

REPORT
OF
THE ASTRONOMER ROYAL
TO THE
BOARD OF VISITORS
OF THE
ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1868, June 6.

A

REPORT OF THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1868, June 6.

I have the honor to offer to the Board of Visitors a Report, on the general transactions in the Royal Observatory, from 1867, May 3, (the date at which the last Report terminated,) to 1868, May 6, and on the state of the Observatory upon the last-mentioned day.

I. Buildings and Grounds:—

No repair or alteration has been made to the original building of Flamsteed. But in one of the small rooms attached to it, forming a part of my dwelling house, it is proposed in the present summer to raise the roof, for the purpose of giving better ventilation to the room.

The room above the Computing Room is still occupied by the Admiralty Chronometers and Trial Chronometers. I hope in no long time to remove them to the South-East Dome, as I shall shortly mention.

In the principal Library, I have placed an iron air-stove; the chimney-grate being found in many circumstances useless for warming the room.

In the Lower Record Room I propose to fix, on the unoccupied walls, additional sets of slate shelves. And I hope soon to remove the stores of printed books, which at present occupy space that was not intended for them, into another place of deposit, to which I shall soon allude.

In the South-East Dome, the alteration proposed last year for rendering the building fire-proof has been completely carried out, under the superintendence of the Admiralty Director of Works. For the wooden staircase, an iron staircase has been substituted. For the two upper wooden floors, there have been fixed floors carried by radiating girders and cross-joists of wrought-iron, whose flanges support light spars which are heavily plastered above and below, and finally carry floors of tiles; a construction which, as I understand, is approved by the best builders of the present day. The lowest floor is paved with flagstones. For the middle room, which is to be appropriated to Chronometers (giving us much more space than we command at present), the requisite tables and shelves, with a Chronometer-oven larger than that which we use now, are in the workmen's hands, but are not yet mounted. In the lower room, I have separated a small space, by a partition of corrugated iron, to be used as Chronometer Office. When all these are ready, the Chronometers will be shifted to this room; and the room vacated by them (above the Computing Room) will be occupied by Computers.

The alteration of the roof of the rotatory dome, to which I alluded in my last Report, has been made, and the leakage has been effectually stopped. There have been occasional small chinks in the upper shutter, &c., as in all places covered with metal.

Of the Magnetic Observatory, I have to describe only a small alteration of flue-pipes in the Basement. I called the attention of the Visitors, in my last Report, to the circumstance that the S.W. (astronomical) part of the Basement was usually warmer than the E. part. To remedy this, first, the gas-stove was shifted in an easterly direction, but its effect was insufficient. Mr. Glaisher then suggested that by providing a proper flue for the gas-burner which illuminates the Horizontal Force Scale, and maintaining this light more constantly instead of the gas-stove, a good equilibrium of temperature might be maintained. This was done, with perfect success; there is no certain difference between the temperature of the two ends of the basement. At the same time, by continual attention to the sources of warmth and ventilation, the temperature of the whole has been maintained in a state of uniformity which *à priori* I should scarcely have thought possible. The great summer heats are now our only enemies, and not very formidable ones.

A proper flue has been provided for the lamp of the Vertical Force scale.

The gas-pipes in this department are usually washed out every week. This operation is attended with the inconvenience of extinguishing the gasburner on the mast (which, as I shall mention, I supposed would at this time be no longer wanted).

No alteration has been made in the Magnetic Offices. A small shed, called the "Telescope-Stand-Shed," has been taken down, to make room for the following building.

In my last Report, Article VIII., I suggested, as a possible subject for future consideration, the providing of some extraneous room in which our accumulation of printed Productions of the Observatory might be deposited. I have now selected a place on our own grounds, at the south-eastern corner of the inclosure, where a building can be erected, about 35 feet in length and 13 in breadth, its back ranging with the back of the Great Shed, and its end ranging with the back of the Magnetic Offices, a sufficient passage being left at the east end of the Magnetic Offices. I propose to fit up this repository by the simple arrangement of six racks of book-shelves, with three alleys between them, each alley having a separate door at the south end; the illumination being given by sky lights made of thick glass plates, of the same size as slates, and intermingled with the slates of the roof. The materials removed from the old floors of the South-East Dome will supply to a considerable extent the wants of this building.

It is an inconvenience attending this plan, that the free draught of air over our grounds and past our thermometers will be in some measure interrupted. The authorities of the Observatory must look forward to an extension of its grounds; a thing which cannot be effected without difficulty.

Our subterranean telegraph-wires were all broken by one blow, from an accident in the Metropolitan Drainage Works on Croom's Hill, but were speedily repaired. Two of the wires, which I have maintained and still maintain with the hope of application to the service of Time-Signals at Devonport and the Start Point, being at present unemployed, I propose to make use of them (with others) for a time, in a new modification of the Earth-Current-experiment, to be mentioned below.

The line of Railway through Greenwich, which, it was believed, was arranged in a form that met the wishes of all parties, and which had received the sanction of all the branches of the Legislature, has now (I believe) been abandoned. I can scarcely doubt that an equivalent line, possibly with features more objectionable to the Observatory, will at some time be proposed; and the disputes, which have already lasted more than thirty years, will be again roused.

II. Moveable Property :—

In my office of Chairman of successive Commissions on Standards, I had received some Standards of Length and Weight from Departments of Government, and I had purchased other Standards and Apparatus of great historical value (as Ramsden's and Roy's Standards of Length, Kater's Scale-beam for weighing great weights, and others);

I had also received Standards and Balance presented by the Government of the United States of America : all which had been deposited in the Royal Observatory, from the absolute want of any office in the British Dominions in which they could with propriety be placed. In the course of the last year, a Department of Standards was created, subordinate to the Board of Trade ; and to this all the Standards, &c. of which I have spoken, have, with the approval of the various Departments to which they might be considered to belong, been transferred. The "Parliamentary Copies" of the National Standards of Length and Weight, located in the Royal Observatory under sanction of an Act of Parliament, remain here.

The Portable Transit (constructed at Pulkowa, on the principle of view through the axis,) is lent to Colonel Sir Henry James, R.E., Superintendent of the Ordnance Survey. A telescope, one of those formerly used as Reversed Telescope for the collimation of the Transit-Circle, is intrusted to Major Tennant, R.E., for use in the observation in India of the Total Solar Eclipse of August 18. A small spectroscope is lent to Colonel Smyth, R.A.

The portrait of John Dollond is returned from the South Kensington Exhibition of Portraits : and the Clock, used at the Ashford Station for changing the communications of telegraph-wires, and thus giving connexion with the Time-Signal-Ball at Deal, is returned ; the necessary adjustments being now made by hand.

III. Manuscripts:—

It is part of the ordinary system of the Observatory to maintain the Manuscripts in the best and safest order. Correspondence of all kinds is always brought to myself, and is deposited in an extensive system of subdivided portfolios in my official room, from which it receives its first and principal arrangement. All papers are punched with the same definite and invariable system of holes. After this, each collection of papers is divided into packets according to well-understood rules ; the papers of each packet are united by threads passed through certain holes of the system above mentioned, to form a packet ; and the packets are united by stronger strings passing through other holes, to form a book : every paper is thus accessible without removal from its place, and every paper is in its proper place. When these books become inconveniently large, they are handed to a binder, who binds them in the same order, separating one packet from another by a notched paper, with numerical references on the notches. An Index at the beginng shows the place of every packet ; and any paper can be found without difficulty.

(7)

The same system is applied to all detached astronomical or other calculations, &c. Those which are made in bound books require no further trouble.

The punctured Chronograph Sheets are preserved in a series of wooden portfolios.

The Catalogue of Manuscripts is maintained and verified as usual.

The copy of Bradley's and Bliss's observations, 1750 to 1762, is in the hands of Dr. Auwers; the copy of Bradley's Zenith-Sector observations has been handed to him by Mr. O. Struve; as also, I believe, the copy of Bradley's loose papers. Great interest is attached by the German Astronomers to the examination of Bradley's originals, or the copies which come next to the originals. I have reason to hope that Dr. Auwers may be induced to visit this country, for the purpose of more severely examining some minute points.

IV. Library :—

The purchases of books are confined to the physical class; and more especially to those which treat of our own subjects, astronomy, magnetism, meteorology, optics; and in these we scarcely go beyond the books whose classical character or antiquity of date seems particularly to claim attention. Our additions therefore are not very extensive. The increase by presents from extraneous bodies is greater. Due attention is given to the binding of small serials, tracts, &c.

The Catalogue of books is carefully maintained, and a comparison of the books with the Catalogue is made every year.

Assistants and Computers are permitted to use the books, under proper regulations. The value of such a Library, both for reference on the matters suggested by the business or correspondence of the Observatory, and for the instruction of all persons connected with the Observatory, is very great.

V. Astronomical Instruments :—

The Transit-Circle is in good order. We have been teased three or four times by the presence, on the wires, of small scraps of iron, which probably were introduced in the operation of cutting away some portions of the central cube. I intend, whenever the object-glass shall be taken off, to explore the interior of the tube as far as possible with magnets, with the hope of picking up any loose particles of iron.

Screw-movements have been applied for adjusting to focus the wires in the field of view of the telescope, and also for adjusting to focus the object-glasses of the micrometer-microscopes of the circle.

New jointed sliding-caps have been applied to cover the holes in the central cube.

A 4 +

The new Reversed Telescopes are in daily use for reciprocal observation through the pierced central cube. On collecting a number of instances, we think that the reading (as regards transit-wires) with interposition of the pierced cube differs from that when the telescope is removed by nearly half a second. I cannot answer with certainty for this small quantity; but I may remark that, with object-glasses of rather large aperture, an erroneous habit in the application of the eye to the eye-glass, combined with a very small error of focal adjustment, is sure to shew itself by a discordance of this kind.

On the graduated band of the Circle, we have discovered that an injury has been done by the carelessness of the workman formerly employed to wipe and oil the pivots. The soft metal has been slightly scratched in some places; and four divisions have been so much injured that the reading with the microscope-micrometer is nearly impracticable. No real injury is done by this, as there are always other divisions within command of the micrometers.

Observations for the astronomical flexure of the telescope, made on Feb. 10, give sensibly the same value and the same sign for the coefficient of flexure as that found in 1867, namely $-0''.34$, instead of $+0''.76$, the coefficient found before piercing the central cube. We have very lately discovered that the attachment of a light sun-shade to the telescope-tube produces a very small difference in the flexure of the telescope, and a petty correction will be required to our sun-observations. The subject requires further examination.

No new observations have been made for determining the errors of graduations of the circle; but on comparing the two former series (1850 and 1856) we have come to the conclusion that it was wrong to reject entirely the results of the first series. We are now using the mean of the two.

I adverted, in my last Report, to the inconvenience sometimes produced by the circumstance that the angular value of a revolution of the telescope-micrometer was nearly an aliquot part of a revolution of the microscope-micrometers. Mr. Simms has now mounted a micrometer-screw, whose revolution $=34''.5$. The screw as at first mounted was exposed to some strain, from which it has been relieved. We have examined it for ascertaining the difference of readings as the head is turned forwards or backwards, and for the drunkenness of the screw; and find both insensible. In the milled-head of the micrometer, I propose to introduce a modification which I introduced some years ago in the heads of the microscope-micrometers, and which has been found very useful. It is, to make the milled-head conical, and to leave no room for the observer to thrust his fingers under the head. The observer is then compelled to press the micrometer-head and micrometer-frame so that the solid hemisphere upon the screw-axis takes a close bearing in the cup which forms its *appui*.

Four supplementary microscopes have been mounted, for Mr. Stone's experimental readings of the circle.

I am preparing to mount in the room an Interior Thermometer of a higher class than those hitherto employed.

The steadiness of the Transit-Clock has been improved by making the contact-springs lighter. We have reason to think that it requires a little more compensation for effects of temperature.

I have given a new form to the head of the clock, for admission of small tin boxes in which a few lumps of quicklime will be placed, in order to keep the air about the wheel-work in a state of dryness.

The clocks generally are in good condition.

The Chronograph Barrel Clock continues to go well. The formation of the spiral line by pressure gives satisfaction.

The Reflex Zenith-Tube is in its usual good order.

The old ivory level scales of the Altazimuth have been changed for metallic scales.

With the view of ascertaining whether the changes in the Zero of Azimuth are occasioned by unsteadiness of bearing of the horizontal pivots in their Y's, the counterpoises were entirely removed through the lunation February 23—March 23, and have been somewhat diminished since. No apparent improvement, however, has been produced in these experiments. The instrument is in its usual efficient state.

The Motor-Clock, adjusted to Mean Solar Time, is in good order. This clock is an instrument possessing singular interest, from the nature of the process by which it is adjusted accurately to the Time which it is intended to exhibit; and from the mechanical structure by which, in conjunction with our galvanic apparatus and telegraphic connexion, it is employed in the rating of chronometers, in the distribution of time-signals through Britain, and in enabling us to receive automatic information of the state of various external clocks and time-signals.

All the sympathetic clocks are in good condition.

The Shuckburgh Equatoreal is efficient. It is employed, however, only as a conveniently mounted telescope, without use of its graduated circles.

The Sheepshanks Equatoreal is in good and serviceable order. The aperture of this telescope, and the attachment of clock-work (though not of the highest class) make it a useful instrument in the Observatory.

The South-East Equatoreal is in the best order. The object-glass has lately been separated and cleaned.

B

When the Equatoreal was mounted in the year 1858, the feet of the iron stands (which are carried by lofty piers of brickwork) for the north support and the south support were connected by two iron ties passing under the floor of the observing room. Upon making preparations, in the last winter, for fixing the iron girders of the new fire-proof floor, it was found that these ties must be altered or removed, and I cautiously tried the effect of removing them. I found, however, that there was not the smallest strain upon them; and when, after separating them for some weeks, the re-attachment was tried, the screws dropped into their holes without the least difficulty. I had then no hesitation in entirely withdrawing the ties. I was prepared to expect this steadiness of adjustment, knowing well the excellence of the gravel foundation and the massive character of the brickwork.

The stuffing-box for deadening the sound of the wheel-work has not yet been remounted; and perhaps some other small matters are not yet brought to their usual state. Everything essential, however, is in perfect order.

A light varnish has been laid upon the graduated limbs.

I have arranged the order of a series of Plans of this instrument; and I hope soon to receive the assistance of a draftsman for preparing them.

The auxiliary instruments, Barometers, Thermometers, &c., are in good order.

The Ancient Instruments have not been specially examined, but they have been preserved with the usual care.

VI. Astronomical Observations :—

As usual, meridional observations of the principal fixed stars and of the bodies of the solar system generally and of the Moon in particular, with the addition of Altazimuth observations of the Moon, have formed the principal employment of the Observatory.

The character of the star-observations may be described nearly in the words of the last Report. We have observed 188 Clock-error-stars; the visible stars of the Nautical Almanac; circumpolar stars; stars occulted by the Moon, and stars conculminating with the Moon; stars required for supplying deficiencies in our published catalogues; completion of the re-observation of Bradley's stars (finished at the end of 1867); stars used in geodetic surveys, British and Foreign; stars specially adapted for testing theories of refraction; a special list circulated by Argelander; and stars exhibiting remarkable proper motion or remarkable changes of magnitude.

The meridional planet-observations include: the Moon on every day when she is visible; the Sun, Mercury, Venus, on all days except Sundays; the large exterior planets when they transit before 15^h, and when they are near the morning moon; the small planets when they pass before 13^h, but only in the first half of each lunation (their observation during the second half of each lunation being undertaken by Mr. Le Verrier, as a duty of the Imperial Observatory of Paris).

Among the meridional observations may be included those of γ Draconis with the Reflex Zenith-Tube, which are made on every practicable day, except during a very inconvenient period of morning transits.

The only regular extrameridional observations for determination of measured place in the heavens are those of the Moon by means of the Altazimuth. These observations, with corresponding observations of stars and of the collimating mark, are made on every day on which she can be seen in any part of the sky.

The following is the table of observations made between 1867 May 3 and 1868 May 6.

With the Transit-Circle :

Transits, including the count of separate limbs	4784
Pairs of observations of the nearly vertical wires of the Reversed Telescopes	286
Reciprocal observations of the nearly vertical wires of the Reversed Telescopes	318
Reflexion-observations of the central transit-wire	271
Circle-observations, each implying a separate reading of the six microscope-micrometers	3824
Reflexion-observations of zenith-distance-wire (included in the Circle-observations)	270
Reflexion-observations of stars (similarly included)	209

With the Reflex Zenith-Tube,

Pairs of observations of γ Draconis, in opposite positions of the instrument	49
Single observations	3

With the Altazimuth,

Azimuths of Moon and stars	766
Azimuths of the collimating-mark	384
Zenith-Distances of the Moon	449
Zenith-Distances of the collimating-mark	384
	B 2

The number of complete observations of the Moon near to the conjunction, is :—

On days when the Moon transited between 21 ^h and 22 ^h mean solar				
time	.	.	.	5
„	„	when between 22 ^h and 23 ^h	.	1
„	„	when between 23 ^h and 24 ^h	.	0
„	„	when between 0 ^h and 1 ^h	.	0
„	„	when between 1 ^h and 2 ^h	.	3
„	„	when between 2 ^h and 3 ^h	.	5

The comparison of places of the Moon observed with the two principal instruments gives :—

With the Transit-Circle, 103, or 8·2 per lunation.

With the Altazimuth, 201, or 16·1 per lunation.

Eleven occultations of stars by the Moon have been observed, of which 8 were disappearances and 3 re-appearances ; and 34 phænomena of Jupiter's satellites.

In the whole of these classes of observations, the number of observations, considered in its proportion to the length of the period to which the Report applies, and with due attention to the position of the heavenly bodies, agrees nearly with those of several preceding years.

The observations of less accurate class have not engaged much attention. With the south-east equatoreal, we have so far watched the lunar spot Linnæus as to be well assured that it has undergone no change in the last year. Calculations have been prepared for the time of sunrise and sunset on that spot, and we hope now to examine it with better effect. It will be remarked that the fire-proofing work in the South East Dome has made it impossible for us to use that instrument for several months.

VII. Reduction of Astronomical Observations :—

In the reduction of the transit-observations, the more advanced stages of calculation are necessarily somewhat in arrear as compared with the first steps. The following statement will shew with what degree of closeness all are kept up :—

Corrections for instrumental errors are applied, and Clock-times			
of transits over true meridian are completed, to	.	.	1868 May 3
Clock-errors and clock-rates are computed and applied, and			
apparent right ascensions are formed, to	.	.	April 17
Stars' corrections are computed, to	.	.	April 23
Stars' corrections are applied, to	.	.	March 31

Mean Solar Times of observation of Sun, Moon, and Planets, are
 computed to 1868 March 5
 Corrections for deficient illumination of limbs of Moon and
 Planets are computed and applied, to 1867 Dec. 31

The stages of reduction of the circle-observations, similarly exhibited, are as follows:—

Corrections for instrumental errors (error of division, flexure of
 telescope, inclination of wire, zenith-point,) are computed and
 applied to 1868 April 10
 Refractions and parallaxes are computed and applied, and true
 geocentric distances formed, to April 10
 Stars' corrections computed and applied, to April 10
 Corrections for deficient illumination of Moon and Planets, com-
 puted and applied to April 10

In computing the refractions for 1868, the following change has been introduced. On comparing the results for circumpolar stars above and below the pole, at Greenwich and at Melbourne, and on comparing the results found at both observatories for stars common to both, Mr. Stone has ascertained that our refractions ought undoubtedly to be diminished. The character of this change agrees with that which I indicated two years ago, as required by the Altazimuth observations. (For more severe test of this conclusion, it is much to be wished that we were possessed of a star-catalogue formed at the Cape of Good Hope.) Relying on its certainty, however, we have now computed our mean refractions by diminishing those of Bessel's *Fundamenta* the proportion of 1 to 0·99797.

For each star observed in 1867, the results for mean R.A. and mean N.P.D. 1867, January 1, as given by each day's observation, are collected, and the mean is taken. From these, the values of R—D are found: and it appears that the sign of that quantity has changed, the correction to results of direct observations having, in 1866 and 1867, the sign + for southern stars. How far this can be connected with the change in the adopted value of the co-efficient of flexure, I am at present unable to say. The correction to colatitude has been investigated in the usual manner, but with the following modification in one point. Hitherto, it has been the custom to consider the errors of the circle-divisions as perfectly known, and in consequence to combine the result for colatitude-correction derived from observations of Polaris (for instance) with that derived from δ U. Minoris, by simply making the weights proportional to the number of observations (with a factor, nearly the same for both, depending on the polar distance). Now Mr. Stone has remarked that our knowledge of the relative errors of the circle-divisions is itself subject to uncertainty, and therefore that, even if

we had an infinite number of observations of Polaris, the probable error of the result would have a finite magnitude. In consequence, a limitation has been placed on the weights to be given to the numerous observations. The correction found for the assumed colatitude is only $0''.03$.

The star-catalogue for 1867 is in progress. The number of stars is 1099.

The observations of the Sun in 1867 are grouped as usual; the groups for the planets are not yet completed. The conversion of errors in R.A. and N.P.D. into errors of longitude and E.N.P.D. is effected for the Sun.

The observations of γ Draconis with the Reflex-Zenith-Tube are reduced to the end of 1867.

The steps of reduction of the Altazimuth observations are the following :—

In Azimuth, the means of circle-microscopes and level-readings are taken, instrumental errors are investigated and applied, and True Azimuths are formed, to	1868 April 14
In Zenith Distance, True Zenith Distances are formed, to	April 14
The corresponding Tabular Azimuths and Zenith Distances are prepared, to	April 14
Tabular Errors of Moon's R.A. and N.P.D. to	April 14
Tabular Errors of Moon's Longitude and E.N.P.D. to	March 19

Occultations of Stars by the Moon are reduced to the end of 1867.

The personal equations in transits are reduced for 1867. They continue to exhibit the same consistency with those of several preceding years which I have long remarked. As affecting the conduct of observations, I consider this to be important. It proves the habit of observation of each individual to be so steady, that the observations of different practised observers may be intermingled without fear of any greater irregularity of results than may arise in the change of nervous state of a single observer.

The oscillations of Azimuth-errors of the two principal instruments, and the small constant difference of lunar errors given by the two instruments, are nearly the same as before.

The investigation for the position of the ecliptic, as founded on the observations of 1867, is completed. On combining its result with those of the six preceding years, it appears that the assumed place of the first point of Aires requires a correction less than $0''.01$. Preparations, including the application of this correction, are now in progress for the formation of a New Seven-Year-Catalogue of Stars, to the epoch 1864.

It is intended to include the results of all the star-observations from 1861 to 1867 ; and, among other objects, it will contain all Bradley's stars hitherto unobserved.

VIII. Printing and Distribution of Astronomical Observations :—

The tabular part of the Astronomical portion of the volume for 1866, with the Introduction, are entirely printed. The Index and Errata are, at the date of this Report, not printed. The volume contains the Paris observations of the small planets made in the second half of each lunation. It will have no Appendix.

The whole of the Meridian observations in both elements for 1867 are sent to the Printer. The whole of the Altazimuth observations in both elements, with the Tabular comparisons, are ready.

Descriptions of the Transit-Circle and Altazimuth have been reprinted, but the accompanying diagrams are not quite ready. I propose to attach these as Appendixes to the volume for 1867.

I lately requested, for my guidance, the opinions of the individual members of the Board of Visitors as to the number of copies of the Astronomical Observations which should be struck off in the impression for 1867. As the members who transmitted to me their remarks were not unanimous in their judgment, I have not felt myself justified in making any change, and I have therefore provisionally applied for 350 copies of the entire volume, 150 separate copies of Astronomical Results, and 250 separate copies of Magnetical and Meteorological Results, as before. These numbers can now be reduced, if the Board of Visitors should so decide. I ask leave to submit this question to the Board, for their formal decision.

IX. Magnetical and Meteorological Instruments :—

The regulation and temperature of the magnetic basement has been almost perfectly mastered. To test it, numerous observations have been made every day, and the result is, that a change of 1° Fahrenheit in the thermometers exterior to the wooden boxes is a very rare occurrence. It is almost needless to remark that the change of temperature within the boxes is much less. In the heats of last summer, the highest temperature rose to about 67° , the change in the day having been about 3° : we hope in future to reduce these extremes. The lowest in the winter was about 59° .

The Upper Declination Magnet, the theodolite by which astronomical and magnetical bearings are connected, and the Lower Declination Magnetometer for photographic continuous record of declination, are in good order. There has been no accidental interruption to their action. For quieting the Lower Magnetometer when, in experiments, its oval damper is removed, a wire intended to dip into water has been provided; but no experiments have been made.

The Horizontal Force photographic Magnetometer is in good condition.

The Vertical Force photographic Magnetometer is in excellent state. It was revised by Mr. Simms in the winter: its knife-edge was then found to be a little injured. Since the last Report there has been only one dislocation of the photographic curve (on 1867 May 27), of almost imperceptible magnitude. The maintenance of the rule of avoiding to bring magnets within several yards of the Vertical Force Magnet, seems to have had the desired effect of leaving its magnetical momentum undisturbed.

For investigating the thermometrical corrections of the Horizontal Force and Vertical Force Magnetometers, experiments were made extending from 1867 December 31 to 1868 February 21, by warming the Magnetic Basement by means of the gas stove, and (in alternation) leaving the Basement exposed to the cold of the external air. At first, this was done only for a few hours at a time, but subsequently it was done for one entire day in one state and the following entire day in the other state, the pairs of observations being repeated thirteen times. The results were, that the indications of the Horizontal Force Magnetometer were scarcely changed by change of temperature: while those of the Vertical Force Magnetometer were considerably changed in the direction opposite to that which the ordinary law of thermal changes would have suggested. It is most probable that the change really produced was principally in the iron frame connecting the magnet with the knife-edge.

The Instrument for the photographic record of the intensity of spontaneous Galvanic Earth Currents in two directions has received some changes, the galvanometers being remade, the needle-suspension being made more firm, and the acting parts made more accessible; and it is in very efficient condition. The contemplated arrangement of its galvanic wires will be mentioned in a following section.

Lathe-turned barrels of ebonite are now introduced for carrying the photographic sheets on which all these instruments make their records. This has been long desired, but has become more imperatively necessary now, when the exact correspondence of times on the magnetic barrels with those on the galvanic-current-barrel is assuming great importance.

The Dip Instrument is in the best order. The needles have been specially revised by Mr. Simms.

The Deflexion apparatus also has been thoroughly revised. It still bears the weak connexion of telescope to which I have formerly alluded.

Without entering into details on all the Meteorological Instruments; but remarking only that the class adapted both to eye-observation and to photographic registration includes barometers and thermometers, dry-bulb and wet-bulb; that the class adapted to mechanical record includes pressure, direction, and speed of wind, and fall of rain (by Osler's, Robinson's, and Crosley's instruments); and that there are four other pluviometers at different elevations, thermometers at different depths in the ground, and maximum and minimum thermometers in the Thames; I may state generally that all are in excellent condition. The friction of the photographic barometer was detected and remedied. Osler's Anemometer, in its modified form, gives a very delicate register of small pressures, but its records of large pressures seem to be larger than those which it would have given in its former state: I cannot assert positively that they are larger; nor, if it be so, can I explain the cause: it is certain that the experimental evaluation of the pressure-scale was accurate. Robinson's Anemometer was broken on 1868 February 1 after having recorded 1494 miles in the preceding 48 hours; it was replaced, in a stronger form, on February 11.

The Electrical apparatus is not efficient. I have given little attention to it, having hoped to receive an instrument on the plan proposed by Professor Sir W. Thomson. An Actinometer is under trial which, it is hoped, will maintain its adjustments.

X. Magnetical and Meteorological Observations:—

With the Declination Theodolite, circumpolar stars have been observed about twice in a month, and a fixed mark much more frequently. Absolute horizontal magnetic force has been measured once or twice a month. The photographic magnetometers have been constantly in action, except when under adjustment or experiment. Dips, as a general rule, have been observed nearly once a week. The registers of the Galvanic Earth-currents were interrupted from 1867 October 25 to 1868 January 30, while the galvanometers were under alteration; and they have been

c

finally suspended from the end of April, in anticipation of the change to be mentioned in the next section.

The meteorological instruments have been uninterruptedly at work. There have been no remarkable occasional observations; cloudy weather almost entirely prevented the observation of the November shower of meteors of 1867.

XI.—Reduction of Magnetical and Meteorological Observations :—

In Magnetic Declination, the micrometer-readings for eye-observations are converted into arc to the present time. The adopted meridional reading of Theodolite is computed to 1868, April 29: All other reductions of eye-observations of the three Magnetometers are nearly completed to 1867 Dec. 31; the corrections for temperature are suspended.

The time-scales are laid on all the photographic sheets to 1867 December 31. The new base-lines are drawn to 1866 December 31; and the measures of ordinates at numerous times in every day are read out at the same time.

The absolute measure of horizontal magnetic force is computed from deflexion-observations to 1867 December 31. The observations of dip are reduced to the present time.

For the year 1867, the mean westerly magnetic declination is $20^{\circ}. 20'$ nearly. The mean value of horizontal force is about 3.851 in English units, or 1.776 in French units; the mean dip about $67^{\circ}. 57'$.

The reduction of the Magnetometer-Indications for the period 1858–1863, with reference to diurnal inequalities, solar and lunar, has been generally finished some time past; but it has been impossible for me to command the necessary leisure for their examination till within the last month. I have now, however, completed the discussion of them, and I find the results very remarkable. It is known to the Visitors that, some years ago, I made a similar reduction for the seventeen years 1841–1857, of which the numerical and tabular details are printed in the Greenwich Observations 1859, and the curves representing the diurnal solar inequalities, classified as means for nominal months and means for years, are published in the Philosophical Transactions 1863. It appeared there that the annual curves had gradually undergone a most striking change from 1841 to 1857; the annual mean for 1841, 1842, &c., having the summer character or large-curve character, while those for 1856, 1857, had the winter character or small-curve character. Now the new reductions show that from 1858 to 1863 the opposite change has taken place in the character of the curves, till finally the

forms of the curves for 1863 do not sensibly differ from those in 1841. There is not the slightest trace of decennial or undecennial period, but rather an absolute negation of it.

The observations have also been very carefully grouped with reference to the Moon's hour-angle; and the mean for every year exhibits the semi-diurnal lunar tide. It occurred to me to group the lunar results for years into classes, distinguished by the large solar curves and the small solar curves mentioned above. And the result is, that, in the years of large solar curves, the lunar semi-diurnal inequality is considerably greater than in the years of small solar curves. In both sets, the combination of the westerly and the northerly inequalities shews that the lunar magnetic tide (which is synchronous for the two ordinates) passes through Greenwich in the direction of a line drawn from the Red Sea to the south of Hudson's Bay.

The cosmical results from these deductions appear to me to be, that magnetic disturbances both solar and lunar are produced mediately by the Earth, and that the Earth in periods of several years undergoes changes which fit it and unfit it for exercising a powerful mediate action.

No progress has been made in the reduction of Magnetic storms through the period 1858—1863, except in the general selection of days. They exhibit no decennial or undecennial period.

In regard to the Earth-current records, the time-scales are laid down to 1867 December 31. In regard to the reduction of the observations, a step of considerable importance has been taken. I chose seventeen days in the years 1865, 1866, 1867, in which the character of the disturbances was rather bold; the ordinates were measured for a great number of times on each day; and, from the two sets of measures given by the Croydon wire and the Dartford wire, by an easy mathematical process were found the values of the galvanic currents in the directions of magnetic north and magnetic west which would produce the same effect; and, assuming that such currents, or currents equivalent to them, are passing through the earth below the magnetometers, there was no difficulty, on the well-known laws of transversal magnetic action, in inferring the magnetic effect which they would produce. And the result was, that the agreement between the magnetic effects so computed and the magnetic disturbances really recorded by the magnetometers was such as to leave no doubt on the general validity of the explanation of the great storm-disturbances of the magnets as consequences of the galvanic currents through the earth. Still there are some points requiring explanation; and, for better elucidation of the whole subject, the following plan is in preparation:—1°. To make a similar comparison for all the disturbed days since the apparatus was erected:—2°. To examine all the undisturbed days with the view of ascertaining whether there is any clear exhibition of diurnal inequality:—3°. To abandon the use of the old wires, each of which terminated at the Royal Observatory.

D

and to adopt two new courses determined by the following considerations : That the directions of the wires, defined for each wire not by the actual course of the wire but by the straight line connecting its extreme points where they communicate with earth, are to be (as before) nearly at right angles ; that the two directions are to intersect near the middle of each ; and that this intersection is to be near the Royal Observatory. I believe that the extent of Greenwich Park would have been sufficient ; but the difficulty of carrying wires through the Park is very great ; and, relying on the long experienced liberality of the South Eastern Railway Company and on the zealous assistance of Charles V. Walker, Esq., I have solicited and obtained permission to make one communication from the Angerstein Wharf to the Lady Well Station, and the other from the North Kent Junction to Morden College. The only unfavourable circumstance is, the great length which must be given to the wires in order to obtain the registration at the Observatory.

All eye-observations of Meteorological Instruments are cleared of adjustment-constants, &c., and are made available for use, to the present time. The mechanical registers of Osler's and Robinson's anemometers are complete without application of corrections. For the photographic registers of barometer and thermometers, time-scales, &c. are prepared to 1867 December 31.

The number of rotations of the vane in 1867 is $+23.3$. If the septennial analogy of the preceding twenty-six years were strictly supported, a negative number might be expected at this time. It is sufficiently possible, either that there is no real persistence in the period, or that the length of the period slightly exceeds seven years.

XII.—Printing of Magnetical and Meteorological Observations :—

The Indications of Magnetometers are printed to the month of October 1866. The Deflexion-observations and Dip-observations for 1866 are printed. The Introduction is in type, in our hands. The discussion of the 1858—1863 observations, and that of the Earth Current observations, to which I have alluded above, cannot be prepared in time for this volume.

The Meteorological observations for 1866, as far as is included in the usual monthly arrangement, are printed. The record of the Meteors of 1866 (about 770 in number), and especially of those of November 14 whose paths were well observed (about 240,) to which it seemed probable that reference might be made more frequently than in ordinary cases, has been placed in the printer's hands, but is not yet printed. [Proof has been received, since the date of this report.]

The number of copies printed (as formerly) is, 350 for binding in the general volume for 1866, and 250 for separate distribution.

The usual daily communication of Meteorological results is made to M. Le Verrier for his Bulletin; and the usual weekly communication to the Registrar General of Births, Marriages, and Deaths, for attachment to the medical section of his Weekly Report.

No part of the magnetometer-indications for 1867 is quite ready for press; the abstracts of dip and deflexion observations are, however, ready. The greater part of the meteorological observations are prepared for press.

The system of taking photographic copies of the photographic sheets is suspended, except in special instances.

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

On 1868 May 6 we have on hand 162 chronometers. Of these, the following are the property of the Admiralty: 87 box-chronometers, 19 pocket chronometers, 9 deck-watches. The following are on trial for purchase: 1 officer's chronometer, 1 chronometer for trial of ship's speed. And of makers' chronometers on competitive trial there are 45. The system is maintained without alteration, of daily comparison of every chronometer (except those whose rates are well known to us) with an adjusted Clock of the sympathetic series, and of testing every chronometer in temperature of about 90 F ahrenheit for a few weeks.

The Board of Admiralty in all cases refer to me for estimations of the value of chronometers to be purchased and for superintendence of the repairs of Government Chronometers.

Among the various matters which cause anxiety in the chronometer-administration is one which, in a pecuniary view, is serious:—the rusting of the balance-springs of chronometers while on service in the Navy. Experience inclines us to believe that the steel in its bright white state is less liable to rust than when it is blue. In order to make sure that no part of the mischief can arise from circumstances under our control in the chronometer-transmission, I have prepared a water-bath, in which all tow, &c. used in packing the chronometers will be dried for several hours.

The trial-number for the mean of the six best chronometers tried in 1867 is some-

what less than in any preceding year ; shewing a continued improvement in chronometers.

The Motor-Clock, and the entire apparatus for maintaining the action of sympathetic Clocks, regulating distant clocks, distributing time-signals through the country, dropping time-signal-balls, firing time-signal-guns, &c., are in a perfectly efficient state. Of the external time-signals, the only one for which I am officially responsible is the Time-Signal-Ball at Deal ; to which the galvanic communication is practically difficult. The report on the success of communication is sensibly the same as last year's ; on 83·3 per cent. of days, the ball was properly dropped ; on 8·2 per cent., in damp weather, the current was assisted by hand ; on 4·9 per cent. no current passed ; and on 3·6 per cent. the wind was too heavy to permit the raising of the ball.

On the Great Clock of Westminster Palace it will be sufficient to remark that, on 50 per cent. of days of observation its error is less than 1^s, and on 96 per cent. it is less than 3^s.

For the clocks at the Lombard-Street Post-Office I some years ago arranged an apparatus by which at noon every day a galvanic current from this Observatory seizes the second-hand of the principal clock and turns it round (if necessary) so as to make it point to 0^s. This apparatus has been long in action without a failure.

The management of the various business of Chronometers and Time-Signals occupies the entire office-time of one of my most trusted assistants and one intelligent Supernumerary Computer.

No step has been taken by the Government in reference to the establishment of hourly time-signals on the Start Point.

No determination of longitude has been made in the past year. I have desired to commemorate the most important determinations of longitude that have ever been made by the erection of a monolith pillar on the Feagh Main station in Valencia ; the point from which longitude is measured eastwardly to Orsk on the frontier of Asia and westwardly to Cambridge in the United States. But the sum demanded by the workers of the quarry was so large that I have taken no further action in this matter.

XIV.—Personal Establishment :—

The personal arrangements of the Observatory are on the following basis. The Astronomer Royal is responsible to the Government and to the Public for every transaction in the Observatory. He is aided by eight Assistants, who are appointed

(usually on his nomination) by the Board of Admiralty, and whose salaries are defined in the Navy Estimates. A sum of money is intrusted to him by the Admiralty for procuring the services of Supernumerary or Junior Computers; and the selection of persons for that employment and the adjustment of their stipends rest entirely with him.

The establishment of Assistants is the same as at the last Report, namely: Mr. Stone, Fellow of Queens' College, Cambridge, Confidential Assistant; Mr. Glaisher, Mr. Dunkin, Mr. Ellis, Mr. Criswick, Mr. Lynn, Mr. Carpenter, Mr. Nash. Mr. Glaisher and Mr. Nash are engaged exclusively in the Magnetical and Meteorological Department; Mr. Ellis is entirely occupied in the morning of every day with the business of Chronometers, Time-Signals, Galvanism, and (occasionally) Money Accounts; Mr. Carpenter's office-time is wholly engrossed with attention to the Library, the Manuscripts, the business of distributing Printed Observations, and other parts of the literary administration. Only Mr. Dunkin (who superintends the Altazimuth work and Transit-Circle adjustments), Mr. Criswick (who controls the Zenith-Distance-reductions), and Mr. Lynn (who superintends the Junior Computers in computations of all kinds, including the whole of the Transit-reductions) have their mornings free for astronomical work. All, however, as well as some of the Junior Computers, are employed in observations; those with the Equatoreal being usually confided to Mr. Carpenter.

There are usually six (at present five) Junior Computers in the Astronomical Department, and three in the Magnetical and Meteorological Department; an additional Computer has lately been taken into employ, that we may be able to proceed with the reduction of the Earth-Current records.

Attached to the Observatory are also a gate-porter, a watchman for the night, and a labourer. No workman is strictly connected with the establishment, although, by custom, we use the services of one leading joiner in particular, and are rarely able to dispense with additional assistance.

As in some former years, we have had the company for a time of some gentlemen who desired to make themselves practically acquainted with the methods followed in this Observatory. Mr. Perry of Stonyhurst College, and Lieutenant Ielagin of the Russian Imperial Navy, have in the past year spent some time here.

XV.—Extraneous Work :—

The reduction of Bradley's observations 1743—1750 has proceeded very far, and Mr. H. Breen has quitted the work. I have collected all the books and papers,

but I have not had leisure to examine them with sufficient care for deciding on the final steps.

Some of our time has been occupied with arrangements for time-signals by galvanic communication at Bombay and Madras ; and personally I have given attention, at the request of Departments of the Government, to matters connected with the Observatories of these places. I have also been in some measure employed on two Commissions upon the subject of Standards.

XVI.—General Remarks.

The duties of an institution like that over which I have the honour to preside appear to me to resolve themselves naturally into the following classes :—

First, the utilitarian part (for which, historically, the Observatory was founded), mainly in aid of Navigation and of Geography as connected with it :

Second, the continuous register of the observable cosmical phænomena naturally connected with the utilitarian duties :

Thirdly, the reference of these cosmical phænomena to mathematical laws, and the occasional discussion of the singularities of phænomena or difficulties of explanation which sometimes present themselves :

Fourthly, the giving to the State, when required, such aid as may be expected from a mathematical and philosophical establishment.

The first of these evidently embraces the observations bearing on the Solar and Lunar Theories, with fundamental rather than extended Sidereal Astronomy ; also Practical Magnetism, and to some extent Meteorology.

The second applies to every astronomical object, without exception, included in the Solar and Stellar Systems, and to the theory of gravitation and the laws of formation connected with them. In Magnetism and Meteorology, it comprehends disturbances of every kind.

The third, and the fourth, cannot from their nature be more precisely defined.

These purposes of the Observatory have been kept in view, in the conduct of the establishment, generally for many years past, and specially through the year which is the subject of this Report.

(25)

In respect of the matters under the third head, I alluded particularly in my last Report to the difficulty which I experienced in making the Meteorological observations practically available. I am still oppressed with the same difficulty ; and, with a store of records, extensive, accurate, and rich, beyond any other which exists, I yet do not see a probability of physical connexions or physical laws sufficiently strong to induce me to enter confidently on an extensive comparison. The want of Meteorology, at the present time, is principally in suggestive theory.

G. B. AIRY.

Royal Observatory, Greenwich,
1868, *May* 19.