the above tables are the same as those used in the Transit-Circle investigation.

The assumed colatitude 38° 31′ 23″·42 was found by applying to the adopted colatitude of the Transit-Circle, with Pulkowa Refractions 38° 31′ 21″·75, a correction of + 1″·67 for geodetic difference of latitude as measured on the plan of the Observatory.

The resulting correction to the assumed colatitude 38° 31′ 23″·42 from these results is − 0″·01. The colatitude determined from the observations of 1908 is, therefore, 38° 31′ 23″·41.

Table for deducing Azimuth Error and m *from Level Error and* n.

The components of *Az* and *m* with arguments *l* and *n* are to be separately taken out and then added.

Level Error or *n*.	Argument Level Error.		Argument *n*.		Level Error or *n*.	Argument Level Error.		Argument *n*.		Level Error or *n*.	Argument Level Error.	
	Az.	*m.*	*Az.*	*m.*		*Az.*	*m.*	*Az.*	*m.*		*Az.*	*m.*
″	″	s	″	s	″	″	s	″	s	″	″	s
0·1	+ 0·13	+0·011	− 0·16	−0·008	**5·1**	+ 6·41	+0·546	− 8·19	−0·427	**10·1**	+12·69	+1·081
0·2	0·25	0·021	0·32	0·017	**5·2**	6·53	0·557	8·35	0·435	**10·2**	12·81	1·092
0·3	0·38	0·032	0·48	0·025	**5·3**	6·66	0·567	8·51	0·444	**10·3**	12·94	1·103
0·4	0·50	0·043	0·64	0·033	**5·4**	6·78	0·578	8·67	0·452	**10·4**	13·06	1·113
0·5	0·63	0·054	0·80	0·042	**5·5**	6·91	0·589	8·83	0·461	**10·5**	13·19	1·124
0·6	0·75	0·064	0·96	0·050	**5·6**	7·03	0·599	8·99	0·469	**10·6**	13·31	1·135
0·7	0·88	0·075	1·12	0·059	**5·7**	7·16	0·610	9·15	0·477	**10·7**	13·44	1·145
0·8	1·00	0·086	1·28	0·067	**5·8**	7·28	0·621	9·31	0·486	**10·8**	13·57	1·156
0·9	1·13	0·096	1·45	0·075	**5·9**	7·41	0·632	9·47	0·494	**10·9**	13·69	1·167
1·0	1·26	0·107	1·61	0·084	**6·0**	7·54	0·642	9·63	0·502	**11·0**	13·82	1·177
1·1	1·38	0·118	1·77	0·092	**6·1**	7·66	0·653	9·79	0·511	**11·1**	13·94	1·188
1·2	1·51	0·128	1·93	0·100	**6·2**	7·79	0·664	9·95	0·519	**11·2**	14·07	1·199
1·3	1·63	0·139	2·09	0·109	**6·3**	7·91	0·674	10·12	0·528	**11·3**	14·19	1·210
1·4	1·76	0·150	2·25	0·117	**6·4**	8·04	0·685	10·28	0·536	**11·4**	14·32	1·220
1·5	1·88	0·161	2·41	0·126	**6·5**	8·16	0·696	10·44	0·544	**11·5**	14·45	1·231
1·6	2·01	0·171	2·57	0·134	**6·6**	8·29	0·706	10·60	0·553	**11·6**	14·57	1·242
1·7	2·14	0·182	2·73	0·142	**6·7**	8·42	0·717	10·76	0·561	**11·7**	14·70	1·252
1·8	2·26	0·193	2·89	0·151	**6·8**	8·54	0·728	10·92	0·569	**11·8**	14·82	1·263
1·9	2·39	0·203	3·05	0·159	**6·9**	8·67	0·739	11·08	0·578	**11·9**	14·95	1·274
2·0	2·51	0·214	3·21	0·167	**7·0**	8·79	0·749	11·24	0·586	**12·0**	15·07	1·284
2·1	2·64	0·225	3·37	0·176	**7·1**	8·92	0·760	11·40	0·595	**12·1**	15·20	1·295
2·2	2·76	0·235	3·53	0·184	**7·2**	9·04	0·771	11·56	0·603	**12·2**	15·32	1·306
2·3	2·89	0·246	3·69	0·193	**7·3**	9·17	0·781	11·72	0·611	**12·3**	15·45	1·317
2·4	3·01	0·257	3·85	0·201	**7·4**	9·30	0·792	11·88	0·620	**12·4**	15·58	1·327
2·5	3·14	0·268	4·01	0·209	**7·5**	9·42	0·803	12·04	0·628	**12·5**	15·70	1·338
2·6	3·27	0·278	4·17	0·218	**7·6**	9·55	0·814	12·20	0·636	**12·6**	15·83	1·349
2·7	3·39	0·289	4·34	0·226	**7·7**	9·67	0·824	12·36	0·645	**12·7**	15·95	1·359
2·8	3·52	0·300	4·50	0·234	**7·8**	9·80	0·835	12·52	0·653	**12·8**	16·08	1·370
2·9	3·64	0·310	4·66	0·243	**7·9**	9·92	0·846	12·68	0·662	**12·9**	16·20	1·381
3·0	3·77	0·321	4·82	0·251	**8·0**	10·05	0·856	12·84	0·670	**13·0**	16·33	1·392
3·1	3·89	0·332	4·98	0·260	**8·1**	10·17	0·867	13·01	0·678	**13·1**	16·45	1·402
3·2	4·02	0·343	5·14	0·268	**8·2**	10·30	0·878	13·17	0·687	**13·2**	16·58	1·413
3·3	4·14	0·353	5·30	0·276	**8·3**	10·43	0·888	13·33	0·695	**13·3**	16·71	1·424
3·4	4·27	0·364	5·46	0·285	**8·4**	10·55	0·899	13·49	0·703	**13·4**	16·83	1·434
3·5	4·40	0·375	5·62	0·293	**8·5**	10·68	0·910	13·65	0·712	**13·5**	16·96	1·445
3·6	4·52	0·385	5·78	0·301	**8·6**	10·80	0·921	13·81	0·720	**13·6**	17·08	1·456
3·7	4·65	0·396	5·94	0·310	**8·7**	10·93	0·931	13·97	0·729	**13·7**	17·21	1·466
3·8	4·77	0·407	6·10	0·318	**8·8**	11·05	0·942	14·13	0·737	**13·8**	17·33	1·477
3·9	4·90	0·417	6·26	0·327	**8·9**	11·18	0·953	14·29	0·745	**13·9**	17·46	1·488
4·0	5·02	0·428	6·42	0·335	**9·0**	11·30	0·963	14·45	0·754	**14·0**	17·59	1·499
4·1	5·15	0·439	6·58	0·343	**9·1**	11·43	0·974	14·61	0·762	**14·1**	17·71	1·509
4·2	5·28	0·450	6·74	0·352	**9·2**	11·56	0·985	14·77	0·770	**14·2**	17·84	1·520
4·3	5·40	0·460	6·90	0·360	**9·3**	11·68	0·995	14·93	0·779	**14·3**	17·96	1·531
4·4	5·53	0·471	7·06	0·368	**9·4**	11·81	1·006	15·09	0·787	**14·4**	18·09	1·541
4·5	5·65	0·482	7·23	0·377	**9·5**	11·93	1·017	15·25	0·796	**14·5**	18·21	1·552
4·6	5·78	0·492	7·39	0·385	**9·6**	12·06	1·028	15·41	0·804	**14·6**	18·34	1·563
4·7	5·90	0·503	7·55	0·394	**9·7**	12·18	1·039	15·57	0·812	**14·7**	18·46	1·573
4·8	6·03	0·514	7·71	0·402	**9·8**	12·31	1·049	15·73	0·821	**14·8**	18·59	1·584
4·9	6·15	0·524	7·87	0·410	**9·9**	12·44	1·060	15·90	0·829	**14·9**	18·72	1·595
5·0	+ 6·28	+0·535	− 8·03	−0·419	**10·0**	+12·56	+1·070	−16·06	−0·837	**15·0**	+18·84	+1·606

Table for Deducing Azimuth Error and m *from Level Error and* n.

The components of *Az* and *m* with arguments *l* and *n* are to be separately taken out and then added.

Level Error or *n*.	Argument *n*. *Az*.	Argument *n*. *m*.	Level Error or *n*.	Argument Level Error. *Az*.	Argument Level Error. *m*.	Argument *n*. *Az*.	Argument *n*. *m*.	Level Error or *n*.	Argument Level Error. *Az*.	Argument Level Error. *m*.	Argument *n*. *Az*.	Argument *n*. *n*.
″	″	s	″	″	s	″	s	″	″	s	″	s
10·1	−16·22	−0·846	15·1	+18·97	+1·616	−24·24	−1·264	20·1	+25·25	+2·152	−32·27	−1·683
10·2	16·38	0·854	15·2	19·09	1·627	24·41	1·273	20·2	25·37	2·162	32·43	1·692
10·3	16·54	0·863	15·3	19·22	1·638	24·57	1·281	20·3	25·50	2·173	32·59	1·700
10·4	16·70	0·871	15·4	19·34	1·648	24·73	1·290	20·4	25·62	2·184	32·75	1·708
10·5	16·86	0·879	15·5	19·47	1·659	24·89	1·298	20·5	25·75	2·194	32·91	1·717
10·6	17·02	0·888	15·6	19·60	1·670	25·05	1·306	20·6	25·88	2·205	33·08	1·725
10·7	17·18	0·896	15·7	19·72	1·681	25·21	1·315	20·7	26·00	2·216	33·24	1·733
10·8	17·34	0·904	15·8	19·85	1·691	25·37	1·323	20·8	26·13	2·226	33·40	1·742
10·9	17·50	0·913	15·9	19·97	1·702	25·53	1·331	20·9	26·25	2·237	33·56	1·750
11·0	17·66	0·921	16·0	20·10	1·713	25·69	1·340	21·0	26·38	2·248	33·72	1·759
11·1	17·82	0·930	16·1	20·22	1·723	25·85	1·348	21·1	26·50	2·259	33·88	1·767
11·2	17·98	0·938	16·2	20·35	1·734	26·01	1·357	21·2	26·63	2·269	34·04	1·775
11·3	18·14	0·946	16·3	20·47	1·745	26·17	1·365	21·3	26·75	2·280	34·20	1·784
11·4	18·30	0·955	16·4	20·60	1·755	26·33	1·373	21·4	26·88	2·291	34·36	1·792
11·5	18·46	0·963	16·5	20·73	1·766	26·49	1·382	21·5	27·01	2·301	34·52	1·800
11·6	18·62	0·971	16·6	20·85	1·777	26·65	1·390	21·6	27·13	2·312	34·68	1·809
11·7	18·79	0·980	16·7	20·98	1·788	26·81	1·398	21·7	27·26	2·323	34·84	1·817
11·8	18·95	0·988	16·8	21·10	1·798	26·97	1·407	21·8	27·38	2·333	35·00	1·826
11·9	19·11	0·997	16·9	21·23	1·809	27·13	1·415	21·9	27·51	2·344	35·16	1·834
12·0	19·27	0·905	17·0	21·35	1·820	27·30	1·424	22·0	27·63	2·355	35·32	1·842
12·1	19·43	1·013	17·1	21·48	1·830	27·46	1·432	22·1	27·76	2·366	35·48	1·851
12·2	19·59	1·022	17·2	21·60	1·841	27·62	1·440	22·2	27·89	2·376	35·64	1·859
12·3	19·75	1·030	17·3	21·73	1·852	27·78	1·449	22·3	28·01	2·387	35·80	1·867
12·4	19·91	1·038	17·4	21·86	1·862	27·94	1·457	22·4	28·14	2·398	35·97	1·876
12·5	20·07	1·047	17·5	21·98	1·873	28·10	1·465	22·5	28·26	2·408	36·13	1·884
12·6	20·23	1·055	17·6	22·11	1·884	28·26	1·474	22·6	28·39	2·419	36·29	1·893
12·7	20·39	1·063	17·7	22·23	1·895	28·42	1·482	22·7	28·51	2·430	36·45	1·901
12·8	20·55	1·072	17·8	22·36	1·905	28·58	1·491	22·8	28·64	2·441	36·61	1·909
12·9	20·71	1·080	17·9	22·48	1·916	28·74	1·499	22·9	28·76	2·451	36·77	1·918
13·0	20·87	1·089	18·0	22·61	1·927	28·90	1·507	23·0	28·89	2·462	36·93	1·926
13·1	21·03	1·097	18·1	22·74	1·937	29·06	1·516	23·1	29·02	2·473	37·09	1·934
13·2	21·19	1·105	18·2	22·86	1·948	29·22	1·524	23·2	29·14	2·483	37·25	1·943
13·3	21·35	1·114	18·3	22·99	1·959	29·38	1·532	23·3	29·27	2·494	37·41	1·951
13·4	21·52	1·122	18·4	23·11	1·970	29·54	1·541	23·4	29·39	2·505	37·57	1·960
13·5	21·68	1·130	18·5	23·24	1·980	29·70	1·549	23·5	29·52	2·515	37·73	1·968
13·6	21·84	1·139	18·6	23·36	1·991	29·86	1·558	23·6	29·64	2·526	37·89	1·976
13·7	22·00	1·147	18·7	23·49	2·002	30·02	1·566	23·7	29·77	2·537	38·05	1·985
13·8	22·16	1·156	18·8	23·61	2·012	30·19	1·574	23·8	29·90	2·548	38·21	1·993
13·9	22·32	1·164	18·9	23·74	2·023	30·35	1·583	23·9	30·02	2·558	38·37	2·001
14·0	22·48	1·172	19·0	23·87	2·034	30·51	1·591	24·0	30·15	2·569	38·53	2·010
14·1	22·64	1·181	19·1	23·99	2·044	30·67	1·599	24·1	30·27	2·580	38·69	2·018
14·2	22·80	1·189	19·2	24·12	2·055	30·83	1·608	24·2	30·40	2·590	38·86	2·027
14·3	22·96	1·197	19·3	24·24	2·066	30·99	1·616	24·3	30·52	2·601	39·02	2·035
14·4	23·12	1·206	19·4	24·37	2·077	31·15	1·625	24·4	30·65	2·612	39·18	2·043
14·5	23·28	1·214	19·5	24·49	2·087	31·31	1·633	24·5	30·77	2·622	39·34	2·052
14·6	23·44	1·223	19·6	24·62	2·098	31·47	1·641	24·6	30·90	2·633	39·50	2·060
14·7	23·60	1·231	19·7	24·75	2·109	31·63	1·650	24·7	31·03	2·644	39·66	2·068
14·8	23·76	1·239	19·8	24·87	2·119	31·79	1·658	24·8	31·15	2·655	39·82	2·077
14·9	23·92	1·248	19·9	25·00	2·130	31·95	1·666	24·9	31·28	2·665	39·98	2·085
15·0	−24·08	−1·256	20·0	+25·12	+2·141	−32·11	−1·675	25·0	+31·40	+2·676	−40·14	−2·094

Correction for Motion of Sun in North Polar Distance.

Signs:—Sun moving South *d* 1 − 27 +; *r* 1 + 27 −.
" " North *d* 1 + 27 −; *r* 1 − 27 +.

N.P.D.	Wires. 1 / 27	2 / 26	3 / 25	4 / 24	5 / 23	6 / 22	7 / 21	8 / 20	9 / 19	11 / 17	13 / 15
° ′	″	″	″	″	″	″	″	″	″	″	″
66. 33	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00
67	·15	·12	·11	·09	·09	·08	·05	·04	·03	·02	·01
68	·27	·21	·19	·17	·15	·14	·09	·07	·05	·04	·02
69	·34	·26	·24	·22	·19	·17	·11	·10	·08	·05	·02
70	·40	·31	·28	·25	·23	·20	·13	·11	·08	·06	·03
71	·44	·34	·31	·28	·25	·22	·15	·12	·09	·06	·03
72	·48	·37	·34	·30	·27	·24	·16	·13	·10	·06	·03
73	·51	·39	·36	·32	·29	·26	·17	·14	·10	·07	·03
74	·54	·41	·38	·34	·31	·27	·18	·14	·11	·07	·04
75	·57	·44	·40	·36	·32	·29	·19	·15	·11	·08	·04
76	·59	·45	·41	·37	·33	·30	·20	·16	·12	·08	·04
77	·61	·47	·43	·39	·35	·31	·20	·16	·12	·08	·04
78	·63	·48	·44	·40	·36	·31	·21	·17	·13	·08	·04
79	·64	·49	·45	·41	·36	·32	·21	·17	·13	·09	·04
80	·65	·50	·46	·41	·37	·32	·22	·18	·13	·09	·04
81	·66	·51	·46	·42	·37	·33	·22	·18	·13	·09	·04
82	·67	·51	·47	·42	·38	·34	·22	·18	·13	·09	·04
83	·68	·52	·48	·43	·39	·34	·23	·18	·14	·09	·05
84	·69	·53	·48	·44	·39	·34	·23	·19	·14	·10	·05
85	·69	·53	·48	·44	·39	·35	·23	·19	·14	·10	·05
86	·70	·54	·49	·44	·40	·35	·23	·19	·14	·10	·05
87	·70	·54	·49	·44	·40	·35	·23	·19	·14	·10	·05
88	·71	·54	·50	·45	·40	·35	·24	·19	·14	·10	·05
89	·71	·54	·50	·45	·40	·35	·24	·19	·14	·10	·05
90	·71	·54	·50	·45	·40	·36	·24	·19	·14	·10	·05
91	·71	·54	·50	·45	·40	·36	·24	·19	·14	·10	·05
92	·71	·54	·50	·45	·40	·36	·24	·19	·14	·10	·05
93	·71	·54	·50	·45	·40	·35	·24	·19	·14	·10	·05
94	·71	·54	·50	·45	·40	·35	·24	·19	·14	·10	·05
95	·70	·54	·49	·44	·40	·35	·23	·19	·14	·10	·05
96	·70	·54	·49	·44	·40	·35	·23	·19	·14	·09	·05
97	·70	·54	·49	·44	·40	·35	·23	·19	·14	·09	·05
98	·69	·53	·48	·44	·39	·34	·23	·19	·14	·09	·05
99	·68	·52	·48	·43	·39	·34	·23	·18	·14	·09	·05
100	·67	·51	·47	·42	·38	·33	·22	·18	·13	·09	·04
101	·66	·51	·46	·42	·37	·33	·22	·18	·13	·09	·04
102	·65	·50	·46	·41	·37	·32	·22	·17	·13	·08	·04
103	·63	·48	·44	·40	·36	·32	·21	·17	·13	·08	·04
104	·61	·47	·43	·39	·35	·31	·20	·16	·12	·08	·04
105	·59	·45	·41	·37	·33	·29	·20	·16	·12	·08	·04
106	·57	·44	·40	·35	·32	·28	·19	·15	·11	·08	·04
107	·54	·41	·38	·34	·31	·27	·18	·15	·11	·07	·04
108	·51	·39	·36	·32	·29	·26	·17	·14	·10	·07	·03
109	·47	·36	·33	·30	·27	·24	·16	·13	·09	·06	·03
110	·42	·32	·29	·27	·24	·21	·14	·11	·08	·06	·03
111	·36	·28	·25	·23	·20	·18	·12	·10	·07	·05	·02
112	·29	·22	·20	·18	·16	·14	·10	·08	·06	·04	·02
113	·16	·12	·11	·10	·09	·08	·05	·04	·03	·02	·01
113. 27	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00

Table of Telescope-Micrometer Equivalents, including Corrections for Inequality of Screw (as printed in 1908 Volume p. cxi.)

Rev. of Mic.	Value in Arc.																
	0rev.	1rev.	2rev.	3rev.	4rev.	5rev.	6rev.	7rev.	8rev.	9rev.	10rev.	11rev.	12rev.	13rev.	14rev.	15rev.	16rev.
				1′	1′	1′	2′	2′	2′ or 3′	3′	3′	3′ or 4′	4′	4′	5′	5′	5′
·00	0″·73	22″·29	43″·84	5″·40	26″·98	48″·58	10″·20	31″·84	53″·50	15″·19	36″·91	58″·61	20″·29	41″·96	3″·62	25″·27	46″·89
·01	0·95	·51	44·06	·62	27·20	·80	·42	32·06	·72	·41	37·13	·83	·51	42·18	·84	·48	47·10
·02	1·16	·72	·27	·83	·41	49·01	·63	·27	·93	·62	·34	59·04	·72	·39	4·05	·69	·31
·03	·38	·94	·49	6·05	·63	·23	·85	·49	54·15	·84	·56	·26	·94	·61	·27	·91	·53
·04	·60	23·16	·71	·27	·85	·45	11·07	·71	·37	16·06	·78	·48	21·16	·83	·49	26·13	·75
·05	·81	·37	·92	·48	28·06	·66	·28	·92	·58	·27	·99	·69	·37	43·04	·70	·34	·96
·06	2·03	·59	45·14	·70	·28	·88	·50	33·14	·80	·49	38·21	·91	·59	·26	·92	·56	48·18
·07	·25	·81	·36	·92	·50	50·10	·72	·36	55·02	·71	·43	0·13	·81	·48	5·14	·78	·40
·08	·46	24·02	·57	7·13	·71	·31	·93	·57	·23	·92	·64	·34	22·02	·69	·35	·99	·61
·09	·68	·24	·79	·35	·93	·53	12·15	·79	·45	17·14	·86	·56	·24	·91	·57	27·21	·83
·10	3·89	·45	46·00	·56	29·14	·74	·37	34·01	·67	·36	39·08	·78	·46	44·13	·79	·43	49·05
·11	·10	·66	·21	·77	·35	·95	·58	·22	·88	·57	·29	·99	·67	·34	6·00	·64	·26
·12	·32	·88	·43	·99	·57	51·17	·80	·44	56·10	·79	·51	1·21	·89	·56	·22	·86	·48
·13	·54	25·10	·65	8·21	·79	·39	13·02	·66	·32	18·01	·73	·43	23·11	·78	·44	28·08	·70
·14	·76	·31	·87	·43	30·01	·61	·24	·88	·54	·23	·95	·65	·33	45·00	·66	·30	·92
·15	·97	·52	47·08	·64	·22	·82	·45	35·09	·75	·44	40·16	·86	·54	·21	·87	·51	50·13
·16	4·19	·74	·30	·86	·44	52·04	·67	·31	·97	·66	·38	2·08	·76	·43	7·09	·73	·35
·17	·41	·96	·52	9·08	·66	·26	·89	·53	57·19	·88	·60	·30	·98	·65	·31	·95	·57
·18	·62	26·17	·73	·29	·87	·47	14·10	·74	·40	19·09	·81	·51	24·19	·86	·52	29·16	·78
·19	·84	·39	·95	·51	31·09	·69	·32	·96	·62	·31	41·03	·73	·41	46·08	·74	·38	51·00
·20	5·05	·60	48·16	·72	·30	·91	·53	36·18	·84	·53	·25	·95	·63	·30	·95	·59	·21
·21	·26	·81	·37	·93	·51	53·12	·74	·39	58·05	·75	·46	3·16	·84	·51	8·16	·80	·42
·22	·48	27·03	·59	10·15	·73	·34	·96	·61	·27	·97	·68	·38	25·06	·73	·38	30·02	·64
·23	·70	·25	·81	·37	·95	·56	15·18	·83	·49	20·19	·90	·60	·28	·95	·60	·24	·86
·24	·91	·46	49·02	·58	32·16	·77	·39	37·04	·70	·40	42·11	·81	·49	47·16	·81	·45	52·07
·25	6·12	·68	·23	·80	·38	·99	·61	·26	·92	·62	·33	4·03	·71	·38	9·03	·67	·29
·26	·34	·90	·45	11·02	·60	54·21	·83	·48	59·14	·84	·55	·25	·93	·60	·25	·89	·51
·27	·55	28·11	·66	·23	·81	·42	16·04	·69	·35	21·05	·76	·46	26·14	·81	·46	31·10	·72
·28	·77	·33	·88	·45	33·03	·64	·26	·91	·57	·27	·98	·68	·36	48·03	·68	·32	·94
·29	·98	·54	50·10	·67	·25	·86	·48	38·13	·79	·49	43·20	·90	·58	·25	·90	·54	53·16
·30	7·19	·75	·31	·88	·46	55·07	·69	·34	0·00	·70	·42	5·11	·79	·46	10·11	·75	·37
·31	·41	·97	·52	12·09	·68	·28	·91	·55	·22	·92	·64	·33	27·01	·68	·33	·97	·59
·32	·63	29·19	·74	·31	·90	·50	17·13	·77	·44	22·14	·86	·55	·23	·90	·55	32·19	·81
·33	·84	·40	·95	·52	34·11	·71	·34	·98	·65	·35	44·07	·76	·44	49·11	·76	·40	54·02
·34	8·06	·62	51·17	·74	·33	·93	·56	39·20	·87	·57	·29	·98	·66	·33	·98	·62	·24
·35	·28	·84	·39	·96	·55	56·15	·78	·42	1·09	·79	·51	6·20	·88	·55	11·20	·84	·46
·36	·49	30·05	·60	13·17	·76	·36	·99	·63	·30	23·00	·72	·41	28·09	·76	·41	33·05	·67
·37	·71	·27	·82	·39	·98	·58	18·21	·85	·52	·22	·94	·63	·31	·98	·63	·27	·89
·38	·93	·49	52·04	·61	35·20	·80	·43	40·07	·74	·44	45·16	·85	·53	50·20	·85	·49	55 11
·39	9·14	·71	·25	·83	·42	57·02	·65	·29	·96	·66	·38	7·07	·75	·42	12·07	·71	·33
·40	·35	·92	·46	14·04	·63	·23	·86	·50	2·17	·88	·59	·28	·96	·63	·28	·92	·54
·41	·57	31·13	·68	·25	·84	·45	19·07	·72	·39	24·10	·81	·50	29·18	·84	·49	34·13	·75
·42	·79	·35	·90	·47	36·06	·67	·29	·94	·61	·32	46·03	·72	·40	51·06	·71	·35	·97
·43	10·00	·56	53·11	·68	·27	·88	·50	41·15	·82	·53	·24	·93	·61	·27	·92	·56	56·18
·44	·22	·78	·33	·90	·49	58·10	·72	·37	3·04	·75	·46	8·15	·83	·49	13·14	·78	·40
·45	·44	32·00	·55	15·12	·71	·32	·94	·59	·26	·97	·68	·37	30·05	·71	·36	35·00	·62
·46	·65	·21	·76	·33	·92	·53	20·15	·80	·47	25·18	·89	·58	·26	·92	·57	·21	·83
·47	·87	·43	·98	·55	37·14	·75	·37	42·02	·69	·40	47·11	·80	·48	52·14	·79	·43	57·05
·48	11·09	·65	54·20	·77	·36	·97	·59	·24	·91	·62	·33	9·02	·70	·35	14·01	·65	·27
·49	·30	·86	·41	·98	·57	59·18	20·80	·45	4·12	25·83	·54	·23	·91	·56	·22	·86	·48
·50	11·51	33·07	54·62	16·19	37·78	59·39	21·02	42·67	4·34	26·05	47·76	9·45	31·13	52·79	14·44	36·08	57·70

Table of Telescope-Micrometer Equivalents, including Corrections for Inequality of Screw—continued.

Rev. of Mic.	Value in Arc.																
	0rev.	1rev.	2rev.	3rev.	4rev.	5rev.	6rev.	7rev.	8rev.	9rev.	10rev.	11rev.	12rev.	13rev.	14rev.	15rev.	16rev.
			0′ or 1′	1′	1′	1′ or 2′	2′	2′	3′	3′	3′	4′	4′	4′ or 5′	5′	5′	5′ or 6′
	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″
·50	11·51	33·07	54·62	16·19	37·78	59·39	21·02	42·67	4·34	26·05	47·76	9·45	31·13	52·79	14·44	36·08	57·70
·51	·73	·29	·84	·41	38·00	·61	·24	·89	·56	·27	·98	·67	·35	53·01	·66	·29	·91
·52	·94	·50	55·05	·62	·21	·82	·45	43·10	·77	·48	48·19	·88	·56	·22	·87	·50	58·12
·53	12·16	·72	·27	·84	·43	0·04	·67	·32	·99	·70	·41	10·10	·78	·44	15·09	·72	·34
·54	·37	·94	·49	17·06	·65	·26	·89	·54	5·21	·92	·63	·32	32·00	·66	·31	·94	·56
·55	·59	34·15	·70	·27	·86	·47	22·10	·75	·42	27·13	·84	·53	·21	·87	·52	37·15	·77
·56	·81	·36	·92	·49	39·08	·69	·32	·97	·64	·35	49·06	·75	·43	54·09	·74	·37	·99
·57	13·03	·58	56·14	·71	·30	·91	·54	44·19	·86	·57	·28	·97	·65	·31	·96	·59	59·21
·58	·24	·79	·35	·92	·51	1·12	·75	·40	6·07	·78	·49	11·18	·86	·52	16·17	·80	·42
·59	·46	35·01	·57	18·14	·73	·34	·97	·62	·29	·99	·71	·40	33·08	·74	·39	38·02	·64
·60	·67	·22	·78	·35	·94	·55	23·19	·84	·51	28·22	·93	·62	·29	·96	·61	·23	·85
·61	·88	·43	·99	·56	40·15	·76	·40	45·05	·73	·43	50·14	·83	·50	55·17	·82	·44	0·06
·62	14·10	·65	57·21	·78	·37	·98	·62	·27	·95	·65	·36	12·05	·72	·39	17·04	·66	·28
·63	·32	·87	·43	19·00	·59	2·20	·84	·49	7·17	·87	·58	·27	·94	·61	·26	·88	·50
·64	·54	36·09	·65	·22	·81	·42	24·06	·71	·39	29·09	·80	·49	34·16	·83	·48	39·10	·72
·65	·75	·30	·86	·43	41·02	·63	·27	·92	·60	·30	51·01	·70	·37	56·04	·69	·31	·93
·66	·97	·52	58·08	·65	·24	·85	·49	46·14	·82	·52	·23	·92	·59	·26	·91	·53	1·15
·67	15·19	·74	·30	·87	·46	3·07	·71	·36	8·04	·74	·45	13·14	·81	·48	18·13	·75	·37
·68	·40	·95	·51	20·08	·67	·28	·92	·57	·25	·95	·66	·35	35·02	·69	·34	·96	·58
·69	·62	37·17	·73	·30	·89	·50	25·14	·79	·47	30·17	·88	·57	·24	·91	·56	40·18	·80
·70	·83	·38	·94	·51	42·10	·72	·35	47·01	·69	·39	52·10	·79	·46	57·13	·78	·40	2·02
·71	16·04	·59	59·15	·72	·31	·93	·56	·22	·90	·61	·31	14·00	·67	·34	·99	·61	·23
·72	·26	·81	·37	·94	·53	4·15	·78	·44	9·12	·83	·53	·22	·89	·56	19·21	·83	·45
·73	·48	38·03	·59	21·16	·75	·37	26·00	·66	·34	31·05	·75	·44	36·11	·78	·43	41·05	·67
·74	·69	·24	·80	·37	·96	·58	·21	·87	·55	·26	·96	·65	·32	·99	·64	·26	·88
·75	·90	·46	0·01	·59	43·18	·80	·43	48·09	·77	·48	53·18	·87	·54	58·21	·86	·48	3·10
·76	17·12	·68	·23	·81	·40	5·02	·65	·31	·99	·70	·40	15·09	·76	·43	20·08	·70	·32
·77	·33	·89	·44	22·02	·61	·23	·86	·52	10·20	·91	·61	·30	·97	·64	·29	·91	·53
·78	·55	39·11	·66	·24	·83	·45	27·08	·74	·42	32·13	·83	·52	37·19	·86	·51	42·13	·75
·79	·77	·32	·88	·46	44·05	·67	·30	·96	·64	·35	54·05	·74	·41	59·08	·73	·35	·97
·80	·98	·53	1·09	·67	·26	·88	·51	49·17	·85	·56	·27	·95	·62	·29	·94	·56	4·18
·81	18·19	·75	·30	·88	·48	6·09	·73	·38	11·07	·78	·49	16·17	·84	·50	21·15	·77	·39
·82	·41	·97	·52	23·10	·70	·31	·95	·60	·29	33·00	·71	·39	38·06	·72	·37	·99	·61
·83	·62	40·18	·73	·31	·91	·52	28·16	·81	·50	·21	·92	·60	·27	·93	·58	43·20	·82
·84	·84	·40	·95	·53	45·13	·74	·38	50·03	·72	·43	55·14	·82	·49	0·15	·80	·42	5·04
·85	19·06	·61	2·17	·75	·35	·96	·60	·25	·94	·65	·36	17·04	·71	·37	22·02	·64	·26
·86	·27	·82	·38	·96	·56	7·17	·81	·46	12·15	·86	·57	·25	·92	·58	·23	·85	·47
·87	·49	41·04	·60	24·18	·78	·39	29·03	·68	·37	34·08	·79	·47	39·14	·80	·45	44·07	·69
·88	·71	·26	·82	·40	46·00	·61	·25	·90	·59	·30	56·01	·69	·36	1·02	·67	·29	·91
·89	·93	·47	3·04	·62	·22	·83	·47	51·12	·81	·52	·23	·91	·58	·24	·89	·51	6·13
·90	20·14	·68	·25	·83	·43	8·04	·68	·33	13·02	·74	·44	18·12	·79	·45	23·10	·72	·34
·91	·35	·90	·46	25·04	·64	·26	·89	·55	·24	·96	·66	·34	40·01	·67	·32	·94	·56
·92	·57	42·12	·68	·26	·86	·48	30·11	·77	·46	35·18	·88	·56	·23	·89	·54	45·16	·78
·93	·78	·33	·89	·47	47·07	·69	·32	·98	·67	·39	57·09	·77	·44	2·10	·75	·37	·99
·94	21·00	·55	4·11	·69	·29	·91	·54	52·20	·89	·61	·31	·99	·66	·32	·97	·59	7·21
·95	·22	·77	·33	·91	·51	9·13	·76	·42	14·11	·83	·53	19·21	·88	·54	24·19	·81	·43
·96	·43	·98	·54	26·12	·72	·34	·97	·63	·32	36·04	·74	·42	41·09	·75	·40	46·02	·64
·97	·65	43·20	·76	·34	·94	·56	31·19	·85	·54	·26	·96	·64	·31	·97	·62	·24	·86
·98	·87	·42	·98	·56	48·16	·78	·41	53·07	·76	·48	58·18	·86	·53	3·19	·84	·46	8·08
·99	22·08	·63	5·19	·77	·37	9·99	·62	·28	14·97	·69	·39	20·07	·74	·40	25·05	·67	·29
1·00	22·29	43·84	5·40	26·98	48·58	10·20	31·84	53·50	15·19	36·91	58·61	20·29	41·96	3·62	25·27	46·89	8·50

Azimuthal Motion in Great Circle in One Sidereal Second, or of a Moon moving uniformly parallel to the Equator in One Lunar Second.

N. P. D.	Azimuth 45°.										N. P. D.
	61°.	62°.	63°.	64°.	65°.	66°.	67°.	68°.	69°.	70°.	
′ 0	11″·3347	11″·4790	11″·6183	11″·7525	11″·8816	12″·0057	12″·1247	12″·2386	12″·3476	12″·4515	′ 0
1	·3372	·4813	·6206	·7547	·8837	·0077	·1266	·2405	·3494	·4532	1
2	·3396	·4837	·6229	·7569	·8858	·0097	·1286	·2423	·3512	·4549	2
3	·3420	·4861	·6252	·7591	·8879	·0118	·1305	·2442	·3529	·4565	3
4	·3444	·4884	·6274	·7612	·8900	·0138	·1325	·2460	·3547	·4582	4
5	·3469	·4908	·6297	·7634	·8921	·0158	·1344	·2479	·3565	·4599	5
6	·3493	·4931	·6320	·7656	·8942	·0178	·1363	·2498	·3583	·4616	6
7	·3517	·4955	·6343	·7678	·8963	·0198	·1383	·2516	·3600	·4633	7
8	·3541	·4978	·6365	·7700	·8984	·0219	·1402	·2535	·3618	·4649	8
9	·3566	·5002	·6388	·7722	·9005	·0239	·1422	·2553	·3635	·4666	9
10	·3590	·5025	·6411	·7744	·9026	·0259	·1441	·2572	·3653	·4683	10
11	·3615	·5048	·6434	·7766	·9047	·0279	·1460	·2590	·3671	·4700	11
12	·3639	·5072	·6456	·7787	·9068	·0299	·1479	·2609	·3688	·4717	12
13	·3664	·5096	·6479	·7809	·9089	·0319	·1499	·2627	·3706	·4733	13
14	·3688	·5119	·6501	·7831	·9110	·0339	·1518	·2646	·3723	·4750	14
15	·3712	·5143	·6524	·7853	·9131	·0359	·1537	·2664	·3741	·4767	15
16	·3737	·5166	·6546	·7874	·9152	·0379	·1556	·2682	·3758	·4784	16
17	·3762	·5190	·6569	·7896	·9173	·0399	·1575	·2701	·3776	·4800	17
18	·3786	·5213	·6591	·7918	·9193	·0419	·1595	·2719	·3793	·4817	18
19	·3810	·5237	·6614	·7940	·9214	·0439	·1614	·2738	·3811	·4833	19
20	·3834	·5260	·6636	·7961	·9235	·0459	·1633	·2756	·3828	·4850	20
21	·3858	·5284	·6659	·7983	·9256	·0479	·1652	·2774	·3845	·4867	21
22	·3882	·5307	·6681	·8005	·9276	·0499	·1671	·2792	·3863	·4883	22
23	·3906	·5330	·6704	·8027	·9297	·0519	·1690	·2811	·3880	·4900	23
24	·3930	·5353	·6726	·8048	·9318	·0539	·1709	·2829	·3898	·4916	24
25	·3954	·5377	·6749	·8070	·9339	·0559	·1728	·2847	·3915	·4933	25
26	·3978	·5400	·6771	·8091	·9360	·0579	·1747	·2865	·3932	·4949	26
27	·4002	·5423	·6794	·8113	·9381	·0599	·1766	·2883	·3950	·4966	27
28	·4026	·5446	·6816	·8134	·9401	·0618	·1785	·2902	·3967	·4982	28
29	·4051	·5470	·6839	·8156	·9422	·0638	·1804	·2920	·3985	·4999	29
30	·4075	·5493	·6861	·8177	·9443	·0658	·1823	·2938	·4002	·5015	30
31	·4099	·5516	·6883	·8199	·9464	·0678	·1842	·2956	·4019	·5031	31
32	·4123	·5539	·6905	·8220	·9484	·0698	·1861	·2974	·4036	·5048	32
33	·4147	·5563	·6928	·8242	·9505	·0717	·1880	·2993	·4054	·5064	33
34	·4171	·5586	·6950	·8263	·9526	·0737	·1899	·3011	·4071	·5081	34
35	·4195	·5609	·6972	·8285	·9547	·0757	·1918	·3029	·4088	·5097	35
36	·4219	·5632	·6994	·8306	·9567	·0777	·1937	·3047	·4105	·5113	36
37	·4243	·5655	·7017	·8327	·9588	·0797	·1956	·3065	·4122	·5130	37
38	·4267	·5678	·7039	·8349	·9608	·0816	·1974	·3083	·4140	·5146	38
39	·4291	·5701	·7061	·8371	·9628	·0836	·1993	·3101	·4157	·5163	39
40	·4314	·5724	·7083	·8392	·9649	·0856	·2012	·3119	·4174	·5179	40
41	·4338	·5747	·7105	·8414	·9670	·0876	·2031	·3137	·4191	·5195	41
42	·4362	·5770	·7127	·8435	·9690	·0895	·2050	·3155	·4208	·5212	42
43	·4386	·5793	·7150	·8456	·9710	·0915	·2068	·3173	·4226	·5228	43
44	·4410	·5816	·7172	·8477	·9731	·0934	·2087	·3191	·4243	·5245	44
45	·4434	·5839	·7194	·8499	·9752	·0954	·2106	·3209	·4260	·5261	45
46	·4458	·5862	·7216	·8520	·9772	·0974	·2125	·3227	·4277	·5277	46
47	·4482	·5885	·7238	·8541	·9793	·0993	·2144	·3245	·4294	·5293	47
48	·4505	·5908	·7260	·8562	·9813	·1013	·2162	·3262	·4311	·5310	48
49	·4529	·5931	·7283	·8584	·9833	·1032	·2181	·3280	·4328	·5326	49
50	·4553	·5954	·7305	·8605	·9854	·1052	·2200	·3298	·4345	·5342	50
51	·4577	·5977	·7327	·8626	·9874	·1072	·2219	·3316	·4362	·5358	51
52	·4600	·6000	·7349	·8647	·9894	·1091	·2237	·3334	·4379	·5374	52
53	·4624	·6023	·7371	·8669	·9915	·1111	·2256	·3351	·4396	·5391	53
54	·4648	·6046	·7393	·8690	·9935	·1130	·2274	·3369	·4413	·5407	54
55	·4672	·6069	·7415	·8711	·9955	·1150	·2293	·3387	·4430	·5423	55
56	·4695	·6092	·7437	·8732	·9976	·1169	·2312	·3405	·4447	·5439	56
57	·4719	·6115	·7459	·8753	11·9996	·1189	·2330	·3423	·4464	·5455	57
58	·4743	·6138	·7481	·8774	12·0016	·1208	·2349	·3440	·4481	·5471	58
59	·4767	·6161	·7503	·8795	·0037	·1228	·2367	·3458	·4498	·5487	59
60	11·4790	11·6183	11·7525	11·8816	12·0057	12·1247	12·2386	12·3476	12·4515	12·5503	60

Azimuthal Motion in Great Circle in One Sidereal Second, or of a Moon moving uniformly parallel to the Equator in One Lunar Second—continued.

N.P.D.	Azimuth 45°.										N.P.D.
	71°.	72°.	73°.	74°.	75°.	76°.	77°.	78°.	79°.	80°.	
0′	12″·5503	12″·6441	12″·7328	12″·8166	12″·8952	12″·9688	13″·0374	13″·1009	13″·1593	13″·2127	0′
1	·5519	·6456	·7342	·8179	·8965	·9700	·0385	·1019	·1602	·2135	1
2	·5535	·6471	·7357	·8193	·8977	·9712	·0396	·1029	·1611	·2144	2
3	·5551	·6487	·7371	·8206	·8990	·9723	·0407	·1040	·1621	·2152	3
4	·5567	·6502	·7386	·8220	·9002	·9735	·0418	·1050	·1630	·2161	4
5	·5583	·6517	·7400	·8233	·9015	·9747	·0429	·1060	·1639	·2169	5
6	·5599	·6532	·7414	·8246	·9028	·9759	·0440	·1070	·1648	·2177	6
7	·5615	·6547	·7428	·8260	·9040	·9771	·0451	·1080	·1657	·2186	7
8	·5631	·6563	·7443	·8273	·9053	·9782	·0462	·1090	·1667	·2194	8
9	·5647	·6578	·7457	·8287	·9065	·9794	·0473	·1100	·1676	·2203	9
10	·5663	·6593	·7471	·8300	·9078	·9806	·0484	·1110	·1685	·2211	10
11	·5679	·6608	·7485	·8313	·9091	·9818	·0495	·1120	·1694	·2219	11
12	·5695	·6623	·7499	·8327	·9103	·9830	·0506	·1130	·1703	·2228	12
13	·5710	·6638	·7514	·8340	·9116	·9841	·0516	·1140	·1713	·2236	13
14	·5726	·6653	·7528	·8354	·9128	·9853	·0527	·1150	·1722	·2245	14
15	·5742	·6668	·7542	·8367	·9141	·9865	·0538	·1160	·1731	·2253	15
16	·5758	·6683	·7556	·8380	·9153	·9877	·0549	·1170	·1740	·2261	16
17	·5774	·6698	·7570	·8393	·9166	·9888	·0560	·1180	·1749	·2269	17
18	·5789	·6713	·7585	·8407	·9178	·9900	·0570	·1189	·1758	·2278	18
19	·5805	·6728	·7599	·8420	·9191	·9911	·0581	·1199	·1767	·2286	19
20	·5821	·6743	·7613	·8433	·9203	·9923	·0592	·1209	·1776	·2294	20
21	·5837	·6758	·7627	·8446	·9215	·9935	·0603	·1219	·1785	·2302	21
22	·5853	·6773	·7641	·8459	·9228	·9946	·0613	·1229	·1794	·2310	22
23	·5868	·6787	·7655	·8473	·9240	·9958	·0624	·1238	·1803	·2319	23
24	·5884	·6802	·7669	·8486	·9253	·9969	·0634	·1248	·1812	·2327	24
25	·5900	·6817	·7683	·8499	·9265	·9981	·0645	·1258	·1821	·2335	25
26	·5916	·6832	·7697	·8512	·9277	12·9992	·0656	·1268	·1830	·2343	26
27	·5931	·6847	·7711	·8525	·9290	13·0004	·0666	·1278	·1839	·2351	27
28	·5947	·6861	·7725	·8539	·9302	·0015	·0677	·1287	·1848	·2359	28
29	·5962	·6876	·7739	·8552	·9315	·0027	·0687	·1297	·1857	·2367	29
30	·5978	·6891	·7753	·8565	·9327	·0038	·0698	·1307	·1866	·2375	30
31	·5994	·6906	·7767	·8578	·9339	·0050	·0709	·1317	·1875	·2383	31
32	·6009	·6921	·7781	·8591	·9351	·0061	·0719	·1327	·1884	·2391	32
33	·6025	·6935	·7795	·8604	·9364	·0073	·0730	·1336	·1892	·2399	33
34	·6040	·6950	·7809	·8617	·9376	·0084	·0740	·1346	·1901	·2407	34
35	·6056	·6965	·7823	·8630	·9388	·0095	·0751	·1356	·1910	·2415	35
36	·6072	·6980	·7837	·8643	·9400	·0106	·0761	·1366	·1919	·2423	36
37	·6087	·6994	·7851	·8656	·9412	·0118	·0772	·1375	·1928	·2431	37
38	·6103	·7009	·7864	·8669	·9425	·0129	·0782	·1385	·1936	·2439	38
39	·6118	·7023	·7878	·8682	·9437	·0141	·0793	·1394	·1945	·2447	39
40	·6134	·7038	·7892	·8695	·9449	·0152	·0803	·1404	·1954	·2455	40
41	·6149	·7053	·7906	·8708	·9461	·0163	·0813	·1414	·1963	·2463	41
42	·6165	·7067	·7920	·8721	·9473	·0174	·0824	·1423	·1972	·2471	42
43	·6180	·7082	·7933	·8734	·9485	·0186	·0834	·1433	·1980	·2478	43
44	·6196	·7096	·7947	·8747	·9497	·0197	·0845	·1442	·1989	·2486	44
45	·6211	·7111	·7961	·8760	·9509	·0208	·0855	·1452	·1998	·2494	45
46	·6226	·7126	·7975	·8773	·9521	·0219	·0865	·1461	·2007	·2502	46
47	·6242	·7140	·7989	·8786	·9533	·0230	·0876	·1471	·2015	·2510	47
48	·6257	·7155	·8002	·8798	·9545	·0242	·0886	·1480	·2024	·2517	48
49	·6273	·7169	·8016	·8811	·9557	·0253	·0897	·1490	·2032	·2525	49
50	·6288	·7184	·8030	·8824	·9569	·0264	·0907	·1499	·2041	·2533	50
51	·6303	·7198	·8044	·8837	·9581	·0275	·0917	·1508	·2050	·2541	51
52	·6319	·7213	·8057	·8850	·9593	·0286	·0927	·1518	·2058	·2549	52
53	·6334	·7227	·8071	·8862	·9605	·0297	·0938	·1527	·2067	·2556	53
54	·6350	·7242	·8084	·8875	·9617	·0308	·0948	·1537	·2075	·2564	54
55	·6365	·7256	·8098	·8888	·9629	·0319	·0958	·1546	·2084	·2572	55
56	·6380	·7270	·8112	·8901	·9641	·0330	·0968	·1555	·2093	·2580	56
57	·6395	·7285	·8125	·8914	·9653	·0341	·0978	·1565	·2101	·2587	57
58	·6411	·7299	·8139	·8926	·9664	·0352	·0989	·1574	·2110	·2595	58
59	·6426	·7314	·8152	·8939	·9676	·0363	·0999	·1584	·2118	·2602	59
60	12·6441	12·7328	12·8166	12·8952	12·9688	13·0374	13·1009	13·1593	13·2127	13·2610	60

Azimuthal Motion in Great Circle in One Sidereal Second, or of a Moon moving uniformly parallel to the Equator in One Lunar Second—continued.

N.P.D.	Azimuth 45°.									N.P.D.
	81°.	82°.	83°.	84°.	85°.	86°.	87°.	88°.	89°.	
′ 0	13″·2610	13″·3042	13″·3423	13″·3754	13″·4033	13″·4262	13″·4441	13″·4568	13″·4644	′ 0
1	·2618	·3049	·3429	·3759	·4037	·4265	·4444	·4570	·4645	1
2	·2625	·3056	·3435	·3764	·4041	·4269	·4446	·4571	·4646	2
3	·2633	·3062	·3441	·3769	·4046	·4272	·4449	·4573	·4646	3
4	·2640	·3069	·3447	·3774	·4050	·4276	·4451	·4574	·4647	4
5	·2648	·3076	·3453	·3779	·4054	·4279	·4454	·4576	·4648	5
6	·2656	·3083	·3459	·3784	·4058	·4282	·4456	·4578	·4649	6
7	·2663	·3089	·3464	·3789	·4062	·4286	·4459	·4579	·4650	7
8	·2671	·3096	·3470	·3794	·4067	·4289	·4461	·4581	·4650	8
9	·2678	·3102	·3476	·3799	·4071	·4293	·4464	·4582	·4651	9
10	·2686	·3109	·3482	·3804	·4075	·4296	·4466	·4584	·4652	10
11	·2693	·3116	·3488	·3809	·4079	·4299	·4468	·4586	·4653	11
12	·2701	·3122	·3494	·3814	·4083	·4302	·4471	·4587	·4653	12
13	·2708	·3129	·3499	·3819	·4087	·4306	·4473	·4589	·4654	13
14	·2716	·3135	·3505	·3824	·4091	·4309	·4476	·4590	·4654	14
15	·2723	·3142	·3511	·3829	·4095	·4312	·4478	·4592	·4655	15
16	·2730	·3149	·3517	·3834	·4099	·4315	·4480	·4593	·4656	16
17	·2738	·3155	·3522	·3839	·4103	·4318	·4482	·4595	·4656	17
18	·2745	·3162	·3528	·3843	·4107	·4322	·4485	·4596	·4657	18
19	·2753	·3168	·3533	·3848	·4111	·4325	·4487	·4598	·4657	19
20	·2760	·3175	·3539	·3853	·4115	·4328	·4489	·4599	·4658	20
21	·2767	·3181	·3545	·3858	·4119	·4331	·4491	·4600	·4659	21
22	·2774	·3188	·3550	·3863	·4123	·4334	·4493	·4602	·4659	22
23	·2782	·3194	·3556	·3867	·4127	·4337	·4496	·4603	·4660	23
24	·2789	·3201	·3561	·3872	·4131	·4340	·4498	·4605	·4660	24
25	·2796	·3207	·3567	·3877	·4135	·4343	·4500	·4606	·4661	25
26	·2803	·3213	·3573	·3882	·4139	·4346	·4502	·4607	·4661	26
27	·2810	·3220	·3578	·3886	·4143	·4349	·4504	·4608	·4662	27
28	·2818	·3226	·3584	·3891	·4146	·4352	·4507	·4610	·4662	28
29	·2825	·3233	·3589	·3895	·4150	·4356	·4509	·4611	·4663	29
30	·2832	·3239	·3595	·3900	·4154	·4358	·4511	·4612	·4663	30
31	·2839	·3245	·3600	·3905	·4158	·4361	·4513	·4613	·4663	31
32	·2846	·3252	·3606	·3909	·4162	·4364	·4515	·4614	·4664	32
33	·2854	·3258	·3611	·3914	·4165	·4367	·4517	·4616	·4664	33
34	·2861	·3265	·3617	·3918	·4169	·4370	·4519	·4617	·4665	34
35	·2868	·3271	·3622	·3923	·4173	·4373	·4521	·4618	·4665	35
36	·2875	·3277	·3627	·3928	·4177	·4376	·4523	·4619	·4665	36
37	·2882	·3283	·3633	·3932	·4181	·4379	·4525	·4620	·4665	37
38	·2890	·3290	·3638	·3937	·4184	·4381	·4527	·4622	·4466	38
39	·2897	·3296	·3644	·3941	·4188	·4384	·4529	·4623	·4466	39
40	·2904	·3302	·3649	·3946	·4192	·4387	·4531	·4624	·4466	40
41	·2911	·3308	·3654	·3950	·4196	·4390	·4533	·4625	·4466	41
42	·2918	·3314	·3660	·3955	·4199	·4393	·4535	·4626	·4466	42
43	·2925	·3321	·3665	·3959	·4203	·4395	·4537	·4628	·4467	43
44	·2932	·3327	·3671	·3964	·4206	·4398	·4539	·4629	·4467	44
45	·2939	·3333	·3676	·3968	·4210	·4401	·4541	·4630	·4467	45
46	·2946	·3339	·3681	·3972	·4214	·4404	·4543	·4631	·4467	46
47	·2953	·3345	·3686	·3977	·4217	·4407	·4545	·4632	·4467	47
48	·2960	·3351	·3692	·3981	·4221	·4409	·4546	·4633	·4468	48
49	·2967	·3357	·3697	·3986	·4224	·4412	·4548	·4634	·4468	49
50	·2974	·3363	·3702	·3990	·4228	·4415	·4550	·4635	·4468	50
51	·2981	·3369	·3707	·3994	·4231	·4418	·4552	·4636	·4468	51
52	·2988	·3375	·3712	·3999	·4235	·4420	·4554	·4637	·4468	52
53	·2994	·3381	·3718	·4003	·4238	·4423	·4555	·4638	·4468	53
54	·3001	·3387	·3723	·4008	·4242	·4425	·4557	·4639	·4468	54
55	·3008	·3393	·3728	·4012	·4245	·4428	·4559	·4640	·4469	55
56	·3015	·3399	·3733	·4016	·4248	·4431	·4561	·4641	·4469	56
57	·3022	·3405	·3738	·4020	·4252	·4433	·4563	·4642	·4469	57
58	·3028	·3411	·3744	·4025	·4255	·4436	·4564	·4642	·4469	58
59	·3035	·3417	·3749	·4029	·4259	·4438	·4566	·4643	·4469	59
60	13·3042	13·3423	13·3754	13·4033	13·4262	13·4441	13·4568	13·4644	13·4469	60

Azimuthal Motion in Great Circle in One Sidereal Second, or of a Moon moving uniformly parallel to the Equator in One Lunar Second—continued.

N.P.D.	Azimuth 30°.										N.P.D.
	61°.	62°.	63°.	64°.	65°.	66°.	67°.	68°.	69°.	70°.	
′ 0	″ 12·2595	″ 12·3930	″ 12·5222	″ 12·6468	″ 12·7669	″ 12·8824	″ 12·9934	″ 13·0998	″ 13·2017	″ 13·2989	′ 0
1	·2618	·3952	·5243	·6488	·7689	·8843	·9952	·1016	·2033	·3004	1
2	·2640	·3974	·5264	·6509	·7709	·8862	·9970	·1033	·2050	·3020	2
3	·2663	·3996	·5285	·6529	·7728	·8881	·9988	·1050	·2066	·3036	3
4	·2685	·4018	·5306	·6550	·7747	·8900	13·0007	·1068	·2083	·3052	4
5	·2708	·4040	·5327	·6570	·7767	·8919	·0025	·1085	·2099	·3068	5
6	·2731	·4061	·5349	·6590	·7787	·8937	·0043	·1102	·2116	·3083	6
7	·2754	·4083	·5380	·6610	·7806	·8956	·0061	·1119	·2132	·3099	7
8	·2776	·4105	·5391	·6631	·7826	·8975	·0079	·1137	·2149	·3115	8
9	·2799	·4127	·5412	·6651	·7845	·8994	·0097	·1154	·2165	·3130	9
10	·2821	·4149	·5433	·6671	·7865	·9012	·0115	·1171	·2182	·3146	10
11	·2844	·4170	·5454	·6692	·7884	·9031	·0133	·1188	·2198	·3162	11
12	·2866	·4192	·5475	·6712	·7904	·9050	·0151	·1206	·2215	·3178	12
13	·2889	·4214	·5496	·6732	·7923	·9069	·0169	·1223	·2231	·3193	13
14	·2911	·4236	·5517	·6752	·7943	·9087	·0187	·1240	·2247	·3209	14
15	·2934	·4257	·5538	·6772	·7962	·9106	·0204	·1257	·2264	·3224	15
16	·2956	·4279	·5559	·6793	·7982	·9125	·0222	·1274	·2280	·3240	16
17	·2979	·4301	·5580	·6813	·8001	·9143	·0240	·1291	·2297	·3256	17
18	·3001	·4323	·5601	·6833	·8020	·9162	·0258	·1309	·2313	·3271	18
19	·3024	·4344	·5621	·6853	·8040	·9181	·0276	·1326	·2329	·3287	19
20	·3046	·4366	·5642	·6873	·8059	·9199	·0294	·1343	·2346	·3302	20
21	·3069	·4387	·5663	·6894	·8079	·9218	·0312	·1360	·2362	·3318	21
22	·3091	·4409	·5684	·6914	·8098	·9237	·0330	·1377	·2378	·3334	22
23	·3113	·4430	·5705	·6934	·8117	·9255	·0347	·1394	·2395	·3349	23
24	·3135	·4452	·5726	·6954	·8137	·9274	·0365	·1411	·2411	·3365	24
25	·3158	·4474	·5747	·6974	·8156	·9292	·0383	·1428	·2427	·3380	25
26	·3180	·4496	·5768	·6994	·8175	·9311	·0401	·1445	·2443	·3396	26
27	·3202	·4517	·5788	·7014	·8195	·9329	·0419	·1462	·2460	·3411	27
28	·3224	·4539	·5809	·7034	·8214	·9348	·0436	·1479	·2476	·3427	28
29	·3247	·4560	·5830	·7054	·8233	·9366	·0454	·1496	·2492	·3442	29
30	·3269	·4582	·5851	·7074	·8252	·9385	·0472	·1513	·2508	·3457	30
31	·3291	·4603	·5872	·7094	·8272	·9403	·0490	·1530	·2524	·3473	31
32	·3313	·4625	·5892	·7114	·8291	·9422	·0507	·1547	·2541	·3488	32
33	·3335	·4646	·5913	·7134	·8310	·9440	·0525	·1564	·2556	·3504	33
34	·3358	·4668	·5934	·7154	·8329	·9459	·0543	·1581	·2573	·3519	34
35	·3380	·4689	·5954	·7174	·8349	·9477	·0561	·1598	·2589	·3534	35
36	·3402	·4711	·5975	·7194	·8368	·9496	·0578	·1615	·2605	·3550	36
37	·3424	·4732	·5596	·7214	·8387	·9514	·0596	·1632	·2621	·3565	37
38	·3446	·4754	·6016	·7234	·8406	·9532	·0614	·1649	·2637	·3580	38
39	·3468	·4775	·6037	·7254	·8425	·9551	·0631	·1665	·2654	·3596	39
40	·3490	·4796	·6058	·7274	·8444	·9569	·0649	·1682	·2670	·3611	40
41	·3513	·4818	·6078	·7294	·8463	·9588	·0666	·1699	·2686	·3626	41
42	·3535	·4839	·6099	·7313	·8483	·9606	·0684	·1716	·2702	·3642	42
43	·3557	·4861	·6120	·7333	·8502	·9624	·0701	·1733	·2718	·3657	43
44	·3579	·4882	·6140	·7353	·8521	·9643	·0719	·1750	·2734	·3672	44
45	·3601	·4903	·6161	·7373	·8540	·9661	·0737	·1766	·2750	·3687	45
46	·3623	·4925	·6181	·7393	·8559	·9679	·0754	·1783	·2766	·3703	46
47	·3645	·4946	·6202	·7413	·8578	·9698	·0772	·1800	·2782	·3718	47
48	·3667	·4967	·6223	·7432	·8597	·9716	·0789	·1817	·2798	·3733	48
49	·3689	·4989	·6243	·7452	·8616	·9734	·0807	·1833	·2814	·3748	49
50	·3711	·5010	·6264	·7472	·8635	·9752	·0824	·1850	·2830	·3763	50
51	·3733	·5031	·6284	·7492	·8654	·9771	·0842	·1867	·2846	·3779	51
52	·3755	·5052	·6305	·7512	·8673	·9789	·0859	·1884	·2862	·3794	52
53	·3777	·5074	·6325	·7531	·8692	·9807	·0877	·1900	·2878	·3809	53
54	·3799	·5095	·6345	·7551	·8711	·9825	·0894	·1917	·2893	·3824	54
55	·3821	·5116	·6366	·7571	·8730	·9843	·0911	·1933	·2909	·3839	55
56	·3843	·5137	·6387	·7590	·8749	·9862	·0929	·1950	·2925	·3854	56
57	·3865	·5158	·6407	·7610	·8768	·9880	·0946	·1967	·2941	·3869	57
58	·3887	·5180	·6427	·7630	·8787	·9898	·0964	·1983	·2957	·3884	58
59	·3909	·5201	·6448	·7649	·8805	·9916	·0981	·2000	·2973	·3900	59
60	12·3930	12·5222	12·6468	12·7669	12·8824	12·9934	13·0998	13·2017	13·2989	13·3915	60

Azimuthal Motion in Great Circle in One Sidereal Second, or of a Moon moving uniformly parallel to the Equator in One Lunar Second—continued.

N.P.D.	Azimuth 30°.										N.P.D.
	71°.	72°.	73°.	74°.	75°.	76°.	77°.	78°.	79°.	80°.	
′ 0	13″·3915	13″·4794	13″·5627	13″·6413	13″·7152	13″·7845	13″·8490	13″·9088	13″·9638	14″·0141	′ 0
1	·3930	·4808	·5640	·6426	·7164	·7856	·8500	·9097	·9647	·0149	1
2	·3945	·4822	·5654	·6438	·7176	·7867	·8510	·9107	·9656	·0157	2
3	·3960	·4837	·5667	·6451	·7188	·7878	·8521	·9116	·9664	·0165	3
4	·3975	·4851	·5681	·6464	·7200	·7889	·8531	·9126	·9673	·0173	4
5	·3990	·4865	·5694	·6476	·7212	·7901	·8541	·9135	·9682	·0181	5
6	·4005	·4879	·5708	·6489	·7224	·7912	·8552	·9144	·9691	·0189	6
7	·4020	·4893	·5721	·6502	·7236	·7923	·8562	·9154	·9699	·0197	7
8	·4035	·4908	·5734	·6514	·7248	·7934	·8572	·9164	·9708	·0204	8
9	·4049	·4922	·5748	·6527	·7259	·7945	·8582	·9173	·9717	·0212	9
10	·4064	·4936	·5761	·6539	·7271	·7956	·8593	·9183	·9725	·0220	10
11	·4079	·4950	·5775	·6552	·7283	·7967	·8603	·9192	·9734	·0228	11
12	·4094	·4964	·5788	·6565	·7295	·7978	·8613	·9202	·9743	·0236	12
13	·4109	·4978	·5801	·6577	·7306	·7989	·8623	·9211	·9751	·0244	13
14	·4124	·4992	·5814	·6590	·7318	·8000	·8633	·9220	·9760	·0251	14
15	·4139	·5006	·5828	·6602	·7330	·8011	·8644	·9230	·9768	·0259	15
16	·4154	·5021	·5841	·6615	·7342	·8021	·8654	·9239	·9777	·0267	16
17	·4168	·5035	·5854	·6627	·7353	·8032	·8664	·9248	·9785	·0275	17
18	·4183	·5049	·5868	·6640	·7365	·8043	·8674	·9258	·9794	·0283	18
19	·4198	·5063	·5881	·6652	·7377	·8054	·8684	·9267	·9802	·0290	19
20	·4213	·5077	·5894	·6665	·7389	·8065	·8694	·9276	·9811	·0298	20
21	·4228	·5091	·5907	·6677	·7400	·8076	·8704	·9286	·9819	·0306	21
22	·4242	·5105	·5921	·6689	·7412	·8087	·8715	·9295	·9828	·0313	22
23	·4257	·5119	·5934	·6702	·7423	·8098	·8725	·9304	·9837	·0321	23
24	·4272	·5133	·5947	·6714	·7435	·8109	·8735	·9313	·9845	·0329	24
25	·4287	·5147	·5960	·6727	·7447	·8119	·8745	·9323	·9853	·0336	25
26	·4301	·5161	·5973	·6739	·7458	·8130	·8755	·9332	·9862	·0344	26
27	·4316	·5175	·5986	·6752	·7470	·8141	·8765	·9341	·9870	·0352	27
28	·4331	·5188	·6000	·6764	·7482	·8152	·8775	·9350	·9879	·0359	28
29	·4345	·5202	·6013	·6776	·7493	·8162	·8785	·9360	·9887	·0367	29
30	·4360	·5216	·6026	·6788	·7505	·8173	·8795	·9369	·9895	·0375	30
31	·4375	·5230	·6039	·6801	·7516	·8184	·8805	·9378	·9904	·0382	31
32	·4389	·5244	·6052	·6813	·7528	·8195	·8815	·9387	·9912	·0390	32
33	·4404	·5258	·6065	·6825	·7539	·8205	·8824	·9396	·9920	·0397	33
34	·4419	·5272	·6078	·6838	·7551	·8216	·8834	·9405	·9929	·0405	34
35	·4433	·5285	·6091	·6850	·7562	·8227	·8844	·9415	·9937	·0412	35
36	·4448	·5299	·6104	·6862	·7574	·8238	·8854	·9424	·9946	·0420	36
37	·4462	·5313	·6117	·6874	·7585	·8248	·8864	·9433	·9954	·0428	37
38	·4477	·5327	·6130	·6887	·7597	·8259	·8874	·9442	·9962	·0435	38
39	·4491	·5341	·6143	·6899	·7608	·8269	·8884	·9451	·9970	·0442	39
40	·4506	·5354	·6156	·6911	·7619	·8280	·8894	·9460	·9979	·0450	40
41	·4520	·5368	·6169	·6923	·7631	·8291	·8903	·9469	·9987	·0457	41
42	·4535	·5382	·6182	·6935	·7642	·8301	·8913	·9478	13·9995	·0465	42
43	·4549	·5396	·6195	·6948	·7654	·8312	·8923	·9487	14·0003	·0472	43
44	·4564	·5409	·6208	·6960	·7665	·8322	·8933	·9496	·0012	·0480	44
45	·4578	·5423	·6221	·6972	·7676	·8333	·8942	·9505	·0020	·0487	45
46	·4593	·5437	·6234	·6984	·7688	·8343	·8952	·9514	·0028	·0494	46
47	·4607	·5450	·6247	·6996	·7699	·8354	·8962	·9523	·0036	·0502	47
48	·4622	·5464	·6260	·7008	·7710	·8365	·8972	·9532	·0044	·0509	48
49	·4636	·5478	·6272	·7020	·7722	·8375	·8981	·9541	·0052	·0516	49
50	·4651	·5491	·6285	·7032	·7733	·8386	·8991	·9550	·0060	·0524	50
51	·4665	·5505	·6298	·7044	·7744	·8396	·9001	·9558	·0069	·0531	51
52	·4679	·5519	·6311	·7057	·7755	·8407	·9011	·9567	·0077	·0538	52
53	·4694	·5532	·6324	·7069	·7767	·8417	·9020	·9576	·0085	·0546	53
54	·4708	·5546	·6336	·7081	·7778	·8427	·9030	·9585	·0093	·0553	54
55	·4722	·5559	·6349	·7093	·7789	·8438	·9039	·9594	·0101	·0560	55
56	·4737	·5573	·6362	·7105	·7800	·8448	·9049	·9603	·0109	·0568	56
57	·4751	·5586	·6375	·7117	·7812	·8459	·9059	·9612	·0117	·0575	57
58	4765	·5600	·6387	·7129	·7823	·8469	·9068	·9620	·0125	0582	58
59	·4780	·5613	·6400	·7140	·7834	·8479	·9078	·9629	·0133	·0589	59
60	13·4794	13·5627	13·6413	13·7152	13·7845	13·8490	13·9088	13·9638	14·0141	14·0596	60

Azimuthal Motion in Great Circle in One Sidereal Second, or of a Moon moving uniformly parallel to the Equator in One Lunar Second—continued.

N.P.D.	Azimuth 30°.									N.P.D.
	81°.	82°.	83°.	84°.	85°.	86°.	87°.	88°.	89°.	
′ 0	″ 14·0596	″ 14·1004	″ 14·1364	″ 14·1676	″ 14·1940	″ 14·2157	″ 14·2325	″ 14·2445	″ 14·2517	′ 0
1	·0604	·1011	·1370	·1681	·1944	·2160	·2327	·2447	·2518	1
2	·0611	·1017	·1375	·1686	·1948	·2163	·2330	·2448	·2519	2
3	·0618	·1023	·1381	·1691	·1952	·2166	·2332	·2450	·2519	3
4	·0625	·1030	·1386	·1695	·1956	·2169	·2334	·2451	·2520	4
5	·0632	·1036	·1392	·1700	·1960	·2172	·2337	·2453	·2521	5
6	·0639	·1042	·1397	·1705	·1964	·2175	·2339	·2454	·2522	6
7	·0647	·1049	·1403	·1710	·1968	·2179	·2341	·2456	·2522	7
8	·0654	·1055	·1408	·1714	·1972	·2182	·2344	·2457	·2523	8
9	·0661	·1061	·1414	·1719	·1976	·2185	·2346	·2459	·2524	9
10	·0668	·1067	·1419	·1724	·1980	·2188	·2348	·2460	·2524	10
11	·0675	·1074	·1425	·1728	·1984	·2191	·2350	·2462	·2525	11
12	·0682	·1080	·1430	·1733	·1988	·2194	·2353	·2463	·2526	12
13	·0689	·1086	·1436	·1738	·1991	·2197	·2355	·2465	·2526	13
14	·0696	·1092	·1441	·1742	·1995	·2200	·2357	·2466	·2527	14
15	·0703	·1099	·1446	·1747	·1999	·2203	·2359	·2467	·2527	15
16	·0710	·1105	·1452	·1751	·2003	·2206	·2362	·2469	·2528	16
17	·0717	·1111	·1457	·1756	·2007	·2209	·2364	·2470	·2529	17
18	·0724	·1117	·1463	·1761	·2010	·2212	·2366	·2472	·2529	18
19	·0731	·1123	·1468	·1765	·2014	·2215	·2368	·2473	·2530	19
20	·0738	·1129	·1473	·1770	·2018	·2218	·2370	·2474	·2531	20
21	·0745	·1136	·1479	·1774	·2022	·2221	·2372	·2476	·2531	21
22	·0751	·1142	·1484	·1779	·2025	·2224	·2374	·2477	·2532	22
23	·0758	·1148	·1489	·1783	·2029	·2227	·2377	·2478	·2532	23
24	·0765	·1154	·1495	·1788	·2033	·2230	·2379	·2480	·2532	24
25	·0772	·1160	·1500	·1792	·2036	·2232	·2381	·2481	·2533	25
26	·0779	·1166	·1505	·1797	·2040	·2235	·2383	·2482	·2534	26
27	·0786	·1172	·1510	·1801	·2044	·2238	·2385	·2483	·2534	27
28	·0793	·1178	·1516	·1806	·2047	·2241	·2387	·2485	·2535	28
29	·0799	·1184	·1521	·1810	·2051	·2244	·2389	·2486	·2535	29
30	·0806	·1190	·1526	·1814	·2054	·2247	·2391	·2487	·2535	30
31	·0813	·1196	·1531	·1819	·2058	·2249	·2393	·2488	·2535	31
32	·0820	·1202	·1536	·1823	·2062	·2252	·2395	·2489	·2536	32
33	·0827	·1208	·1542	·1827	·2065	·2255	·2397	·2490	·2536	33
34	·0833	·1214	·1547	·1832	·2069	·2258	·2399	·2492	·2537	34
35	·0840	·1220	·1552	·1836	·2072	·2260	·2401	·2493	·2537	35
36	·0847	·1226	·1557	·1841	·2076	·2263	·2403	·2494	·2537	36
37	·0854	·1232	·1562	·1845	·2079	·2266	·2405	·2495	·2538	37
38	·0860	·1238	·1567	·1849	·2083	·2269	·2407	·2496	·2538	38
39	·0867	·1244	·1572	·1853	·2086	·2271	·2409	·2497	·2538	39
40	·0874	·1249	·1577	·1858	·2090	·2274	·2410	·2498	·2538	40
41	·0880	·1255	·1583	·1862	·2093	·2277	·2412	·2499	·2539	41
42	·0887	·1261	·1588	·1866	·2097	·2279	·2414	·2500	·2539	42
43	·0893	·1267	·1593	·1870	·2100	·2282	·2416	·2501	·2539	43
44	·0900	·1273	·1598	·1875	·2104	·2285	·2418	·2503	·2539	44
45	·0907	·1279	·1603	·1879	·2107	·2287	·2419	·2504	·2540	45
46	·0913	·1284	·1608	·1883	·2110	·2290	·2421	·2504	·2540	46
47	·0920	·1290	·1613	·1887	·2114	·2292	·2423	·2505	·2540	47
48	·0926	·1296	·1618	·1891	·2117	·2295	·2425	·2506	·2540	48
49	·0933	·1302	·1623	·1896	·2121	·2297	·2427	·2507	·2540	49
50	·0939	·1308	·1627	·1900	·2124	·2300	·2428	·2508	·2540	50
51	·0946	·1313	·1632	·1904	·2127	·2303	·2430	·2509	·2540	51
52	·0953	·1319	·1637	·1908	·2131	·2305	·2432	·2510	·2541	52
53	·0959	·1325	·1642	·1912	·2134	·2308	·2433	·2511	·2541	53
54	·0966	·1330	·1647	·1916	·2137	·2310	·2435	·2512	·2541	54
55	·0972	·1336	·1652	·1920	·2140	·2313	·2437	·2513	·2541	55
56	·0978	·1342	·1657	·1924	·2144	·2315	·2438	·2514	·2541	56
57	·0985	·1347	·1662	·1928	·2147	·2317	·2440	·2515	·2541	57
58	·0991	·1353	·1667	·1932	·2150	·2320	·2442	·2515	·2541	58
59	·0998	·1358	·1671	·1936	·2153	·2322	·2443	·2516	·2541	59
60	14·1004	14·1364	14·1676	14·1940	14·2157	14·2325	14·2445	14·2517	14·2541	60

Time Interval between the Passages over two consecutive close Vertical Wires in the different Azimuths.

N.P.D.	Azimuth.						N.P.D.	Azimuth.					
	90°.	80°.	70°.	60°.	45°.	30°.		90°.	80°.	70°.	60°.	45°.	30°.
° ′	s	s	s	s	s	s	° ′	s	s	s	s	s	s
19	...	...	...	...	...	15·26	40	9·09	7·50	5·43	4·13	3·08	2·57
19 30	...	...	...	...	...	12·00	40 30	7·79	6·78	5·13	3·99	3·02	2·53
20	...	...	...	...	...	10·21	41	7·01	6·07	4·87	3·87	2·97	2·50
20 30	...	...	...	...	...	9·01	41 30	6·37	5·75	4·65	3·75	2·91	2·47
21	...	...	...	...	...	8·15	42	5·90	5·40	4·46	3·65	2·86	2·44
21 30	...	...	...	...	...	7·47	42 30	5·51	5·09	4·28	3·55	2·81	2·41
22	...	...	...	...	...	6·93	43	5·20	4·84	4·12	3·46	2·77	2·38
22 30	...	...	...	...	...	6·49	43 30	4·92	4·62	3·99	3·38	2·73	2·35
23	...	...	...	...	...	6·12	44	4·70	4·43	3·86	3·30	2·69	2·32
23 30	...	...	...	...	...	5·80	44 30	4·49	4·25	3·74	3·23	2·65	2·30
24	...	...	...	...	...	5·52	45	4·31	4·10	3·64	3·16	2·61	2·28
24 30	...	...	...	...	...	5·27	46	4·02	3·84	3·45	3·03	2·54	2·23
25	...	...	...	...	...	5·05	47	3·77	3·62	3·29	2·92	2·47	2·18
25 30	...	...	...	...	...	4·86	48	3·56	3·44	3·15	2·82	2·41	2·14
26	...	...	...	...	...	4·68	49	3·39	3·28	3·03	2·74	2·35	2·10
26 30	...	...	...	...	...	4·52	50	3·24	3·15	2·92	2·65	2·30	2·06
27	...	...	...	...	13·14	4·37	51	3·11	3·03	2·82	2·58	2·25	2·03
27 30	...	...	...	...	10·42	4·23	52	2·99	2·92	2·74	2·51	2·21	1·99
28	...	...	...	...	8·88	4·11	53	2·89	2·82	2·66	2·45	2·17	1·96
28 30	...	...	...	...	7·86	3·99	54	2·80	2·74	2·59	2·39	2·13	1·93
29	...	...	...	...	7·12	3·88	55	2·71	2·66	2·52	2·34	2·09	1·91
29 30	...	...	...	...	6·56	3·78	56	2·64	2·59	2·46	2·29	2·06	1·88
30	...	...	...	...	6·10	3·69	57	2·57	2·53	2·40	2·25	2·02	1·85
30 30	...	...	...	...	5·72	3·60	58	2·51	2·47	2·35	2·21	1·99	1·83
31	...	...	...	...	5·41	3·52	59	2·45	2·41	2·30	2·17	1·96	1·81
31 30	...	...	...	...	5·14	3·44	60	2·40	2·36	2·26	2·13	1·94	1·79
32	...	...	...	...	4·90	3·37	62	2·31	2·27	2·18	2·07	1·89	1·75
32 30	...	...	...	...	4·69	3·30	64	2·23	2·20	2·12	2·01	1·84	1·71
33	...	...	...	19·04	4·51	3·23	66	2·16	2·14	2·06	1·96	1·80	1·68
33 30	...	...	...	12·36	4·34	3·17	68	2·10	2·08	2·01	1·91	1·77	1·65
34	...	...	...	9·78	4·19	3·11	70	2·05	2·03	1·97	1·88	1·74	1·63
34 30	...	...	...	8·36	4·05	3·05	72	2·01	1·99	1·93	1·85	1·71	1·61
35	...	...	...	7·39	3·93	3·00	74	1·97	1·95	1·90	1·82	1·69	1·59
35 30	...	...	...	6·71	3·82	2·95	76	1·94	1·92	1·87	1·79	1·67	1·57
36	...	...	27·10	6·19	3·71	2·90	78	1·92	1·89	1·84	1·77	1·65	1·56
36 30	...	...	13·64	5·76	3·61	2·85	80	1·89	1·87	1·82	1·75	1·64	1·55
37	...	...	10·31	5·41	3·52	2·80	82	1·88	1·85	1·81	1·74	1·63	1·54
37 30	...	...	8·65	5·12	3·44	2·76	84	1·87	1·84	1·80	1·73	1·62	1·53
38	...	27·46	7·57	4·86	3·36	2·72	86	1·86	1·84	1·79	1·73	1·62	1·53
38 30	...	13·60	6·81	4·65	3·28	2·68	88	1·85	1·83	1·78	1·72	1·61	1·52
39	16·08	10·23	6·24	4·45	3·21	2·65	90	1·84	1·83	1·78	1·71	1·61	1·52
39 30	11·10	8·57	5·80	4·28	3·14	2·61							

The quantities are deduced from the formula $\frac{21{\cdot}65 \text{ tan parallactic angle}}{15 \text{ sin colatitude sin azimuth}}$.

Log sin parallactic angle + log sin N.P.D. =

9·7943703 Azimuth 90°	9·7673561 Azimuth 70°	9·6438553 Azimuth 45°
9·7877218 „ 80°	9·7319009 „ 60°	9·4933403 „ 30°

The above quantities are log sin perpendicular from pole on Azimuth = log (sin colat sin Azimuth).

Hence the value of the time interval can be written as $\frac{21{\cdot}65}{15}$ sec par. angle cosec N.P.D.