

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

Read at the Annual Visitation of the Royal Observatory, 1870, June 4.

A

187160AMM..31I...1A

REPORT OF THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1870, June 4.

THE view of the state of the Royal Observatory presented in this Report applies to its general condition on 1870, April 30. The interval of time included in its record of work done is the space of twelve lunations, beginning on 1869, May 11, and ending on 1870, April 30.

I. Buildings and Grounds :—

In the Astronomical Department the modifications introduced have been very small.

The ground-floor room in the East Buildings facing the north, now looking into the Glass Passage, which was lately called the East Depôt, and was used for deposit of printed volumes, is now appropriated as an ante-room to the Supernumerary Computers.

All printed books have been removed from the Lower Record Room, and its shelves are occupied by manuscripts. It is estimated by Mr. Carpenter that an additional length of ten feet of shelving is required every year; and in a few years some additional shelves must be provided.

A 2

In the Equatoreal Room of the South East Dome, the friction of the roof-shutter, to which allusion was made in my last Report, returned in a troublesome degree. A small portion of a plate of iron in the roof was cut away, and the annoyance has ceased.

A temporary rough bridge or gallery has been carried from the north-west window of the Equatoreal Room to the leads above the Library. The object of this is to give facilities to Mr. Stone's observations on the radiating heat of the stars. The thermo-pile is carried by the telescope of the Equatoreal ; but it was found impracticable to use the galvanometer in the proximity of so much moving iron. Wires were, therefore, led from the thermo-pile to the Library, where the galvanometer could be efficiently used, and the bridge was constructed to give rapid transit from the telescope to the galvanometer.

An iron door for the Equatoreal Room is in preparation, and will probably be mounted before the presentation of this Report. Its intention is to cut off one of the possible inlets of fire into that room.

In the first division of the Magnetic Ground (now called the Magnetic Court), the Occasional Observatory has been removed to the South Ground, as will shortly be mentioned.

No alteration has been made in the upper rooms of the Magnetic Observatory. But the staircase which leads down into the Magnetic Basement, and which was inclosed in the upper story by pannelled sides and a door, has now also been inclosed in the lower story by pannelled sides and a door. We have strong reason for believing that this arrangement contributes sensibly to cut off the communication with the changing atmosphere of the upper regions, and thus to maintain uniformity of temperature in the Basement.

Signs of dry rot were lately remarked in the floor of the Basement. As the floor supports nothing important, the injury is limited to a possible giving way of some planks ; none, however, has yet occurred. To promote ventilation for the future, I have removed portions of some of the planks so as to leave long narrow chinks across the room, which give very free passage of air, without inconvenience to the feet.

The Earth-Current self-registering apparatus has hitherto been placed in the western arm of the Basement, nearly in contact with its south wall, and under the staircase. We are commencing (and shall probably have finished before the Visitation) to transfer this apparatus to the eastern arm of the Basement, to be nearly in contact with the south wall there. The apparatus will thus be more accessible ; and it seems probable that the removal of the lights from the west to the east end will tend to destroy the slight elevation of temperature which has usually been remarked at the west end. The immediate motive for this shift was, to give facility for the introduction of

mechanism for imprinting simultaneous photographic hour-lines on the registering barrels, of which I shall speak hereafter.

On the external east wall of the south arm of the Magnetic Observatory, a small shed has been erected, for receiving the cushions of the Basement well-windows.

In the Magnetic Ground (the space between the Magnetic Observatory and the Magnetic Offices) a shed seven feet high has been built expressly for the shelter of detached telescopes and telescope-stands. By the substitution of this low shed for the Great Shed, and by attention to the tree-foliage, the ventilation of the space has been improved.

In the South Ground, the Great Shed and the Depôt for Printed Publications were erected shortly after the last inspection by the Visitors. Anxiety was expressed by some persons in regard to the risk of damp to the books inclosed in a wooden shed without artificial warmth. Mr. Carpenter, who has been instructed carefully to examine the books, informs me that during this winter there has been no sign of damp. It is unnecessary for me to allude further to the Ladder Shed, Plank Shed, and Rough Timber Yard (the positions of which are carefully mapped), than to say that the acquisition of this additional ground has given great facility for the orderly arrangement of such offices, imperatively required in an establishment like that of the Royal Observatory.

The Occasional Observatory is erected in the northern part of the South Ground. It is fitted with a stone pier, and in other respects is prepared for reception of the Water Telescope, to which I shall allude hereafter.

For preserving in neatness the footpaths and roads through these grounds, they are protected by low fences of iron wires carried by short stumps.

The Observatory Map has been extended, by the assistance of a professional surveyor, to include the South Ground, and to exhibit the buildings in their present state. Sections of the grounds of the Observatory have also been taken in different directions.

Our galvanic wires are in the same state as at the Visitation of 1869. In the descent of the wires underground from the Observatory, the softened earth above them had yielded to the rain and exposed the iron pipe inclosing the wires; it is covered now by concrete. A general repair of the wires on the poles of the S. E. Railway has been made by C. V. Walker, Esq., Engineer of Telegraphs for the Railway, at the expense of the Observatory, in conformity with the terms of our agreement. On the earth-current wire from Angerstein Wharf to Lady Well, unusual interruptions occurred, the cause of which has never been discovered; they have, however, ceased entirely. The four earth-current wires (two going, two returning)

(6)

were led from the Magnetic Observatory to a south-west chimney above the dwelling house which communicated with a bed room ; the noise made by the wires when stretched tight was so offensive that I have had the attachment shifted to a south-east chimney.

I alluded in the last Report to the difficulty of seeing the Chingford mark in consequence of the growth of the trees of Epping Forest behind it. I have lately learned that those trees are the property of Richard Hodgson, Esq., late Secretary of the Royal Astronomical Society ; and I am bound to acknowledge the liberality of that gentleman, in spontaneously undertaking that the trees shall be cleared away whenever it shall be necessary, to the extent that may be required to make the Obelisk visible.

On the state of arrangements regarding a proposed railway through Greenwich town or through Greenwich Park, I am unable to give accurate information. A bill was introduced by the S. E. Railway Company to cancel the proposal sanctioned by Parliament for a line passing through the town and on the north side of the Royal Hospital Schools, and to substitute a line through Greenwich Park. I understand that objection was made to this, and that extension of time was then solicited. The general impression appears to be that the Park is safe from invasion for the present. Meanwhile, it is understood that measures are in progress for forming the short railway from the bottom of Maze Hill in East Greenwich towards Woolwich (making a junction with the North Kent Railway near the Charlton Station) ; a step in every way desirable.

II. Moveable Property :—

The most important parts of our moveable property will be mentioned under the heads of Manuscripts, Library, and Instruments. The other moveables are in general good order. Care has been taken to brand with the Observatory mark the wooden instruments and furniture of all kinds.

The small spectroscope to which I alluded in the last Report has been returned. The only instrument of any value which is absent is the Portable Transit (with a view through the axis), which is still in the hands of Sir Henry James. The command of this instrument has enabled Captain Clarke to make some important investigations on the peculiarities incident to that construction.

III. Manuscripts :—

From a very early period in my connexion with the Royal Observatory, I perceived that it would be desirable to establish some plan of arranging papers, by which they should be placed in order and made mechanically secure before the operations of the professional binder commenced ; that in fact, except for the papers last come to hand, there should scarcely be such a thing as a fugitive paper in the Observatory. The system then arranged has been steadily carried out ; at present it is accurately worked by Mr. Carpenter.

All bound volumes have lately been collated with their catalogue, and were found correct.

Many of our original observations are recorded in pencil memorandum-books. The books which are closed in each year are collected, under the three heads of Meridional, Extrameridional, and Magnetic and Meteorological ; and for each of these a box is constructed. Wooden portfolios are prepared for the large sheets, which are wrapped on the Chronograph Barrel and receive the punctures given by the clock-seconds and the observing touch-piece.

The manuscript copies of unpublished observations and calculations, to which I alluded in my last Report as lent to foreign astronomers, are still in their hands. They consist of various papers of Bradley and Bliss, and were communicated to Dr. Auwers and M. O. Struve. Those who know the degree of adoration with which Bradley is regarded by the German astronomers will not be surprised at the importance which they attach to these papers.

IV. Library :—

Our Library is made valuable by being in great measure confined to the four subjects of astronomy, optics, magnetism, and meteorology. The principal current publications on these subjects are presented to us ; some are purchased in the ordinary way ; and some of a periodical nature are received through Her Majesty's Stationery Office.

Mr. Carpenter superintends the binding and cataloguing of the books, and the general charge of lending them to the assistants.

The books were lately compared (as is done annually) with the Catalogue, and were found perfect.

V. Astronomical Instruments :—

The Transit-Circle is in good order. A few months since we were annoyed by a failure in the illumination of the field of view. The reflector was cleaned, but in vain; at last it was discovered that one of the lenses (the convex lens) of the combination which forms the object-glass of a Reversed Telescope in the interior of the transit-axis, and through which all illuminating light must pass, had become so corroded as to be almost opaque. The material of this lens, I believe, was plate-glass. A new crown-lens was prepared by Mr. Simms, to suit the flint-lens which remained; but, as the indices of refraction and dispersion were different, the focal length of the combination was shortened about $3\frac{1}{4}$ inches; and it became necessary to alter the position of the mark which is carried by the other end of the transit-axis.

The Reversed Telescopes and auxiliary apparatus of all kinds are in perfect order.

The discussion by Mr. Stone of the observations which, at his suggestion, were made, of the length of the same arc in different positions of the circle, have led him to the conclusion that the distortion of the circle is insensible.

The intervals of the fundamental divisions at 60° distance were re-examined during some very cold weather in February of the present year. The result did not sensibly differ from that found at a previous examination.

We have lately begun to act on the system of using, for the reduction of each night's observations, the Nadir Point and the Correction for Runs determined on that night. I have for the present adopted this system at the suggestion of Mr. Stone. It is to be remarked that, while on the one hand it makes each night independent of the faults of all other nights, on the other hand it leaves all results affected by the one unbalanced error of the one determination. My own judgment is in favour of using the mean of several nights' determinations when there is no obvious sign of instrumental change. It is, however, a point on which experienced men may well differ.

The Transit-Clock is in good order. Its compensation for temperature is now satisfactory.

An alteration has been made in the mounting of the contact-springs (by which the clock completes a galvanic circuit at every second) so as to permit their removal and restoration without disturbing the dial or the seconds' hand.

The surfaces of each pair of the contact-springs, which formerly were both of platinum, are now one of platinum and one of gold. In the western pair, the platinum is connected with the zinc pole of the battery; in the eastern pair, the platinum is connected with the graphite pole. We hope by one of these arrangements to preserve the platinum from the injury which it receives from the galvanic spark.

A stiffer spring has been applied to the pendulum-suspension.

We are still occasionally troubled with rust on the steel portions of the transit-clock. This had been partly prevented by the introduction of lime ; but another inconvenience has thus been introduced, that of the dissemination of lime-powder over many parts of the clock-mechanism. For the present, the application of lime is discontinued.

The other clocks are in good order. The new clock to be constructed by Messrs. Dent, of 61, Strand, is not yet finished.

The Motor Clock for Mean Solar Time, with its six sympathetic clocks, and all the apparatus for giving and receiving galvanic signals, are in good order. The galvanic communication with the clock in the Royal Hospital Schools has become bad ; and it is probable that the wires may be entirely removed.

The Chronograph-Barrel has required some repair from Messrs. Dent. The pivot-holes of the pricker-levers had become much enlarged ; and the spindle of the rotating-lever which acts on the pendulum had been cut by the edges of the steel anti-friction-wheels. It is now in excellent order.

The Reflex Zenith-Tube is in perfect order, and requires no special notice. The Altazimuth also is in excellent condition. I am preparing at present for the following small modification. In the long and delicate levels, which are essential for this instrument, we have been somewhat annoyed by the great variation in the length of the bubble. Some years ago, Professor Piazz Smyth proposed (and I believe used), for purposes connected with his experiment of stabilizing a telescope on board ship, a level with a second chamber communicating with the principal chamber by a small hole, through which air could be passed, either for the purpose of reducing the observing-bubble to very small dimensions, or for altering its length at pleasure. An artist (Mr. Alfred Holmes) has taken up this idea practically, and I have engaged him to replace one of the levels of the Altazimuth by a level of this construction. Should the experiment succeed, I shall probably exchange all the six levels.

The Shuckburgh and Sheepshanks Equatoreal are in their usual state. No necessity has occurred for giving close attention to the clock-work of the latter ; but when leisure permits, an attempt will be made to render it more accurate.

The South-East Equatoreal is in perfect order. When viewing Mercury on the Sun's disc with its telescope, I was struck with the necessity for correcting atmospheric dispersion, and I was led to arrange a new eye-piece for that purpose, which may be a useful adjunct to telescopes in general. In the last winter, the clock-work was stopped in consequence of water having lodged in a curve of the discharge-pipe, and having become frozen there ; I have changed the direction of the pipe, and have led the discharge into a useless well. I mentioned in the last Report that elaborate plans

B

of the Equatoreal were prepared. I have, with much pains, drawn up a complete explanation of the plans ; and the whole description is now ready for publication.

The Barometers, Thermometers, and other small instruments, are in good order.

The ancient instruments, so far as I have remarked, are in proper order. When measures shall be taken for cleaning the limbs of Bradley's quadrants, I propose also to clean Sharp's quadrant.

I alluded in the last Report to a telescope whose tube should be filled with water, for examination of the coefficient of sidereal aberration, when the pencil of light passes through a considerable extent of refracting medium. I have decided to use it in determining the apparent zenith-distances of γ Draconis at the proper seasons of the year. The instrument is in all important points completed. It is to be mounted upon the stone pier in the Occasional Observatory (formerly Struve's Observatory) now planted on the South Ground. The instrument admits of instantaneous reversion, with its micrometer in N. and S. positions ; it admits also of being fixed with its micrometer in the E. and W. position, for determination of its scale. The construction of the instrument requires several unusual arrangements ; amongst others, the means of cleaning the lower plate-glass from mud, and of clearing the internal surface of the object-glass from bubbles.

VI. Astronomical Observations :—

The practice of the Observatory remains faithful to its ancient traditions. With the meridional instruments, we carefully observe, to the extent that appears necessary, 188 clock stars ; Nautical Almanac, circumpolar, and occultation stars ; stars favourable for examination of refraction, Argelander's, proper-motion, and variable stars ; stars used in geodesy or any other pursuit ; also, with the Reflex-Zenith Tube, γ Draconis on every convenient day. Among the moveable bodies, the Moon only is observed on every practicable day without exception ; the Sun and inferior planets on week-days ; the large external planets when they transit before 15^h, and the small ones when before 13^h, but only for the first half of lunation : M. Le Verrier, and his successor M. De Launay, having undertaken to observe them during the second half. With the Altazimuth, the Moon and proper stars are observed on every practicable night, and these are the only regular extra-meridional observations.

(11)

The following are the numbers of ordinary observations made between 1869, May 11, and 1870, April 30.

With the Transit-Circle :

Transits, the separate limbs being counted as separate observations	3,857
Pairs of observations of the nearly vertical wires of the reversed telescopes	290
Reciprocal observations of the nearly vertical wires of the reversed telescopes	313
Reflexion-observations of the central transit-wire	288
Circle-observations, each requiring a separate reading of the six micrometer-microscopes	3,319
Reflexion-observations of zenith-distance wire (included in the circle-observations)	275
Reflexion-observations of stars (similarly included)	259

With the Reflex-Zenith-Tube,

Pairs of observations of γ Draconis, the instrument being reversed between the observations	48
Single observations	3

With the Altazimuth :

Azimuths of the Moon and stars	542
Azimuths of collimating-mark	326
Zenith distances of the Moon	354
Zenith distances of collimating-mark	326

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

On days when the Moon passed between 21^h and 22^h Mean Solar

Time	3
” ” between 22 ^h and 23 ^h	2
” ” between 23 ^h and 24 ^h	0
” ” between 0 ^h and 1 ^h	0
” ” between 1 ^h and 2 ^h	3
” ” between 2 ^h and 3 ^h	3

B 2

The numbers of places of the Moon observed with the Transit-Circle and the Altazimuth are :—

With the Transit-Circle, 93, or 7·8 per lunation.

With the Altazimuth, 175, or 14·6 per lunation.

The monthly number of observations with each instrument is, I believe, lower than it has been since the tale of observations has been examined. It proves that, generally, the weather has been unusually unfavourable for observations.

Three disappearances and one re-appearance have been observed in occultations of stars by the Moon, and sixteen phænomena of Jupiter's satellites.

The occultation of Saturn by the Moon on 1870, April 19, was observed by three observers. There was no visible distortion of the planet, and no encroachment by either body upon the disk of the other.

The South-East Equatoreal has been partly occupied with the thermo-multiplier employed by Mr. Stone for the measure of heat radiating from the principal stars. Although, in the system of observations necessarily engrossing the powers of the Royal Observatory, the Equatoreal cannot occupy a conspicuous place ; yet, on occasions like the present, its flood of light, its accuracy of definition, its firmness of mounting, and the truth of its clock-movement, are invaluable. Mr. Stone's results for the radiation from Arcturus and α Lyræ appear to be incontrovertible, and to give bases for distinct numerical estimation of the radiant heat of these stars.

There has been little opportunity of employing the instrument on other objects, except in a drawing of Jupiter by Mr. Carpenter. The comparison of this with drawings made eight or nine years ago appears to negative the idea of any change in the colours of Jupiter's belts.

VII. Reduction of Astronomical Observations :—

The best form for this Report is that which I have usually adopted, of stating the day to which each of the principal steps of reduction is effected. The following table, constructed in this form, shews the state of calculations on 1870, April 30 :—

For Meridional Transit Observations :

The observed transits are cleared of instrumental errors, and	
clock-times of transit over the true meridian are exhibited, to . 1870, April 30	
Apparent right-ascensions from observation are formed by	
application of clock-errors and rates, to	April 25

Stars' corrections are computed, to	April 28
Mean right-ascensions of Stars from observation, reduced to 1870, January 1, are formed by combination of the two last- mentioned elements, to	Jan. 31
Mean Solar Times of observation of Sun, Moon, and Planets are prepared, to	Feb. 15
Corrections for deficient illumination of Moon's and Planets' limbs are applied, to	1868, Dec. 31

For Meridional Circle Observations :

Means of microscope-micrometers are taken, and corrected for telescope-micrometer, errors of graduation, flexure, inclination of wire, and zenith-points, exhibiting apparent zenith-dis- tance, to	1870 April 20
Refraction, parallax, and colatitude are applied to form true geocentric north polar distances, to	April 6
Stars' corrections are applied, forming mean north polar distances on 1870, January 1, to	Feb. 10
Corrections for deficient illumination of Moon's and Planets' limbs are applied, to	April 6

In the reductions of the Circle-Observations, the diminished Mean Refractions (Bessel's $\times 0.99797$) are used.

The investigation of the personal equations for 1869 is finished ; they scarcely differ from those of the preceding year.

The results for Mean R.A. and Mean N.P.D., 1869, Jan. 1, of each star, are collected, but their means are not taken ; and the further inferences for R—D, correction to assumed latitude, position of ecliptic, and geocentric and heliocentric errors of planetary tables, are therefore not made for 1869.

For the results of 1868, I have to offer the following statement. In printing the individual results for Mean R.A. and Mean N.P.D., remarking that, since the introduction of the Transit-Circle, the two elements are very commonly observed at the same transit, I have thought it convenient to combine the two systems of ledgers, so as to exhibit at once to the eye all the separate results of both elements for each star as deduced from observation. The value of R—D is nearly the same as in 1867. The colatitude is exactly that which Mr. Stone expected to find after the diminution of refraction, namely $38^{\circ}. 31'. 21''.63$.

The observations of γ Draconis made with the Reflex-Zenith-Tube are reduced to the end of 1869.

The Altazimuth observations are reduced to the following stages :—

In Azimuth, Means of Micrometer-Microscopes are formed, and corrections for level-readings, instrumental errors, and Azimuthal Zero, so as to exhibit True Azimuths, to	1870, Mar. 24
In Zenith Distance, True Greenwich Zenith Distances are formed, by combinations of similar character, to	April 23
The corresponding Tabular Azimuths and Zenith Distances are computed, to	April 9
The apparent Tabular Errors of Moon's place in R.A. and N.P.D. are computed, to	Mar. 24
The apparent Tabular Errors of Moon's place in Longitude and E.N.P.D. are computed, to	Feb. 25

On all these reductions I may remark that they are almost more advanced than I could have expected to find them, considering how much labour has been employed on the New Seven-Year Catalogue, the Description of the Equatoreal, and Mr. Breen's Corrections of orbital-elements of Jupiter and Saturn.

For the New Seven-Year Catalogue, in which all the results of star-observations from 1861 to 1867 are reduced to the epoch 1864, all results have been for some time past fully prepared for press. The number of stars is 2760.

VIII. Printing and Distribution of Astronomical Observations :—

The volume of observations 1867 has been distributed in the usual manner.

Of the Astronomical part of the Volume for 1868, the following is the state. The whole is printed, except six hours of the Star-Ledgers, and part of a sheet of the Circle-Observations. The Proofs of the Introduction have been read. There are three Appendixes, namely ;—First, Mr. Breen's investigation of the Corrections to the Orbital Elements of Jupiter and Saturn (a paper originally communicated to the Royal Society, but which, in carrying out a Resolution of the Board of Visitors passed at their last meeting, has been annexed to the Greenwich Observations, 1868): this Appendix is entirely printed. Second, the New Seven-Year Catalogue of Stars: this is printed as far as 13^h. of Right-Ascension. Third, the Description of the Great Equatoreal, illustrated by engravings: this is entirely printed.

The number of copies printed is,—350 copies of the volume including Appendixes, 350 separate copies of the New Seven-Year Catalogue, and 250 separate copies of each of the other Appendixes. Of the Investigation of the Corrections of Elements of Jupiter and Saturn, 100 have been placed at the disposal of Mr. Breen, leaving 150 for disposal by the Observatory.

No part of the manuscript for 1869 is yet sent to the printer. It has been found prudent to abstain from printing observations until the reductions are very far advanced.

Observations are communicated in manuscript whenever it appears that they can be useful. Extensive series of lunar observations have thus been communicated in the last year, to serve as bases for determinations of longitude in the hydrographical surveys of foreign governments.

IX. Magnetical and Meteorological Instruments:—

Under the care of Mr. Glaisher, the Magnetic Basement is maintained in a state of nearly uniform temperature. The daily changes are small; generally speaking, not exceeding 1° Fahrenheit; in some few days amounting to 3° . These, however, are the ranges shown by the thermometers outside the double boxes; in the inside, it is probable that the changes are less. It is more difficult to grapple with the annual changes, especially with the rise of temperature in the summer heats; from October to May the temperature may be maintained, by attention to the gas-stove, between 59° and 62° ; but on some occasions in the summer it has exceeded 70° .

The Upper Declination-Magnet for absolute determinations of Magnetic-Declination, with the reversed telescope attached to it, and the Theodolite by which that reversed telescope as well as circumpolar stars are viewed, is in perfect order. The three Magnetometers for photographic register of small changes, in Declination, Horizontal Force, and Vertical Force, are all good. It is our practice to devote a few days at the end of every year to examination of the state of the instruments, and of what may be called the "standing adjustments"; on these occasions we avail ourselves of the assistance of Mr. Simms for special examination of the Vertical Force Magnetometer. Its knife-edge was found, at the end of 1869, in an excellent state. There have been no dislocations of photographic curve.

Careful observations have been made for assuring the identification, in the earth-current registering apparatus, of the wires led from the four different stations. The insulation of those wires is very good. On March 24 one of them was found to be defective and was repaired.

A small change has been made in the wheel-work of the clock-movement which turns the barrel of the Earth-Current Magnetometers, to diminish the shake among the wheel-teeth. The apparatus is in excellent order. I propose to move it from the south wall of the western arm of the basement to the south wall of the eastern arm, where it will be more accessible, and more conveniently situate for application of the apparatus to which I now proceed to allude.

I have at length arranged a plan for photographic impression of hour-lines upon the photographic sheets of the three galvanometers and of the Earth-Current Magnetometers, and am taking the first steps for carrying it into effect. It was found that by use of the existing lights, and in one instance by a special light, a line in the proper position could be impressed on each barrel; all that is necessary is, to uncover and cover the light at the proper times. I have so arranged the requisite shades that all the lights can be uncovered and covered by the action of a single wire. I have sketched the plan of a clock which shall act upon that wire, and am only waiting for some experiments on the force required, in order to put in hand the construction of the clock.

Every part of the dip-instrument has been revised; one of its needles required a small correction. No steps have been taken for making observations at different hours of the day. The state of weather sometimes interposes difficulties in this operation.

The deflexion-instrument is in good order.

The meteorological instruments (barometer, thermometers dry and wet, thermometers in the ground and in the Thames, Osler's and Robinson's anemometers, pluviometers at different elevations,) remain in their former state, with the following exceptions. I have procured one of Adie's barometers, the fundamental action of which is similar to that of the aneroid, but with flat bulb of glass instead of metal; we have hitherto used it little. The clock-work which carries the photographic cylinder for the dry-bulb and wet-bulb thermometers has been so altered as to effect the revolution in 50 hours instead of 48 hours; this is for the purpose of completely separating the traces of the two instruments. The use of the Dreadnought Hospital Ship in the Thames has ceased, and the Observatory-thermometers attached to it, for record of the temperature of the water of the Thames, have been very lately removed;

It is possible that we may be able to connect them with some other ship of the Government.

Some years ago I mounted for public view a barometer, exhibiting the changes of atmospheric pressure on a rather large scale. I have wished to exhibit thermometrical changes in the same manner, but I have not succeeded in arranging an instrument to my satisfaction.

We are still without self-registering electrical apparatus.

X. Magnetical and Meteorological Instruments :—

Astronomical zeros of the Declination-Theodolite have been determined by observation of circumpolar stars about twice in a month ; more frequent observations of a fixed mark have been made, merely for verifying the steadiness of the Theodolite. Eye-observations of each of the magnetometers have been taken about four times every day. The self-formed photographic register of each has never been intentionally omitted. The register of earth-currents has been always in action. The observations for absolute measure of terrestrial horizontal magnetic force have been made, sometimes once, sometimes twice, in a month. Dips are observed more frequently.

All the meteorological instruments have been constantly used, by eye or for self-registration, according to the adaptments of their construction. The assemblage of their results contains the most perfect meteorological record, except only in atmospheric electricity, available either for civil or for scientific purposes, that it appears possible to obtain.

The meteor-shower on 1869, November 13-14, was partially observed through clouds.

XI. Reduction of Magnetical and Meteorological Observations :—

The astronomical zero of the Declination-Theodolite is computed to 1870, April 18 ; its readings for eye-observations of the Upper Declination-Magnet are reduced to arc to the present time. The equivalents for eye-observations of the Horizontal Force

c

Force Magnet are prepared to the present time, and those for the Vertical Force Magnet to 1869, December 31. No corrections for temperature are applied. These eye-observations serve for zeros in the interpretation of the photographic records.

Time-scales are laid down in the photographic sheets to the end of 1869; new or convenient base-lines of measure are drawn for the three ordinates to the ends of 1868, 1869, and 1869; and ordinates are measured to the ends of 1868, 1868, and 1869.

For the year 1868, 11 days were originally selected as disturbed days; and I wish to have this number regarded as the number of disturbed days peculiar to 1868, on the same scale of disturbance as that which has been adopted in communications made by me to the Royal Society. But, understanding it to be the wish of the Visitors that the exhibition of disturbances should be somewhat liberal, I added to this list 12 days of less disturbance: and for these 23 days the ordinates of the photographic curves have been measured at every salient point, and no further reduction is made. For the remaining days of the year, mean pencil-curves have been drawn, and the ordinates have been measured at every hour; and these have been grouped to obtain diurnal and other inequalities for every month, in the way in which it has been done in communications to the Royal Society.

The reduced observations on disturbed days have not been discussed since the end of 1857.

Terrestrial horizontal force in absolute measure is computed to 1869, December 31. Dips, to the date of this Report.

In 1869, the mean westerly declination was $20^{\circ}.4'$ nearly: the mean horizontal force 3.860 (English units) or 1.783 (Metrical units): the mean dip about $67^{\circ}.54'.36''$. But as the apparent result for dip depends (for mechanical reasons) on the dimensions of the needle, the following statement may be interesting:—

Mean Dip, 1869, given by 9-inch needles	.	.	.	.	$67.52.40$
6-inch „	.	.	.	.	$67.54.37$
3-inch „	.	.	.	.	$67.56.30$

No numerical measures have yet been taken of the photographic registers of spontaneous earth-currents, recorded with the earth-current wires in their new position.

For the meteorological observations, the following is the report:—The records of the two anemometers require no addition of scales. The eye-observations of all the other instruments are completely reduced, and the dew-point and the degree of moisture are inferred from the dry and wet thermometers, to the present time. Time-scales have been attached to the photographic curves of the barometer and the two thermometers, and the new base-line of the barometrical register is drawn to the end of

1869: no base-line is required for the thermometrical registers, as the wires upon the thermometer-tubes give a negative photographic record at every degree.

The number of rotations of the vane in 1869 was $+4.9$.

At the end of my last Report to the Visitors, I alluded to a proposed systematic reduction of the meteorological observations during the whole time of their efficient self-registration. Having received from the Admiralty the funds necessary for immediate operations, I have commenced with the photographic registers of the thermometers, dry-bulb and wet-bulb, from 1848 to 1868. The ordinates of the dry-bulb thermometer through this whole period, and those of the wet-bulb through more than half of the whole, as also the corresponding eye-observations (giving zero-corrections) for the whole time, are entered into proper printed forms; and facilities are arranged (similar to those which I used in the great Reduction of Lunar Observations) for summing them through any arbitrary periods. These periods will be determined by considerations of winds and other general meteorological phenomena: a small portion have already been marked off.

XII.—Printing of Magnetical and Meteorological Observations :—

For 1868, the results derived from the self-registering magnetometers in Declination, Horizontal Force, and Vertical Force, reduced to the state of Diurnal Inequalities in Monthly Groups, are printed in a tabular form. The indications of the magnetometers on twenty-three disturbed days are printed in the state of simple record. The observations, with reductions, for absolute measure of horizontal force, and the results of the dip-observations, are also printed.

The ordinary meteorological observations for 1868 are printed, merely in a monthly arrangement available for civil purposes. The meteors of the November period, the great waves of atmospheric pressure, the rain-fall at various elevations, the readings of the deep-sunk thermometers, are printed.

The Introduction (which I have re-written with much care) is expected immediately from the printer. Among other things, it contains information on the three methods which I have tried for determination of the thermal correction applicable to the results of the horizontal-force and vertical-force magnetometers. From the experience of later years, I am inclined to believe that the hot-air process required greater care, especially

in the maintenance of uniform temperature for some hours, than was bestowed on it; supposing due attention given to this point, I think that the hot-air method, as well as the hot-water method, is trustworthy for the horizontal-force magnetometer. But for the vertical-force magnetometer I am certain that only one method can be trusted, namely, the variation of the temperature of the instrument-room without displacement of the vertical-force-instrument from its bearings: a process analogous to that used many years ago by Sir E. Sabine for determining the thermometrical correction of pendulum-observations. When it is considered that the whole statical force of terrestrial magnetism upon a large magnet does not exceed four or five grains, it is evident that an untraceable thermal effect upon the mechanical mountings of the magnet may produce a disturbance in the conditions of equilibrium far exceeding that produced by the trifling modification in that force of four or five grains. If, for instance, the principal pinch of the magnet in its carrier is slightly excentric, the unequal thermal expansion of its two arms will so disturb the balance as completely to vitiate all results deduced by the aid of purely magnetic corrections.

The whole number in the impression of the Magnetic and Meteorological Observations is 600 copies; of which 350 are attached to the general volume of Greenwich Observations, and 250 are intended for separate distribution.

Certain simple results of meteorological observations have been communicated every day, by telegraph, to M. Le Verrier, and are now communicated to his successor, M. De Launay. A page of meteorological results is communicated every week to the Registrar General of Births, Deaths, and Marriages.

For 1869, the magnetic results for dip and horizontal force, and nearly the whole of the meteorological abstracts, are ready for press.

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

Our chronometer-room contains at present 219 chronometers; namely, 150 box-chronometers, 23 pocket-chronometers, and 9 deck-watches, all belonging to the Government; and 37 chronometers which have been placed here by chronometer-makers as competing for the honorary reputation and the pecuniary advantages to be derived from success in the half-year's trial to which they are subjected. I take this opportunity of stating that I have uniformly advocated the policy of offering good prices for the chronometers of great excellence, and that I have given much attention

to the decision on their merits ; and I am convinced that this system has greatly contributed to the remarkably steady improvement in the performance of chronometers.

In the trial which terminated in August 1869, the best chronometers (taking as usual the average of the first six) were superior in merit to those of any preceding year.

All chronometers are rated daily till they are approved, and, afterwards, weekly ; and all are tried some weeks in a temperature approaching to 90° Fahrenheit.

The labours of the Observatory are not confined to the rating chronometers and estimating their value ; they include also the entire management of their repairs, the receipt of chronometers from all parties, and the issues to out-ports and to ships. A very great amount of labour is expended on these transactions, and on the necessary communications with the Admiralty and with chronometer-makers.

In sending chronometers, with their balances wedged, to all parts of the world, only one accident has been suspected. But several have arisen from the rude wedging by naval officers who send chronometers here. I hope to secure the assistance of an eminent chronometer-maker, which may lead to general adoption of a simple plan of his invention in the construction of the chronometer, intended to dispense with this wedging, and which has been perfectly successful in two instances placed before me.

The experience of bright steel springs is still favourable to their preservation from rust.

Selections of chronometers have sometimes been made when required for purchase by the India Office and by other departments of Government.

The Greenwich Observatory Time Ball has been dropped with unerring regularity and accuracy. The public dial near the entrance gate of the Observatory, which is sympathetic with the " Motor Clock," and is worthy of all confidence, is now frequently used by the public for the comparison of chronometers.

The general system of communication of time-signals originating from our Motor Clock to nearly every part of the kingdom is in perfect order. In the communications to the Time Signal Ball at Deal, by a remarkably difficult telegraphic line, I find that, on 82·5 per cent. of days, the ball was dropped freely ; on 10·7 per cent., with damp weather and a defective wire, the assistance of the attendant's hand (without appreciable error of time) was required ; on 1·1 per cent., the violence of the wind made it imprudent to raise the ball ; on 5·4 per cent., the communications were interrupted ; and on a single day, the ball was erroneously dropped by telegraph-currents on the railway. On occasions like the last, a black flag is hoisted on the tower, to warn spectators of the ball-drop that an error has been committed. After these and all other failures, the ball is dropped by hand at 2^h (the usual time being 1^h).

In the Great Clock of Westminster Palace, the attendant on which receives time-signals from us, 44 per cent. of the errors are under 1^s and 96 per cent. under 3^s .

Time is efficiently given to the Lombard Street Post Office (where a clock which gave much trouble was found, on being transported to Greenwich, merely to have a lever slightly out of balance), and to the India Store Office.

In November 1869 I again took the sense of the Admiralty on the proposal to establish hourly time-signals on the Start Point. Their Lordships decided to maintain the former decision adverse to the proposal.

The telegraphs have not been used in the past year for the determination of longitudes. For this and similar purposes I remark that, as I understand, in the new subordination of telegraphs to the Post Office, the Post Office accepts all the customary engagements of the former proprietors of the telegraphs; and I have no doubt that, in case of need, every assistance will be given by that Department.

XIV.—Personal Establishment :—

All external communications to or from the Observatory pass through the Astronomer Royal, who plans all observations, calculations, and publications; superintends all ordinary matters of building repairs, instrumental equipment, general discipline, &c., and is in fact responsible for every transaction within the Observatory. He is aided by Mr. Stone, as Confidential Assistant and (in his own absence) General Representative; Mr. Glaisher, who is charged with the immediate care of the Magnetical and Meteorological Department; Mr. Dunkin, with the Altazimuth; Mr. Ellis, with the Time Department and Money Accounts; Mr. Criswick, with Circle Reductions; Mr. Lynn, with the superintendence of Supernumerary Computers; Mr. Carpenter, with the Equatoreals, the Library and Manuscripts, the distribution of Observations, and the literary administration; Mr. Nash, with duties of the Magnetical and Meteorological Department in subordination to Mr. Glaisher. These gentlemen are borne on the Admiralty Books, with salaries sanctioned by the Admiralty. Besides these there are at the present time five supernumeraries attached to the Astronomical Department, three to the Magnetical and Meteorological Department, and two now employed on the Meteorological Reductions 1848–1868; the admission, the stipends, and the removal of the supernumeraries are fixed by me, after consultation with the First Assistant and the Assistants to whose department they are usually attached.

My best thanks, and the thanks of all who are interested in the Observatory, are due to the Assistants by whom its honor and utility have been so ably and zealously supported.

Very lately, the duties of Mr. Dunkin and Mr. Lynn have been interchanged, in order to relieve Mr. Dunkin (the senior observing assistant) in some degree from the severity of observations.

There are also a gate-porter, a night-watchman, (whose rounds are verified with the assistance of the "watchman's clock,") and a labourer, and we are never without carpenters, one of whom is almost considered as a permanent officer.

XV.—Extraneous Work:—

In the reduction of Bradley's observations anterior to 1750, the elements of the resulting star-catalogue are prepared, and a skeleton-form has been printed for reception of the numbers, but no further step has been taken for want of a proper computer..

The examination of the proof-sheets of Mr. Breen's paper on Jupiter and Saturn was a far heavier work than its extent would seem to imply.

The necessity of acting soon with reference to the Transit of Venus, 1874, was laid before the Government, who answered liberally to the appeal. With the funds placed at my disposal I purchased three 6-inch equatoreals, and have ordered two: I have also ordered altazimuths (with accurate vertical circles only), and clocks, sufficient, as I expect, to equip five stations. For methods of observation, I rely generally on the simple eye-observation, possibly relieved of some of its uncertainty by use of the colour-correcting eyepiece to which I have alluded. But active discussion has taken place on the feasibility of using photographic and spectroscopic methods; and it will not be easy for some time to announce that the plan of observations is settled.

Questions relating to the Colonial Observations are sometimes addressed to myself. Occasionally also, trials of various proposals of clock construction and decisions on clock-expences, and, more regularly, trials of Navy Telescopes, are referred to the Observatory.

The Royal Commission on National Standards, still sitting, has necessarily occupied a portion of my time.

In compliance with a request from the Lords of Committee of Privy Council on Education, I gave a short course of Lectures on the Magnetism, &c. of Iron Ships, at the School of Naval Architecture in the Kensington Museum.

XVI.—General Remarks.

Adverting to the selection of the classes of observation, the care for the preparation of fitting instruments, the personal organization necessary for advantageous use of them, the orderly labour of observing, reducing, and publishing the observations, I express my opinion, and I almost reckon on that of the Visitors, that the Royal Observatory has maintained its place well as an Observing Establishment.

There can be no doubt, I imagine, that these are the first and necessary duties of the Observatory; and that these must be secured, at whatever sacrifice, if necessary, of other pursuits.

Still the question has not unfrequently presented itself to me, whether the duties to which I allude have not, by force of circumstances, become too exclusive; and whether the cause of Science might not gain if, as in the Imperial Observatory of Paris for instance, the higher branches of mathematical physics should take their place by the side of observatory-routine.

I have often felt the desire practically to refresh my acquaintance with what were once favourite subjects: Lunar Theory and Physical Optics. But I do not at present clearly see how I can enter upon them with that degree of freedom of thought which is necessary for success in abstruse investigations.

G. B. AIRY.

*Royal Observatory, Greenwich,
1870, May 18.*