ADDRESS

OF

THE ASTRONOMER ROYAL

TO

THE INDIVIDUAL MEMBERS OF THE BOARD OF VISITORS OF THE ROYAL OBSERVATORY, GREENWICH,

1865, OCTOBER 21:

AND

REPORT

OF

THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1866, *June* 2.

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THE INDIVIDUAL MEMBERS OF THE BOARD OF VISITORS

OF THE ROYAL, OBSERVATORY, GREENWICH.

In planning the Transit-Circle of the Royal Observatory, it was intended that its collimation-error should be determined by the use of two reversed-telescopes or collimators respectively on the north and south sides of the instrument. This system implies that means be provided for occasionally giving to each reversed-telescope a clear view of the other; and it was arranged that, for this purpose, a lifting apparatus should be used for raising the transit-telescope so far that there should be no interrupting substance between the object-glasses of the two reversed telescopes. It did not occur to myself, or to any of the artists employed in the construction, that it would be much better to perforate the central cube, so that there would at all times be clear view from one telescope to the other without the trouble of raising the transit-circle.

It was soon remarked that an important advantage had been lost by this imperfect construction,* and an alteration of the interior of the cube was contemplated. But, in consequence of the meeting in the centre of the cube of a system of strengthening edge-ribs, it did not appear possible to perforate the existing cube without very materially injuring its strength, and that proposal was abandoned.

The expense and inconvenience of making a new cube, including with it the cones and pivots, which are made in the same casting, would be very considerable.

A short time since I caused to be constructed in wood a very accurate model of the transit-circle-telescope with its cube and axis. On examining this, it appeared that, though it would not be permissible to cut away the central knot of the edge-ribs, no sensible injury would be done by cutting away, in the form of a system of sectors, those parts of the opposite faces of the cube which are included between the geo-

* In each of the instruments copied from that at Greenwich, by the same artists, care was taken to construct the central cube in a perforated form, making them in this respect superior to the Greenwich prototype.

metrical projections of the edge-ribs above-mentioned. The operation was first performed on the model, and, when telescopes of proportional apertures were mounted in positions corresponding to those of the reversed telescopes of the real instrument, the wires of one telescope were very fairly seen by view with the other telescope.

The same operation has now been performed on the cube of the instrument; the extremities of the sectorial openings on each face of the cube being bounded by the circumference of a circle 7 inches in diameter. The acute angles of the sectors, it was found, are rather more encumbered by the rounding of the iron-casting, than they were in the wooden model.

The apertures of the existing reversed-telescopes are $3\frac{3}{4}$ inches. With these, it is found that the interruption to the light, caused by the thickness of the edge-ribs, and the mass of matter at their union, creates a sensible difficulty in the application of the system. The wires of one telescope may be seen with the other, perhaps sufficiently well to call attention to any accidental failure of adjustment, but not sufficiently well for the periodical adjustment of one wire on the image of the other. Apertures of 5 inches would give sufficient light.

It has, however, been remarked, that in constructional propriety, and possibly for astronomical accuracy, the apertures of the reversed-telescopes ought to approach more nearly to the aperture (8 inches) of the transit-circle-telescope. Otherwise the adjustments for collimation will depend on a limited portion of the transit-object-glass; while its whole surface is used for observation of transits. It appears that, without considerable alteration of the buildings, it would scarcely be possible to introduce 8-inch telescopes; but it would be possible to introduce 7-inch telescopes.

On communicating with Mr. Simms, I have reason to think that the expense of a pair of reversed-telescopes, with 7-inch object-glasses of the first order, mounted in iron tubes and on iron supports, would be about 200*l*. The expense might be diminished by using object-glasses of a somewhat inferior class.

The present is a proper time for bringing before the Board of Admiralty any proposal affecting the provision of funds for the equipment of the Royal Observatory.

And I now request the opinions of Members of the Board of Visitors:

Whether it is proper to recommend the establishment of 7-inch reversed-telescopes for view through the cube, perforated as I have described?

and,

Whether it is proper to recommend that the said telescopes have object-glasses of the highest order, competent (if required under any change of circumstances) to be used for the most accurate astronomical observations?

G. B. AIRY.

Royal Observatory, Greenwich,
1865, *October* 21.

REPORT OF THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1866, *June* 2.

The Report which I last presented to the Board of Visitors was brought up to 1865 May 10. The present Report terminates on 1866 May 14, applying to the state of current business on that day, and to the principal occurrences between the two days specified. The Heads of Report are the same as those which I have adopted for many years.

I. Buildings and Grounds:—

No alteration has been made to the substantial buildings, and none but the most ordinary repairs have been executed.

On 1865 May 23, a thunder-storm of great violence passed very close to the Observatory. After one flash of lightning, I was convinced that the principal building was struck; and while on my way to seek for marks of injury, I saw another flash strike Greenwich Hospital. No very certain marks of the first flash were seen upon the lofty building of the Observatory; but several galvanometers in the Magnetic Basement were destroyed. Lately it has been remarked that one of the old chimneys of the principal building had been dislocated and slightly twisted, at a place where it was surrounded by an iron stay-band led from the Telegraph Pole which was planted upon the leads of the Octagon Room; which stay-band (intended only as a guard

against accidents) had never sustained and could never have exerted any mechanical force. The top of the Telegraph Pole was furnished with seventeen sharp spikes; and was connected with the iron stay to the chimney, an iron conducting-rod to the leads, two iron wires more than 400 feet long to the Magnetic Basement, and nine iron wires more than 800 feet long across the Park. It appears therefore that the electric current was divided into at least two courses, namely by the iron stay to the chimney and by the iron wires to the Magnetic Basement. It also seems probable that the cluster of sharp spikes had attracted the electricity in one shock, instead of drawing it off gradually. The Telegraph Pole has lately been removed.

The snow-storm and gale of wind on 1866 January 11, which caused so much interruption in all the telegraphs of the south of England, completely destroyed the open-air telegraphic communications of the Royal Observatory; and our partial telegraphic service has since then been carried on through some spare wires accompanying that of the Electric and International Company to which I alluded in my last Report. On consideration of the serious interruptions to which we have several times been exposed from the destruction of our open-air Park-wires and street-wires, I have made an arrangement for leading the whole of our wires in underground pipes as far as the Greenwich Railway Station. Repeated delays have occurred, such as are almost unavoidable where the interests of several companies are concerned; and finally, it has been found impracticable to reinstate all our communications until a new subaqueous cable shall be laid across Deptford Creek. At present therefore the galvanic lines for the earth-currents, and those for occasional communication with an Admiralty line, are interrupted. On completing these lines it is proposed to dismount the turn-plate which is intended for Admiralty communication, from the Gothic House at Deptford, and to fix it at the Deptford Station where the South Eastern Line crosses the Admiralty Line.

The Magnetic Basement has been perfectly dry, except on the following occasion. I must premise that, for conveniently removing the large quantities of water used in the photographic operations, a pump is established in a dry well about 30 feet outside of the Magnetic Observatory, by which the water is thrown at once into a subterraneous drain. In the late spring, much soil-water collected itself in this well, and oozed by the side of the suction pipe into the Basement. The pump has now been fitted with the means of exhausting the dry well, when necessary. The ground, also, in the neighbourhood of the Magnetic Observatory has been hollowed into such a form as to throw the rain water to a distance. I anticipate that the ground will be made drier than it ever was before.

The temperature of the basement has been maintained as near as possible to 59° Fahrenheit. For this purpose, it is necessary sometimes to use the warmth of the

gas-stove, sometimes to shade the windows externally and to sprinkle the upper floor with water.

The Tower at Deal for the Time-Signal-Ball has been properly inclosed and fitted for the residence of the Ball-Attendant.

I alluded in my last Report to the demand for a fire-proof Chronometer Room; and to the scheme of rendering the present room fire-proof. With the sanction of the Board of Admiralty, I have had some consultations with the Admiralty Surveyor of Buildings on this proposal. So many difficulties, however, appear, that for the present I withdraw that plan. But it is desirable to keep the matter in view, both for the purpose of insuring the safety of the Chronometers, and for the purpose of gaining room. I believe that it will be practicable, by withdrawing a number of Chronometers from rating or winding, to store them in such a manner that the present pressure for room may be relieved, but it is desirable that we should not feel ourselves driven to that resource.

The roof of the old staircase to the Octagon Room (the original roof, I believe), has been found to be in a very bad state, and I propose to restore it in the approaching summer. In contemplation of this, I have deferred some small repairs to the staircase-walls, &c.

The establishment of the proposed new Collimators or Reversed Telescopes in the Transit Circle Room will require small alterations in the north and south walls of the room, the new telescopes being longer than the old ones.

The subject of Railways approaching the Royal Observatory still requires notice. Between the date of my last Report to the Visitors and the last Meeting of the Visitors, the Chairman (Sir John Hanmer) of the Committee of the House of Commons to whom the "Greenwich and Woolwich Line" of the South Eastern Railway was referred, with some Members of the Committee, and with the Secretaries and Engineers of the Railways concerned, together with the President of the Royal Astronomical Society, came to the Royal Observatory, inspected the ground, and (after receiving the Report of some experiments for which my First Assistant and another Assistant were sent to Ireland), finally assented to the adoption of a line which I indicated, passing between the buildings of the Hospital Schools and the public road to Woolwich. This line has been promoted in the present Session of Parliament, and, so far as I am aware, proceeds in its official course without difficulty. Connected with this is the proposal of the London, Chatham, and Dover Railway. That company, two years ago, received powers to make a railway up to the wall

of Greenwich Park; but in the present Session they applied for a bill to withdraw that railway, and, instead, to make a junction with the South Eastern line above-mentioned. Their bill has been rejected, not on the merits of the case, but on some point of Standing Orders. I regret that this final settlement of a long troublesome matter has been interrupted, and I hope that the interruption may produce only a short delay.

II. Moveable Property.

All our disposable modern standards of length have been placed in the hands of Colonel Sir Henry James, R.E., Director of the Trigonometrical Survey of Britain, for comparison with the Ordnance Standards, and with the standards of other countries. No other change worth remark has been made in the disposal of our property.

Catalogues are kept up, and Instruments and Auxiliary Apparatus are maintained in good order; beyond this, I have no special announcement to make.

III. Manuscripts.

Our current manuscripts are collected, indexed, bound, and catalogued, without change of system. The bound manuscripts are periodically compared with the catalogue. The correspondence applies to a great range of scientific subjects.

The copy of Bradley's observations, 1743 to 1750, lately in the hands of Mr. Breen, has been returned to the Observatory.

The copy of Bradley's and Bliss's observations, 1750 to 1762, was conveyed by Dr. Winnecke to Pulkowa, and has since been placed in the hands of Dr. Auwers at Gotha, for revision of Bessel's reductions.

The copy of Bradley's loose papers has been sent to Pulkowa.

A copy has been made of Bradley's Zenith Sector Observations; it is now waiting for an opportunity of conveyance to Dr. Auwers.

IV. Library.

The Library, still confined in general to astronomical, magnetical, meteorological, and physical subjects, continues to increase slowly; the catalogue of books is kept up regularly; and the books are periodically compared with the catalogue.

I have no special remark to make on it.

V. Astronomical Instruments.

On the Transit Circle I have to offer the following remarks:

It will be in the recollection of the Visitors that in the autumn of last year I circulated among them an Address, in which, after alluding to the advantage of piercing the central tube of the Transit Circle, in order that one of the Reversed Telescopes might view the other without the necessity of raising the Transit Circle, I described the experiment on a model made in co-operation with the President of the Royal Astronomical Society, and on the step which I had subsequently taken of piercing the flat sides of the central cube of the Transit Circle without injuring any part of its internal brace-ribs, and of the necessity which then appeared for the use of reversed-telescopes with object-glasses not less than 5 inches in diameter, but for which 7 inches would be preferable; and I solicited the judgment of the Visitors on the propriety of proceeding with these larger telescopes. Fortified by the opinions which reached me, I requested and obtained the sanction of the Admiralty to the mounting of 7-inch reversed telescopes of the best quality. Mr. Simms has the telescopes in hand; the cast-iron tubes are prepared.

No new experiments have been made for ascertaining the astronomical flexure of the telescope. Theoretically they may seem desirable, as a small portion of that part of the cube which resisted general flexure has been removed.

In connexion with this, however, I have to mention an investigation lately made by Mr. Stone (First Assistant). Mr. Stone made observations of the meridional zenith-distance of the same object at different points of the same horizontal wire. On comparing these, it appears certain that the middle part of the wire drops, in reference to the parts near the first and last vertical wires, by nearly one-fifth of a second. This, it is evident, enters into the determination of instrumental flexure. It does not affect the validity of the numerical astronomical correction, except to this extent that, according to the state of tension, there may be a small variation between the corrections on different days. It may be well to take measures for stretching the horizontal wire with the greatest force that it will bear.

In continuation of the plan of determining carefully the errors of graduation of the special divisions which are used for the objects most frequently observed, these errors have been determined for the divisions used in observing δ Ursæ Minoris and 51 Cephei.

The lenses of the object-glass have been once separated and cleaned.

A comparison has been made of different parts of the surface of the object-glass; by placing on it a cap with a small aperture which, by rotation of the cap, could be brought over different parts of the disk; and then observing the co-incidence of direct and reflected images of the wires. In this way it has been found practicable to determine the error of focal adjustment, not only more exactly than by any other

method, but also with greater precision than can be corrected by our mechanical powers of adjustment. With due allowance for the small error observed, the agreement of foci for different sections of the object-glass is very accurate.

The arrangement which I made in the construction of the instrument for illuminating the wires in a dark field is, mechanically, extremely convenient; but it possesses the inconvenience that the intensity of the light could not be easily modified. After long thought, I have made a simple arrangement which is perfectly successful. The illuminating light falls upon four reflecting prisms; and a plate is now interposed in the path of the light before it enters the prisms, with rectangular holes of such dimension that, by motion of the pierced plate in a direction making an angle of 45 degrees with the meridian, the effective axial length of the four prisms (on which depends the extent of wire illuminated) is not affected, while the breadth of the prisms (on which depends the intensity of illumination) is modified.

Some irregularities in the rate of the Transit Clock appeared to be due to the weight and power of the springs, especially to one of the two pairs, which are used to produce galvanic circuits at every second of transit-clock time. These have been made lighter, and there appears to be no doubt that the rate of the clock is improved.

In the Chronograph-Barrel-Clock, the proposed alteration in the mechanism of the water resistance has been made, and with advantage. The Visitors are aware that in this clock, and in that of the South East Equatoreal, it has been my object to give the necessary tangential resistance to the conical pendulum in a form that produces no centripetal pressure; which is effected by means of a bell-crank lever in which the recess of the pendulum from the center dips a small spade into water. In order to avoid change of relative elevations, I had used an ill-arranged apparatus for the Chronograph pendulum; I have now made the small difference of elevations, and have introduced an apparatus similar to that of the South East Equatorial.

There seems to be friction, not yet thoroughly traced out, in the upper wheels of the clock. And we suspect an error in the compensation of the pendulum; but it is not easy to make experiments upon it.

The Reflex Zenith Tube is in good order. The check of the mercury-tremors, by suspension of the mercury trough upon gutta percha cords, is still effective.

The Altazimuth is in its usual good order. In the last Report I mentioned my idea that the sudden changes of azimuth-zero might arise from a sudden start of the three radii of the azimuthal circle in their three Y's, and that the liability to these starts might be diminished by diminishing the load upon the azimuthal circle. The diminution of load has been effected, by bringing the pressure of the counterpoise of the

revolving frame entirely upon the stone pier, but I do not find that any sensible improvement is made in the steadiness of the azimuth-zeros.

In the Reversed Telescope or Collimator used for occasional reference of the Altazimuth, the focal mark is within the principal building of the working observatory, while the object-glass is fixed in the wall of the South Dome. From a collation lately made by Mr. Dunkin, it appears that the apparent zenith-distance of the mark changes with changes of atmospheric temperature, at the rate nearly of one second of arc in zenith distance for one degree of temperature. No such change has yet been traced in the reading of the horizontal circle for observation of the mark.

The Motor Clock, employed for action of every kind which requires the use of accurate Greenwich Mean Solar Time without the need for numerical correction, is in good order; preserving a sufficiently steady rate, with great uniformity of arc of vibration. I have formerly mentioned that a steel bar-magnet, parallel to the pendulum rod, is carried by the pendulum-rod; mounted originally in order to give us the power, in the computing-room, of accelerating or retarding the vibrations during a limited time, by throwing a galvanic current of one or other kind into a fixed coil which is placed below the magnet, and lately used for general adjustment of the clock-rate by bringing a piece of iron, fixed in the clock case, nearer to or further from the other pole of the steel magnet. The last mentioned apparatus is so convenient that I can recommend its use for clocks in general.

The galvanic apparatus for distribution of currents consists of the following parts. First, a contact is made at every swing of the pendulum, which sends the current that drives the wheel-work of all the sympathetic clocks, and also works a relay by which we distribute any number of seconds'-currents. Secondly, in the course of a wire which passes through the clock-face, there are two interruptions, of which one is closed a short time before and after every 60^m, and the other is closed at 60^s exactly; the circuit thus formed precisely at every hour works a relay by which accurate hourly currents are distributed. Thirdly, the connexions are altered at certain portions of the hour, so as to enable us to receive return-signals from the Deal Ball, the Westminster Palace Clock, and the Post Office Clocks.

The Shuckburgh Equatoreal is substantially in good order, having had its limbs cleared and its internal reflector repolished; but still requiring attention to its hour-circle-microscopes.

The Sheepshanks Equatoreal is in good order.

The South-East Equatoreal is in perfect order. The following additions have been made to its subsidiary apparatus.

An eye-piece has been provided for viewing the Sun, on the principle proposed by Sir John Herschel, using a glass prism with external reflection, in a form which permits much of the radiant heat to pass through it.

In my original construction of the Equatoreal, two pairs of galvanic wires were led (by means of insulated rings and touching-springs, at the polar and declination pivots) to the eye-end of the telescope; one pair being for galvanic contact, to make impressions on the Chronograph register, the other pair being intended to drive a galvanic chronometer in sympathy with the Transit-Clock. The chronometer, though sometimes acting well (as in the Eclipse Observations of 1860), often gave us a great deal of trouble. At last I determined, on the proposal of Mr. Ellis, to attempt an extension of Mr. R. L. Jones' regulating principle. It is well known that Mr. Jones has with great success introduced the system of applying galvanic currents originating in the vibrations of a normal pendulum, not to drive the wheel-work of other clocks, but to regulate to exact agreement the rates of their pendulums which were, independently, nearly in agreement; each clock being driven by weight-power as before. The same principle is now applied to the chronometer. I supplied an old worthless half-second chronometer; upon the axis of its balance a small magnet is fixed (its centre being pierced by the balance-staff), a coil in the fixed part of the chronometer embraces this magnet as in the ordinary galvanometer, and a current is sent through the coil at every second of the Transit-Clock. The construction is perfectly successful; the chronometer remains in coincidence with the Transit-Clock through any length of time, with a small constant error as is required by mechanical theory. The only inconvenience is, that the beats can scarcely be heard; I propose to introduce a small galvanic magnet, merely to make an audible sound.

The intromission of the water which drives the clock-movement has been managed with great convenience to the observer, by a screw apparatus in the Equatoreal Room which regulates the tap in the basement. For the purposes of experiment, I am also introducing a means of throwing on the water by another tap in the lower story.

The Thermometers and Barometers are in good order. The Thermometer used with the Altazimuth has a varying error, amounting through the whole extent of its scale nearly to one degree of Fahrenheit; and though a very small part of this is used in the Altazimuth observations, I have determined to substitute a new thermometer or a new scale.

I alluded in my last Report to two portable instruments which were to be made for the Observatory; a Transit Instrument by Mr. Brauer, optician of the Pulkowa Observatory, and an Altazimuth by Mr. Simms, both with diagonal reflectors and axial eye-views. The former is finished, under the kind superintendence of Mr. Otto Struve; but the time of its arrival will depend on the state of the ice in the Baltic. The latter I hope to be able to exhibit to the Visitors.

The Ancient Instruments are preserved in their usual safe condition. I have to announce to the Visitors an addition to our former series; a large Quadrant, an undoubted work of Abraham Sharp; presented by the Reverend N. S. Heineke.

This Quadrant is partly described by Smeaton in a paper on the Graduation of Astronomical Instruments, in the Philosophical Transactions, 1786. Although one line of its divisions is remarkably well cut, I can hardly believe that it has ever been intended for a working instrument.

VI. Astronomical Observations.

It seems almost unnecessary to repeat, what I have so often stated; that the first care in the direction of the observations with the Transit-Circle is, to determine with the utmost accuracy the relative Right Ascensions and the absolute Polar Distances of the principal fixed stars, proper steps being taken in every way (and particularly by extension of the daily series of R.A. determinations when the weather permits it) to give to those determinations a thoroughly independent and fundamental character; that the second care is, by incessant observations of the Sun, to obtain for every year independent determinations of the position of the Ecliptic among the stars, and for almost every day, independent determinations of the position of the Sun as referred to the Ecliptic; and that the third, and that which is most strikingly characteristic of the Greenwich Observatory, is, to lose no opportunity of observing the Moon on the meridian. Carrying out the spirit of the last of these pursuits, the Altazimuth is employed with the most laborious watchfulness, for observing the Moon at least once on every day in which she can be seen in any part of the sky.

Proceeding now to subordinate objects, the following are the principal classes of stars observed on the meridian: Stars for determination of clock-error, the number of which is 188; Nautical Almanac Stars, visible in the latitude of Greenwich; Circumpolar Stars, to be used for determination of the instrumental meridian; Stars culminating with the Moon, as given in the proper section of the Nautical Almanac; Stars occulted by the Moon; Stars of the Greenwich Seven-Year Catalogue, for which the number of observations in that Catalogue appeared to be too small; Stars of Bradley's Catalogue not observed at Greenwich since 1835 (the number in the entire list as drawn up by Mr. Stone being about 1211, of which 573 have been completely and 359 partially observed); Stars used in the British Survey by Colonel Sir Henry James; Stars adopted by the late Captain Gilliss and Mr. B. Gould in the Survey of the United States of America; Stars which pass near the northern and southern horizons, giving important indications for correcting refraction-tables; Stars supposed to have large proper motions; Variable Stars, observed for position only, but giving incidental information as to magnitude; Argelander's list of Stars, prepared with the view of determining the systematic differences between the results of different observatories; Sirius and neighbouring stars (Sirius being considered unfit for use as a clock-star). To these is to be added γ Draconis, observed at every opportunity with the Reflex-Zenith-Tube.

It has long been established as a rule in the Observatory, to omit observations of ordinary objects on Sundays. From this rule, however, is excepted the Moon, with the stars required for instrumental corrections; an observer with the Transit-Circle and one with the Altazimuth being appointed for that object when visible on Sundays. As regards other moving bodies; the Sun, Mercury, Venus, are observed on every week-day; Mars, Jupiter, Saturn, Venus, Neptune, when they pass before 14^h (now extended to 15^h), and sometimes in the morning when the Moon requires the attention of an observer; the asteroids when they pass before 13^h, but only in the first half of each lunation, (the observations in the second half being undertaken by M. Le Verrier).

The number of meridional observations with the Transit-Circle from 1865 May 10 to 1866 May 14 is as follows :—

Transits, limbs of the Sun, &c. being counted separately	5423
Pairs of observations of the Reversed Telescopes	282
Reflexion-observations of the transit-wires	295
Observations of one Reversed Telescope by the other	51
Circle-observations of all kinds, multiple micrometer readings being counted as only one	4702
Reflexion-observations of the zenith-distance-wire, included in Circle-observations	292
Reflexion-observations of stars, similarly included	213

With the Reflex-Zenith-Tube, γ Draconis has been observed as follows :—

Pairs of observations, the instrument being reversed between	64
Single observations	3

With the Altazimuth, observations have been made as follows :—

Azimuths of Moon and Stars	722
Azimuths of the Reversed Telescope	408
Zenith Distances of the Moon	394
Zenith Distances of the Reversed Telescope	408

Complete observations of the Moon have been taken on days near to the time of conjunction, in the following number. The solar hour of Moon's transit on the same civil day defines with sufficient accuracy her distance from the Sun.

Moon's transit between 21^h and 22^h	5 observations.
Moon's transit between 22^h and 23^h	1
Moon's transit between 23^h and 24^h	0
Moon's transit between 0^h and 1^h	0
Moon's transit between 1^h and 2^h	2
Moon's transit between 2^h and 3^h	7

With the two instruments, Transit-Circle and Altazimuth, complete observations of the Moon have been taken as follows :—

With the Transit-Circle, 110, or 8·8 per lunation.
With the Altazimuth, 203, or 16·2 per lunation.

Omitting the mere observation of the times of certain phænomena, the Equatoreals have not been used for any determinations of numerical accuracy. But an examination of the Sun's surface with the South East Equatoreal under favourable circumstances has convinced me of the accuracy of the description which compares it with interlacing willow-leaves or rice-grains ; and the spectrum-apparatus has sometimes been used for inspection of star-spectra. [Addition, May 24.—The spectrum-apparatus has been employed for examination of the new star in Corona.]

The number of observed occultations of stars by the Moon is 7 ; 3 disappearances and 4 reappearances. The number of phænomena of Jupiter's satellites is 12.

VII. Reduction of Astronomical Observations.

The state of the reduction of transits for right-ascensions will be understood from the following record of the dates to which successive steps of the computations are completed :—

Clock-time-transits over true meridian corrected for instrumental errors	May 5
Clock-errors and clock-rates	May 4
Apparent right-ascensions of center of object	April 27
Stars' corrections computed	May 5
Stars' corrections applied	March 31
Corrections for deficient illumination of limbs of Moon and Planets	1865 Dec. 31
Mean Solar Times of observation of Sun, Moon, and Planets	1865 Dec. 31

The state of the reduction of circle-observations for north-polar distances will in like manner be gathered from the following register of dates :—

Corrections are applied for error of division, flexure of the telescope, &c., zenith-point, refraction, and parallax ; and true geocentric zenith-distances are formed ; to	April 5
Stars' corrections computed	February 23
Stars' corrections applied	1865 Dec. 31
Corrections for deficient illumination	1865 Dec. 31

The mean right ascensions and mean north polar distances deduced from the individual observations of each star are collected to the end of 1865, and the means are formed. The value of R—D is investigated from the N. P. D. of the stars which have been observed by reflexion; it is a very little larger than that of late years, showing that a correction is required to N.P.D. from direct observations, amounting at the Pole (where it is nearly maximum) to 0″·25. The Catalogue of Stars is in preparation; the number of stars is 1159. The colatitude found from the observations of 1865 is within 0″·02 the same as that found in 1864.

The ordinary reductions and groupings of the observations of Sun, Moon, and Planets, in Right Ascension and North Polar Distance, are finished to the end of 1865, wanting only small applications of the corrections for R—D. The reductions for errors in Longitude and Latitude and in Heliocentric Places are finished to the end of 1864.

The observations with the Reflex Zenith Tube are reduced to the end of 1865.

The reductions of the Altazimuth observations are brought to the following state, described, as those of the Transit Circle, by the days to which different steps of the computations are completed:

Observed Azimuths are reduced, instrumental errors are investigated and applied, and True Azimuths from the Meridian are computed to	April 5
True Greenwich Zenith Distances are computed to . .	May 9
Tabular Greenwich Azimuths and Zenith Distances are computed to	April 27
Errors of Tabular R.A. and N.P.D. are formed to . .	April 5
Errors of Tabular Longitude and Ecliptic N.P.D. are formed to.	April 5

The reductions of observed occultations of Stars by the Moon are complete to the end of 1865.

The reductions generally are in a very slight degree more advanced than at the corresponding period of last year.

Among the influences of general character to be drawn from these reductions, the following are the most striking.

The personal equations in transits are very little altered. The following table of results for the last six years may be interesting. It is to be remarked that all are reduced to Mr. Dunkin (D.) as standard; but, on comparing his errors with the mean of the others, there appears to be good reason for thinking that his habits have not

sensibly changed. It is also to be remarked that the number of observations by L is comparatively small.

Observer.	1860	1861	1862	1863	1864	1865
	s	s	s	s	s	s
S	− 0·07	− 0·13	− 0·14	− 0·14	− 0·13	− 0·09
D	0·00	0·00	0·00	0·00	0·00	0·00
E	− 0·09	− 0·13	− 0·15	− 0·16	− 0·17	− 0·15
C	+ 0·14	+ 0·15	+ 0·15	+ 0·16	+ 0·12	+ 0·13
L	+ 0·31	+ 0·35	+ 0·21	+ 0·29	+ 0·30	+ 0·24
JC	+ 0·13	+ 0·09	+ 0·08	+ 0·07	+ 0·10	+ 0·09
K	+ 0·01	+ 0·01	+ 0·03	+ 0·03	− 0·08	− 0·05

These numbers are not deduced from experiments, but from observations taken in the ordinary course.

The azimuth-errors of the Transit-Circle and of the Altazimuth fluctuate nearly as in past years.

The obliquity given by the winter solstices is about 1″ greater than that by the summer solstice.

The Errors of the Moon's Tabular Longitude, as deduced from observations with the Altazimuth, usually have a numerically greater negative value or a numerically smaller positive value than those derived from the Transit-Circle. The only explanation which I can conjecture is this. In the necessity of securing an observation of the Moon as soon as she can be seen at a proper altitude, more than two-thirds of the observations, and particularly those with small altitudes, are taken on the East side of the Meridian. Of those compared with Transit-Circle observations more than four-fifths are on the East Side. A constant error in refractions would then produce a constant error in right ascension or longitude. It seems that our applied refraction may possibly be too large.

VIII. Printing and Distribution of Astronomical Observations.

The observations for 1864 are completely printed. The Paris observations of Asteroids are inserted, as in the preceding volume. The volume contains a few measures of the lines in Star-Spectra made in 1863. And, in addition to the Report on Chronometer Rates and the Report to the Visitors, usually attached, it has two Appendixes; one containing the calculations of the value of the Moon's Semidiameter deduced from 295 Occultations observed at Cambridge and Greenwich from 1832 to 1860, and showing that the occultation semidiameter is less than the telescopic semidiameter by 2″·0; the other containing the Reduction of the Planetary Observations made at the Royal Observatory in the years 1831-1835; filling up the gap, between the Planetary Reductions 1750-1830 made several years ago under my superintendence, and the Reductions contained in the Greenwich Volumes 1836 to the

present time; and conducted on the same general principles. Both these works have been planned and executed by Hugh Breen, Esq. (formerly Assistant of the Royal Observatory), subject to my general superintendence.

The number of copies printed is 350, with 150 additional copies of Results and Appendixes, and 250 additional copies of Magnetical and Meteorological work. The impression is not yet bound.

A large portion of the manuscript for 1865, in all the sections preceding the Results, is sent to the Government Printer. The present state of printing is this: Transits are printed to February 16; Circle observations not begun; Azimuths observed with the Altazimuth to March 13; Zenith Distances observed with the Altazimuth to May 12; Comparison of Tabular Azimuths and Zenith Distances with observed Azimuths and Zenith Distances to May 5.

It is sometimes found convenient not to hurry the printing of the earlier tabular sections of the volume until the Reductions are completed; as, in the course of reduction, errors in the original records are discovered, which can thus be corrected in the printed statement of observations.

IX. Magnetical and Meteorological Instruments.

Preceding Reports to the Visitors have sufficiently placed on record the structure of the Magnetic Basement and the corresponding command of temperature of the Magnetic Instruments. The great heats of the summer of 1865 tried every arrangement very severely (the temperature of the Basement once rising to 71°, and the diurnal range being 4°), and we were compelled to shade the window-wells and their neighbourhood (the interior and exterior windows being constantly closed), and to sprinkle the upper floor with water. By this caution in summer, and by an additional carpet and the warmth of the gas stove in winter, I anticipate no difficulty in keeping down our annual variation within about 5° and our diurnal variation within 3°. The temperature has, in the present month, once fallen to 57°.

The upper free Declination-Magnet was left, at the time of the last Report, without any check on its vibrations, which sometimes became very troublesome. (They could be reduced, in Gauss's manner, by the use of a hand-magnet; but that course was accompanied with serious objections, shortly to be mentioned.) I have therefore attached to its carrier a brass bar, vibrating in water, which sufficiently effects its purpose. The lower or photographic Declination-Magnet has a large mirror for photographic records; and a damper (the same which has been in use since 1841), an oval copper ring in the

vertical plane, embracing the magnet with a free interval of about two inches all round. Both these Magnets are in good order. The upper Magnet, it will be remembered, is observed by means of the same Theodolite which can be turned to the Circumpolar Stars, and thus serves to give independent measures of Western Declination as zeros for the Declination Photographs.

The Horizontal Force Magnetometer is in good order. This instrument carries a small mirror on which telescope-observations are made for zeros, and a large mirror for photographic records. It has an oval damper.

In the last Report, I communicated to the Visitors some conclusions on the effect of the Dampers; based on experiments in which the Dampers were slewed through small angles (1° or 2°), from which it was inferred that their magnetic action tended to diminish the apparent disturbances of the magnets by about $\frac{1}{120}$ part; a result applying both to the Declination and to the Horizontal Force Magnetometers. Dr. Lamont suggested that it might be more satisfactory not to slew the damper, but to try the difference of effects of an external disturbing cause, with damper in place and damper away. This accordingly was done; an external magnet being mounted so as to produce a disturbance of the magnitude of the largest earth disturbance; and its disturbing effect being measured, with the presence and in the absence of the damper. The result was, that no certain difference could be found between the disturbances when the damper was present and when it was away. With the Horizontal Force Magnetometer, the observations were easy, and the results were accordant and decisive; with the Declination Magnetometer, the observations were troublesome and the results discordant; and I propose to repeat the experiment. I believe that the damping rings used on the Continent are in the horizontal plane; while those at Greenwich are in the vertical plane, a position which I regard as very greatly preferable to the other.

The Vertical Force Magnetometer is furnished with a small mirror for telescope-observations and a large mirror for photography, but has no damper. It has made its registrations of the variations of Vertical Force with the utmost beauty and delicacy. Nevertheless, a very few dislocations have occurred (two in the present year), of which I can give no certain explanation. In three instances, dislocations in one direction were corrected after a few days by equal dislocations in the opposite direction; I suspected looseness of screws, but could find none. In most, perhaps in all, of the other instances, the dislocations have been caused by carrying a small magnet across the upper room. It seems as if the induction accompanying this transient passage produced a quasi-permanent change in the intensity of the magnetism. In future, the instrument will not be exposed to this danger.

The knife-edge was revised by Mr. Simms in December.

The co-efficient of thermal change has not been investigated. I am very sceptical on the validity of the methods hitherto employed.

The Dip Instrument is in good order. The individual results given by it are extremely accordant. The instrument and its needles were revised by Mr. Simms in December last. Since the improvement of the agates, the flat needles have exhibited the fault which was theoretically to be expected; and their use has been discontinued.

The Kew Deflexion Instrument is in its usual state. It was thoroughly examined by Mr. Simms in December. The weakness of structure, to which I have previously called attention, has not been corrected.

The apparatus for registration of spontaneous earth-currents, which was perfectly efficient to January 11, but which was then rendered useless by the destruction of its wires, has after four months delay been again brought on May 5 to a serviceable state.

The Meteorological apparatus is in perfect working order. The instruments read by eye to give zeros for self-registering instruments are, barometer, and dry and wet thermometers. Corresponding to them are, barometer and thermometers, photographically self-registering; and Osler's anemometer, mechanically self-registering. Other instruments, self-registering or accumulating, are; maximum and minimum thermometers, in the air, for sun-radiation and sky-radiation, and in the Thames; Robinson's anemometer; and Osler's and six other pluviometers at different elevations. All the thermometer-scales have been verified. The movement of the pencil of Osler's pluviometer has been improved by introduction of a "parallel motion" by Mr. Browning. The Electrometer is not very perfect: I believe that our position is not very favourable. The Actinometer has been in a good state, but appears liable to depart rapidly from perfect adjustment.

I am at present preparing a modification of Osler's Anemometer, by which the instrument will be made more sensitive to gentle currents of air; and I am also fitting up Robinson's anemometer in such a manner as to exhibit a current time-register of the velocity of the wind.

An Anemometer planned by C. O. F. Cator, Esq., has been for a short time under trial.

X. Magnetical and Meteorological Observations.

The three photographic magnetometers have been worked with uninterrupted steadiness. Dips have been observed once or twice each week; absolute measures of

horizontal magnetic force have been made about twice a month; and absolute reference to the astronomical meridian, by star observations about twice a month, and by use of a fixed mark very frequently.

The Earth-currents have been recorded on every day throughout the periods in which (as described in the last section) the wires have been continuous. There have been various modifications of the law and intensity of the currents, not yet sufficiently examined; but the following instance deserves special notice.

On examining the photographic sheets of 1865, August 2, we were struck with the indications of spontaneous galvanic currents of extreme violence. At the same time we learned by the usual public reports that the time, when the signals on the Atlantic Telegraph (then in course of immersion) became indistinct, coincided exactly with the time when the spontaneous currents began. It appeared to me therefore almost certain that the apparent fault in the cable was merely a consequence of these powerful currents. Professor William Thomson has favoured me with a very full statement of what was observed, which seems to establish that there really was a mechanical fault in the cable. The agreement of times however must be regarded as one of the most remarkable coincidences that has ever been noticed.

The difference in intensities of the spontaneous currents at different times is very great; as great as the difference of intensities of atmospheric electricity in serene weather and in a thunderstorm. It will be necessary for us to decide which of these states we will record, for the same instrument will not register both.

The various meteorological instruments described in the last section have been worked with unceasing regularity.

Special observations for the Bulletin of M. Le Verrier were regularly kept up till the general ruin of telegraphs in the month of January cut off the commercial telegraphic communication with London. On April 17, the London District Telegraph Company kindly gave us notice that they were again able to transmit our messages; and these were immediately resumed.

In the year 1865, the Actinometer was used on 58 days, producing 78 observations. It was remarked on one day (September 8) that the rise of the fluid in one minute was 61 divisions of the scale.

The remarkable shower of luminous meteors on 1865 November 13 was well observed.

XI.—Reduction of Magnetical and Meteorological Observations.

In eye-observations of the magnetic instruments, the equivalents for micrometer reading of Declination and scale-reading of Horizontal Force are formed to the present

time; those for scale-reading of Vertical Force to 1865 December 31. Theodolite Reading for North Meridian is prepared to April 24, but entered to 1865 December 31. Temperature corrections are entered to January 20. In the photograms, the time-scales are laid down to 1865 December 31; the new base-line (for measures of ordinates), derived from eye observations, is drawn, for Declination to 1865 February 8, for Horizontal Force to beginning of 1865, and for Vertical Force to end of 1865; other preparations being in a state of advance. The ordinates of the Vertical Force curve have been measured to the end of 1865. The Deflexion Observations are reduced to the end of 1865; and the Dip Observations to the date of this Report.

The Mean Magnetic Westerly Declination for 1865 is about 20°. 35′; the mean Horizontal Force, in English units, about 3·828, or, in French units, about 1·765; and the mean Dip about 68°. 2′. The dip at the present time appears slightly to exceed 68°. 1′.

On the photograms of Earth-Current observations, the time-scales are laid down to the end of 1865. I pointed out in my last Report that the intensities, in the direction of Magnetic North and Magnetic West might be found graphically from those in the directions of Croydon and Dartford, by use of proportional compasses. These compasses have been prepared; but they have not yet been actually used in reductions.

In reducing the Magnetometer Results from 1858 to 1863, a good beginning has been made. The separation of days too much disturbed to admit of graphical mean curves drawn by eye has been made; and, on the days which admitted it, the mean curves have been drawn for 1858. The ordinates at Solar Hours of 1858 are measured entirely for two instruments, and almost entirely for the third. Lunar Time Scales are laid down for the whole period 1858–1863 on all the photograms. The Thermometer readings are entirely copied, and their first sums and means are taken; and steps are made in their further application.

The Meteorological Results admit of being combined in such an infinity of different ways, as almost to prevent our attempting any one form of further reduction until special demands for it arise. Our ordinary reductions of meteorological observations consist for the most part of daily means and other inferences, adapted to the wants of civil life, and printed, in the first instance, in the Weekly Reports of the Registrar General. But every possible care is taken, in the register of eye-observations, and in the adjustment of zeros on the sheets of self-registering instruments, to place the whole in such a state that they can at once be used for any future investigation. The mass of accurate meteorological observations thus collected, commencing in 1840,

(the photographic part beginning in 1848), exceeds, I believe, any other in the world.

The sheets of Osler's anemometer require no care subsequent to that of the daily adjustment. On the photograms of Barometer and Dry-bulb and Wet-bulb Thermometers, the time-scales are laid down to 1865 December 31. For the Barometer, the new base-line is drawn, to the same day; the Thermometers, which photographically mark their own degrees, require none.

The number of complete revolutions made by the vane of Osler's anemometer in the year 1865, estimated positive in the direction N., E., S., W., was + 26.05.

The following table of the annual rotations of the vane from 1841 to the present time is perhaps interesting. It seems to indicate something like a septennial period. The result given for 1845 is for $10\frac{1}{2}$ months only.

		1846	+ 1·8	1853	− 1·9	1860	− 2·1
		1847	+ 11·0	1854	+ 6·8	1861	+ 16·5
1841	+ 5·4	1848	+ 12·1	1855	+ 10·8	1862	+ 13·7
1842	+ 13·1	1849	+ 23·3	1856	+ 16·1	1863	+ 28·4
1843	+ 20·7	1850	+ 15·9	1857	+ 14·7	1864	+ 17·2
1844	+ 21·7	1851	+ 19·1	1858	+ 24·1	1865	+ 26·0
1845	+ 8·9	1852	+ 8·8	1859	+ 14·0		

XII.—Printing of Magnetical and Meteorological Observations.

The Magnetical and Meteorological Observations are entirely printed, to the extent to which I proposed to print them, for 1864. The Visitors will remember my statement in the last Report, that the total interruption of the use of the self-registering Magnetometers by the works on the Basement during the first half of the year, and the unsatisfactory character of the suspensions in the second half, induced me to lay aside all thoughts of printing the usual "Magnetic Indications." It then became unnecessary to print a large part of the Introduction. In consequence of this diminution of the extent of work, the printing has advanced more rapidly than usual.

The Deflexion Observations and Dip Observations are printed in their customary form. The Meteorological observations are printed in their usual fulness; they include Actinometer Observations, which have not appeared for some years.

As in late years, 600 copies are printed, of which 350 are bound in the Volume of Greenwich Observations, and 250 are circulated separately.

For 1865, the Vertical Force Indications, the abstracts of Dip and Deflexion, and the Damper Experiments, are nearly ready for press; and almost the whole of the Meteorological work is ready.

Two copies of every magnetic photographic sheet are taken; those which carry the curves of Declination and Horizontal Force to 1863 December 31, and those which carry the curve of Vertical Force (accompanied by the Barometer) to 1864 December 31.

XIII.—Chronometers, Communications of Time, &c.

The number of Chronometers now on hand is 217; consisting of the following different classes. Admiralty Box-Chronometers 124; Pocket Chronometers 16; Deck Watches 11; Deck Watches on trial 9; Makers' Chronometers on Annual Competitive Trial 56; on trial for a Department of Government 1. The Competitive Chronometers, the Government Chronometers lately received after repairs, and still under trial for steadiness and compensation, and the Chronometers under orders for issue, are rated every day; all others, once a week. Every Chronometer is at some time tried in heat, to a temperature of 90° Fahrenheit, for three weeks.

The judgment of the comparative merits of Chronometers is made by me, and the management of the repairs of Chronometers is effected by me, or under my immediate superintendence.

The system of sympathetic clocks is used without alteration, and with great convenience and advantage. It is an important part of this principle that a person sitting at a desk in the computing-room can compare distant clocks (sidereal with solar), can mechanically correct the error of the solar clock, and will by this act necessarily correct the clock used for chronometer-rating, and the clock used for exhibiting and distributing time-signals.

By the principal corrected solar-clock or "Motor Clock," currents are sent at every second to regulate an Observatory Clock of peculiar construction at London Bridge, by which the distribution of communications is changed. Then by the Motor Clock, hourly signals are sent on the S.E. Railway, one of which drops the Deal Time Ball (under my official superintendence); and hourly signals are sent to the Office of the Electric and International Telegraph, whence, by means of mechanism arranged by Mr. Varley, and now under the care of Mr. Culley, they are distributed over Britain and fire guns at Newcastle and Shields. The apparatus at the Post Office in connexion with the Royal Observatory is at present receiving some changes, but will shortly, I expect, be in an efficient state. Signals are sent to the Westminster Clock for the guidance of its manager, and that clock, as well as the Post Office Clocks when in proper connexion, automatically send signals to inform me of their state; these return-signals are sent at minutes intermediate to the integral hours, when the Motor Clock has made new arrangements for exhibiting return-signals instead of sending signals

The signals through the London District Telegraph for Chronometer-makers are not yet restored. Some signals go to the offices of private merchants in London.

The British Horological Institute have brought before the Court of Common Council of the City of London, the subject of Public Time Signals of accurate character in London; but I do not know the present state of the transaction.

I retain the intention of repeating the proposal, when circumstances shall appear favourable, for exhibiting an hourly time-signal on the Start Point; and, in the restoration of our wires, some arrangements are made with that subject specially in view.

XIV.—Personal Establishment.

The Assistants whose names are borne on the Government Books are; Mr. E. J. Stone, M.A., Fellow of Queen's College, Cambridge; Mr. J. Glaisher, F.R.S.; Mr. Dunkin; Mr. Ellis; Mr. Criswick; Mr. Lynn, B.A., Univ. London; Mr. Carpenter; Mr. Nash. To these gentlemen respectively are assigned the duties of;—Confidential Assistant;—Superintendent of the Magnetical and Meteorological Department;—Superintendent of Altazimuth and of standing adjustments of Transit Circle;—care of Chronometers, Galvanism, Time Work, Money Accounts;—general observation and reductions;—control of Supernumerary Computers in the Astronomical Department;—general and equatoreal observation, with care of Library, Manuscripts, and printed works issued by the Observatory;—and assistance in the Magnetical and Meteorological Department.

At present, six Supernumerary Computers are employed in the Astronomical Department, three in the Ordinary Magnetical and Meteorological Department, and three on the Magnetic Reductions 1858–1863.

There are also an ordinary labourer, a gate-porter, and a night-watchman. Two or three workmen are usually employed.

The responsibility for every transaction in the Observatory is centralized in myself.

XV.—Extraneous Work.

The only work in progress, not included in the routine of current work or work of short standing, is the reduction of Bradley's observations 1743–1750, effected principally by Mr. H. Breen (formerly Assistant of the Royal Observatory) but under my general superintendence. The revision of certain parts has been made in the Observatory, by Mr. Stone and Mr. Carpenter.

XVI.—General Remarks.

Every successive year adds something to the annual labours of the Observatory. This arises, not simply from the occasional additions to its general plan of work (as in the extension of Lunar observations by the Altazimuth, the distribution of time-signals, &c.), or from the rise of new astronomical wants (as in the observation of small planets), but also from those associations with older times that distinguish an old establishment from a new one, as the re-observation of Bradley's stars, the further reduction of Lunar, Planetary, and Magnetical observations of many years past, &c. To this I must add, as a part which comes particularly under my personal cognizance, the increased notoriety of the Institution, and the quantity of correspondence, official and general, which follows that notoriety.

Since I first took charge of the Observatory, its personal establishment, measured by the rank as well as the number of the persons employed, has been less than doubled. But I would fain believe that the amount of work produced has been increased in a much higher proportion.

However this may be, I am anxious to convey to the Visitors; that while, on the one hand, every effort is made to maintain to the utmost desirable extent (with reference to the advantage of science) the quality of the observations and calculations, the extent of observations and calculations, and the breadth of their diffusion through the world; on the other hand, I endeavour to effect this at the least practicable expense. I trust that in both these attempts I may enjoy the sympathy of the Visitors.

G. B. AIRY.

Royal Observatory, Greenwich,
1866, *May* 17.