REPORT

OF

THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1860, *June* 2;

AND

ADDRESS

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1860, May 12.

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THE rule which I have adopted in several past years, of presenting to the Visitors a Report applying to a period of 12½ lunar months, appears so convenient that I shall retain it on the present occasion. I proceed therefore to lay before the Visitors a Report on proceedings in the Observatory from 1859, May 16, to 1860, May 20, and on the state of the Observatory on 1860, May 20. The usual order will be followed.

I. Buildings and Grounds.—No important change has been made in the buildings, and no new buildings have been erected. It may be convenient, however, to put the following matters on record.

The Visitors will remark that several cabinets and shelf-cases, which for many years have been attached to the walls of the Octagon Room, are now removed. This was a more serious work than the mere verbal terms imply. Some ignorant carpenter, to make place for these insignificant shelvings, had cut through Sir Christopher Wren's cornices and mouldings, and had planed the astragals off from the pannels; so that it was impossible to remove the obstructive additions without undertaking the heavy work of restoring the cornices, &c. After many years' endurance of the unsightly fixtures, I at length determined at all events to remove them, and in the last autumn (the first time for perhaps half a century), the shelves, &c. were taken down, the cornices, &c.

were restored, and the room was exhibited in the form in which the celebrated architect left it. Two cases are still usually kept in the room for convenience, but the walls behind them are perfect, and the cases are not attached to the walls.

Upon the roof of the Octagon Room is planted a pole (erected, at my request, by the London District Telegraph Company) for carrying the open-air telegraph wires, which swing from this point to a similar pole erected on the roof of a house in George Street, far beyond the Park Wall. I shall allude hereafter to the necessity of adopting this system for our galvanic communication.

The roof of the large S.E. Dome has been altered in conformity with the plan explained at the last meeting of the Visitors. The slope of the zinc covering has been increased, and thicker sheets of metal have been used. Since this change was made, the roof has been perfectly tight against rain.

The internal fittings of the large Dome (principally a partial amphitheatre of fixed seats on the south side, a quadrantal chair-frame turning in azimuth and carrying two sliding chairs, and a curb to support a cradle with the sliding chair which it carries for intra-axial observations, with closets for auxiliary instruments, &c.) have been prepared as was contemplated. These will doubtless require occasional changes, as experience in the use of the Equatoreal shall suggest.

When the projecting cornice was constructed at the top of the tower which carries the S. Dome, it was necessary (for safety) to load its inner edge, and two courses of brick were built on it for that purpose. As this erection seemed to obstruct the lower views of the telescope, it has been removed, and, in its stead, plates of cast-iron of nearly the same weight have been substituted. These plates, besides removing the apparent obstruction, have the advantage of binding together the brick-work of the tower-walls.

The want of a covered passage to the Chronographic Room, to which I have before alluded, is still occasionally felt. It will not, however, be easy to supply it.

The maps and plans of Observatory Grounds and Buildings are maintained.

II. Moveable Property.—Scarcely any alteration has been made in the moveable articles of the Observatory, unless I may include under that term the apparatus of rough kind which is necessary for the use of instruments, especially of the new Equatoreal. The furniture and detached instruments are in general good order.

The copies of the National Standards of Length and Weight are in proper condition.

III. Manuscripts.—The whole of the Manuscripts of the Board of Longitude, to which I have several times alluded, are now bound, and the Indexes to nearly the whole are written out. Mingled with a great deal of worthless matter (though, in its most worthless state, always having a somewhat scientific character) these volumes contain invaluable materials for a history of science through the greater part of the last century, and it is to be wished that at some time they may be used for that purpose.

I take this opportunity again to remind the Board that the Minutes of the Visitors from 1784 to 1830 are missing. It seems not impossible that they may have come into the hands of some officer of the Royal Society at the time when a revision of the Visitation was contemplated. I should be very glad to receive any information on the possible place of this book.

The Manuscripts which arise in the daily conduct of the Observatory are regularly arranged and bound.

IV. Library.—The Library has received little increase except from the maintenance of serial works, and from the presents of books of various kinds made principally by foreign institutions.

V. Astronomical Instruments:—

The Transit-Circle is in general good order. No alteration or repair has been made to it. In its auxiliary barometer, the brass-work of the index, which was found nearly rotten, has been in part replaced.

On the Reflex-Zenith-Tube and the Altazimuth I have no special remark to make. No repairs have been made to them, and they are in general good order.

The Chronographic Barrel Apparatus, though generally doing its duty very well, has not lately been quite so steady in its motions during fractional parts of a second as I could wish. The active cause of this unsteadiness is some irregularity in the communication of force through the train of wheels: the want of suppression of its effects arises from the want of sufficient moment of inertia in the fly. I propose to add a multiplying wheel, by which the fly, instead of revolving once in two seconds

as at present, will be made to revolve several times in one second.—The mere resistance of the atmosphere, also, is found to be scarcely sufficient to determine the conical angle of the pendulum with sufficient accuracy (an adjustment which requires attention, because the effect of a given angle of swing on the rate of the pendulum is six times as great for a conical pendulum as for a plane pendulum). I contemplate the introduction of an apparatus, on a lighter scale, similar to that which I have introduced with perfect success in the water-clock of the Great Equatoreal; where the enlargement of the pendulum's arc dips a plane resisting piece into water, and thus produces a resistance which is purely tangential, without any of the centripetal force which accompanies frictional resistance, however the friction may be applied. This principle, in the water-clock of the Great Equatoreal, is found to produce astronomical accuracy of motion.—The galvanic wires which convey the currents that give the observation-punctures on the Barrel are now connected with the touch-piece on the eye-end of telescope of Great Equatoreal; so that the observation-punctures are now made by the same pricker from contacts at either of the three instruments, Transit-Circle, Altazimuth, or Equatoreal.

The Galvanic Apparatus within the Observatory has received the following addition. The visitors will remember that a pair of galvanic springs was mounted in the Transit-Clock, giving 59 contacts in 60 seconds, by which the motion of a 10-inch clock in the South-Eastern Dome is regulated to sympathy, and by which the movement of a Chronometer carried by the eye-end of the Great Equatoreal is absolutely maintained, (a 59-tooth wheel, and a 59-division dial, one special division counting for two seconds, being required for this Chronometer). The same current is now made to pass also through a similar Chronometer in the Computing Room, which is thus maintained in sympathy with the Transit-Clock. There is also, placed near the Chronometer just mentioned, another small clock which, by a special pair of wires from the Solar Motor Clock, and a portion of the Clock Battery, is kept in sympathy with the Motor Clock. And near to these is a commutator for changing the direction of the current of an appropriated battery. The use of this battery is to produce attraction or repulsion of a galvanic coil (without core) which is fixed within the case of the Motor Clock, upon one pole of a bar-magnet, which is carried by the pendulum-rod, and is parallel to the pendulum-rod. The pole of the bar-magnet swings immediately above the pole of the galvanic coil, so as to receive the greatest attraction or repulsion which the coil can give: when the force is attractive, the force of gravity on the pendulum is augmented, and the clock is made to gain; when the force is repulsive, the clock is made to lose. The Galvanic Superintendent has, therefore upon his desk, a representative of the Transit-Clock and a representative of the Motor Clock, which he can compare; and when, by this comparison, and the necessary reduction, he has ascertained the error of the Motor Clock, he has merely to turn the

commutator-handle, and to let it remain in that position for a certain time, in order to correct the small error of the Motor Clock. By using a battery of low power, the correction of the Motor Clock may be made very gradual, and this is sometimes desirable, for the following reason: It is probable that we may soon make it our business to regulate, by action at every second on the pendulum, clocks at the London Bridge Terminus, at the Office of the London District Telegraph Company, at the Chronometer Makers' Institution at Clerkenwell, &c. As the force transmitted to these distances is small, the rates of the clocks without adjustment must be very near together, say within $\frac{1}{1000}$ part. If then we had attempted to correct our Motor Clock by the old process, which changed its rate for a time by $\frac{1}{100}$ part, its action upon the distant clock would have failed to draw that clock's pendulum into sympathy with its own, the difference of $\frac{1}{100}$ in the rates for that time being too wide. But by the new process we can, with the utmost personal convenience, affect the rate by not more than $\frac{1}{2000}$ or $\frac{1}{3000}$ part, and the regulation of the distant clock will then never fail.

Our external galvanic communication has received a very important change. We had found for some time that our two underground wires leading to the Blackheath Gate of the Park, and there adapted to communicate either with one of the Admiralty wires (to the Admiralty, or to Woolwich, Chatham, Sheerness, Deal,) or with one of the Submarine Company's wires (to the London Office, or to Calais or Ostend,) had become practically useless. One of the four underground wires crossing Blackheath to the Lewisham Station of the North Kent Railway (there communicating by the London Bridge Station with Lothbury and with Deal,) had shown signs of decay, but the others were very good; but about the month of August last year the whole of the four wires failed. We have taken up parts and replaced them by new wire, but apparently the whole of the gutta percha has perished. No special fault has been found, but every yard is faulty. I determined after this to trust no more to underground wires; and having received the permission of the Right Honourable the First Commissioner of Parks and Public Works, to extend wires at sufficient elevation above the Park; and having been met in my application to the London District Telegraph Company by the most liberal offer on their part; I have stretched seven wires in the open air from the top of the Octagon Room to the top of a house in George Street. From this point the wires are carried on in a similar manner to the following destinations:—One is the property of the London District Telegraph Company. Four are led to the Railway Station in Greenwich, whence, under the care of Charles V. Walker, Esq., they are continued on poles till they rejoin the continuation of the former North Kent lines at the railway junction. (Mr. Walker is preparing arrangements for placing the wires in open air all the way to the London Bridge Station.) Two are led along the poles of the London District Telegraph Company to Deptford Broadway, where they meet the lines of the Submarine

Company, and where they will communicate by turnplate either with the Admiralty line or with the Submarine line, as formerly at the Blackheath Gate of Greenwich Park.

The North Equatoreal (Shuckburgh's) is in the same state as for several years past. It is useless, except as a telescope-carrier; and its position, in respect of its command of the heavens, is very nearly the worst that could have been selected within the Observatory Inclosure. It is probable that at some time I may be induced to move it.

The East Equatoreal (Sheepshanks') and the Double-Image Micrometer adapted to it, are in good order. The counterpoise and roller do not act well, and I doubt their fitness for an instrument whose axis-diameter, at the bearing points, is so large.

The South-East Equatoreal may now be considered in a state for use. At present, I am not aware that it wants anything, except convenient arrangements of shade-glasses; but other things will suggest themselves in experience. The instrument was fully described in the last Report; and I shall now allude only by name to its chief peculiarities, remarking that no change of principles has been made since the Visitors saw it last year. They are, then, the Upper and Lower Oval (the Upper Oval being partly cut through to admit of clear view beyond the celestial pole), the skeleton prismatic sides, the excentric position of the declination-axis (to give clear view beyond the celestial pole), the declination circle and its microscopes, the bridle-rods for approximate measure of N.P.D., the adjustible hour-circle and its three microscopes (two carried by the Lower Oval, one by a fixed support), the clock-work acting on the hour-circle, the water-power and reaction-machine which drive it, the pendulum and chronometric-governor which regulate it (the enlargement of the pendulum-arc dipping a revolving spade into an annular trough of water); also, the leading of gas to all parts of the instrument, and even to the eye-end of the telescope, and the leading of galvanic communication to the 10-inch clock, to the chronometer on the eye-end of the telescope, and to the contact-springs there. I shall, however, allude more at length to its adjustments.

The first adjustment was that of the position of the Polar Axis. For this purpose, the polar distances of stars, and also of the Sun, were observed (graduated face of declination-circle right and left), at hour-angles about 3^h on each side of the meridian, and the N.P.D. derived from the declination-circle readings were compared with those obtained from catalogued places corrected for refraction and parallax. The approximate place had been settled with care, and very little alteration was necessary. The alteration

was easily effected by the excellent adjusting screws which Messrs. Ransomes and Sims had provided.

The following adjustments could not be made until the clock-work was in perfect efficiency. I will shortly speak of it; and, supposing it effective, will now state the order of adjustments of the instrument following the first, already described.

The second was that of collimation (in the same sense as for a transit instrument). The hour-circle was so adjusted that its graduations represented the imaginary graduations on the celestial equator; and then, by the continued action of the clock-movement, the graduations of the hour-circle continued to represent those of the celestial equator. The telescope was directed to an equatoreal star (η Virginis), with declination-circle east, and by means of the microscopes of the Lower Oval reading the divisions of the hour-circle, its apparent R.A. was obtained. Then the polar axis was turned half round, and the telescope was directed to the same star, declination-circle west, and by the microscopes of the Lower Oval reading the hour-circle, its apparent R.A. was again obtained. If, after applying corrections for refraction, these R.A. agreed, there was no error of collimation. In this manner it was easy to set a meridional wire to the line of collimation. Observations were made, not only near the meridian, but also several hours to the east and the west: a slight difference in their results seemed to show that there is a trifling lateral flexure of the telescope.

The third adjustment was that of the declination-axis. The wire being set to the line of collimation, Polaris was observed, declination-circle east and west, and its R.A. was read in the same way. The discordance of results showed that one end of the declination-axis required to be raised $\frac{1}{16}$ of an inch, which was easily done.

It is almost unnecessary to allude to the fixation of the zero of hour circle (by referring to true sidereal time) or to that of declination-circle (by making the N.P.D. readings nearly supplementary, face east and face west). By means of the declination-circle, the bridle-rods were graduated by Mr. Dunkin to every degree, and were then subdivided and engraved by Mr. Simms.

The aggregate of existing errors, I believe, will not amount to many seconds in any position of the telescope. But, at some future time, I hope to reduce them still lower.

The reaction-machine of the clock-work at first gave some trouble. I do not doubt that, with due modification of adjustments, the same machine may be adapted to varying heads of water; but, after repeated trials of pressure from the water-mains and pressure from a fixed cistern supplied by the water-mains, I found the use of the fixed

cistern so much the more convenient that I have entirely quitted the use of direct pressure from the water-mains. After many trials, the weight required to keep the intermediate bevelled wheel up to its work (on which depends the immersion of the pendulum-spade in the water of its annular cistern) was settled. Many trials were required to determine the proper rapidity of the leverage by which the movement of the frame of intermediate wheel closes the throttle; a very slow closing of the throttle for a given motion of the intermediate-wheel-frame was found to be best. When all was brought to good order, and most severe uniformity of motion was produced, the clock occasionally stopped, from some friction in the apparatus conveying the maintaining force. The following changes were then made. First, on the advice of Mr. G. A. Biddell, the bearing of the turbine, which had been brass upon brass, was changed to hard wood upon brass (as in the bearings of the screw-shafts of screw-steamers). Secondly, the diameter of the supply-pipe was increased. Thirdly, the diameter of the turbine was reduced from 20 inches to 16 inches, as its speed (21 feet per second) seemed to approach too near to the speed nominally due to the head of water (28 feet per second). Fourthly, a large part of the weight of the turbine and spindle was supported by antifriction wheels upon a counterpoise lever. The action of the clock-movement now appears to be perfect, and I think it probable that it is the smoothest and most uniformly rated motion in existence.

It will be remarked that the uniformity of action of the clock-work depends, in the last instance, upon the truth of the large 2-minute worm or screw, which acts in the racked teeth of the hour-circle. Many months ago, I had requested Messrs. Ransomes to point out to me the screw-cutting machine which they intended to use for the generation of this worm. I then had a brass cylinder placed in the machine, and had lines scratched upon it by the action of the machine, representing the spiral of the worm, and I had a frame expressly prepared to carry a micrometer-microscope for measures of the longitudinal ordinate of the spiral. After numerical analysis of these measures, I was well satisfied with the accuracy of the machine. I have since examined the appearance of a star under the wire, but have seen nothing like a disturbance with a period of two minutes.

For cutting each tooth of the hour-circle, the circle was placed in position by microscopic reference to Mr. Simms' graduations.

At the time of writing this Report, I have not yet examined the performance of the object-glass with due severity, although all that I have seen leads me to think that it is very good. But I think it proper to remark that, on inspecting its lenses before planting it on the tube, it was remarked that the surface of the flint-glass exhibited a great number of circular spots almost $\frac{1}{7}$ inch in diameter, in symmetrical arrangement.

On my reporting this to Mr. Merz, that artist informed me that these spots are the representatives of certain points of pitch on which the lens is supported during some part of the process of grinding, and that they become visible in consequence of the unequal action of damp atmosphere upon the surface of the glass. I confess that I could wish that the glass furnished had not been so sensitive to the moisture of the atmosphere.

The revolving quadrantal chair-frame with its sliding chair (as for the Northumberland Telescope), and the intra-axial cradle carrying a sliding chair, are completed.

The ancient instruments have been cleaned; but I find it very difficult to maintain their brass limbs in continued brilliancy.

VI. Astronomical Observations.—The work which is considered as taking precedence over all other is the maintenance of uninterrupted Meridional Observations. The catalogue of clock-stars includes 195 stars, which are observed if possible every year. Other stars which have been observed are: Stars for completion of the list of stars of 5th magnitude visible at Greenwich; a few variable stars, and stars with proper motion; stars used in th edefinition of the Oregon boundary; and some pairs of circumpolar stars of convenient use for determining azimuthal errors. Among wandering bodies, the Moon is observed at every transit at which she is visible, the Sun on every day except Sundays; the planets whose places are sufficiently well known, at every transit when they pass between evening twilight and 15^h; and the large planets when they pass after 15^h, if the Moon passes after 15^h.

Transits are in all cases observed by the chronographic method, except for slow-moving circumpolar stars, or during derangements of the apparatus.

In the last autumn, I circulated a notice among Astronomers, pointing out the loss of labour in attempting to make meridional observations of small planets unless the errors of ephemerides are pretty well known, and requesting that, as soon as the place of a planet should be indubitably ascertained by extra-meridional observations, even though subject to some small error, it might be communicated to me. This invitation has received numerous responses from the most active equatoreal observers; and in consequence we have been enabled to observe meridionally several small planets which otherwise might have been lost. No attempt has been made to observe those for which no trustworthy approximate places could be found.

The number of Meridional Observations from the end of 1859, May 16, to the end of 1860, May 19, is as follows :—

Transits (two limbs, or two different systems of wires being counted as two)	6,267
Pairs of observations of the collimators by the Transit-Circle	314
Observations of transit-wires by reflexion	319
Observations of Collimator by Collimator	52
Circle observations of all kinds	6,134
Observations of wire by reflexion (included in the last number)	306

With the Reflex-Zenith-Tube, the following observations of γ Draconis have been made :—

Pairs of observations in reversed positions	76
Single observations	6

With the Altazimuth, the following observations have been made :—

Azimuths of Moon and Stars	807
Azimuths of the Collimator	436
Zenith-distances of the Moon	427
Zenith-distances of the Collimator	436

The numbers of complete observations of the Moon near the beginnings and endings of lunations are as follows :—

When meridian-passage occurred between 21^h and 22^h, mean solar time	4
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	4
Between 2^h and 3^h	4

And the whole number of days of complete observations of the Moon is,—

With the Altazimuth, 214, or 17·1 per lunation.
On the Meridian, 131, or 10·5 per lunation.

With the Double-Image-Micrometer, γ Virginis has been measured on 1 day, Jupiter on 3 days, Saturn on 2.

The number of occultations of stars by the Moon is 25, and the number of phænomena of Jupiter's Satellites is 58. An eclipse of the Moon also has been observed.

With the South-east Equatoreal, little has yet been done. One remarkable appearance of Jupiter (confirmed by the accounts of other observers) has been communicated to the Royal Astronomical Society, and two drawings only of other appearances (at the time of my writing) have been made. The very fine season which preceded the change of weather on May 8 was unfortunately lost from interruption by painters and other workmen in the Dome.

VII. Reduction of Astronomical Observations.—In the computation of Right Ascensions as deduced from Meridional Observations; True Transits and Clock Errors and Rates are prepared to 1860, May 11; Apparent Right Ascensions of Center of Object are found to May 5; Stars' Corrections are entered to May 3, but are applied only to February 27; Personal Equations are applied to 1859, May 26; Corrections for deficiency of illumination on the limb of the Moon, &c. to the end of 1859. Mean Solar Times to 1860, April 30, for Meridional observations, and to May 4 for Altazimuth observations. In the computation of North Polar Distances as deduced from Meridional Observations, True Zenith Distances are found to May 13 and examined to April 13; Star-Corrections are computed to the end of April; but these, and corrections for deficiency of illumination, are entered only to the end of 1859.

The Ledgers of Stars' Mean R.A. and Mean N.P.D. are complete to the end of 1859, and the Star Catalogue is in progress. The number of stars is 897.

The comparisons of Observed and Tabular Diameters and Right Ascensions of Planets are completed to 1859, May 26. The comparison of N.P.D. of Planets, the investigation of the Position of the Ecliptic, the Errors of Sun, Moon, and Planets in Longitude and E.P.D., and the Heliocentric Errors of the Planets, are finished to the end of 1858. This part of our work is not quite so forward as was the corresponding work at the time of the last Visitation.

For the Reflex-Zenith-Tube, all is complete to the end of 1859.

For the Altazimuth observations, the Azimuths and Zenith Distances are completely reduced to March 15 and April 13, respectively; and the principal steps are completed to the present time. The Moon's Errors in R.A., N.P.D., Longitude, and Ecliptic N.P.D., are found to March 15.

The few observations with the Double-Image-Micrometer are not fully reduced.

The computation of the Occultations for 1859 is in progress; the preliminary interpolations being prepared. This division of reductions is less advanced than usual.

On discussing the results of observations, the following conclusions suggest themselves:—

The personal equations of observers remain nearly as in the preceding year. Mr. Dunkin's method of observing transits having changed about $\frac{1}{20}$ of a second of time with respect to the others.

The Transit-Circle and its Collimators still present those appearances, of generally uniform agreement among themselves and of occasional fluctuation with regard to circumpolar stars, which lead to the conclusion that the ground undergoes occasional movements. So firm has this conviction become, that the use of the collimators for indirect determination of azimuthal error, by a method which implied their fixedness for a time, has by degrees been almost totally abandoned.

The apparent existence of a discordance between the results of Direct Observations and Reflexion Observations (after the application of corrections for flexure, founded upon observations of the horizontal collimator-wires), to an extent far greater than can be explained by any disturbance of the direction of gravity on the quicksilver by its distance from the vertical, or by the attraction of neighbouring masses, perplexes me much. The best law that I can suggest for it is sin. Z.D. $\times$ $\cos^2$ Z.D.; but I do not perceive anything like a mechanical *vera causa* which would justify me in assuming such a law.

The colatitude, from the observations of Polaris in 1859, is $38°.31'.21''{\cdot}36$; and that from all the circumpolar stars $38°.31'.21''{\cdot}56$; still prolonging the series of diminishing values. This may depend in part on error in correcting for the discordance between reflexion-observations and direct-observations.

The relative position of the Altazimuth and its Collimator is comparatively steady; while the Zero of Azimuth, as deduced from star-observations, fluctuates with changes of temperature. Little inconvenience practically results from this; as the observers, when it is possible, always observe a star as well as the Moon.

In regard to further reductions, it has been my practice, since the commencement of my presidency over the Observatory, to collect the results of observations of stars in every period of six years, for the purpose of forming a general Catalogue. The fourth of these periods terminates at the end of 1859; but, remarking that the

collection of stars of the 5th magnitude may be made somewhat more complete by another year's observation, I propose to delay the Catalogue to the end of 1860, and then (if there shall be no reason for further delay), to form a Seven Years' Catalogue.

VIII. Printing of Astronomical Observations.—The volume for 1858 has been distributed lately. The printing for 1859 is in the following state:—The Transits with the Transit-Circle are printed to the middle of February (two sheets); the Zenith Distances with the Transit-Circle to March 21 (four sheets); and the Azimuths with the Altazimuth to April 25 (two sheets). This printing is not so much advanced as usual. The tardiness does not arise in the Observatory, but originates (I believe) in the occupation of the Queen's Printer on parliamentary printing. The number of copies is the same as in several years past, namely, 350 for the complete volume, with 150 additional separate copies of the "Results of Astronomical Observations."

I alluded in the last Report to a possible extension of the distribution of printed Observations. I took the first step (the printing of a Circular Letter): but, since that time, though I have had the letter almost constantly before me, I have been so incessantly engaged with business which seemed to have a prior claim on my attention that I have taken no further step.

In the course of the year past, I ascertained that it would be possible to purchase, from the representatives of Dr. Maskelyne, the remaining stock of Maskelyne's Observations. On my representing this to the Admiralty, I was at once supplied with the necessary funds, and the whole of these books are now lodged in the Observatory.

It is much to be wished that the impression of Bradley's Observations also could be obtained for the Observatory.

IX. Magnetical and Meteorological Instruments.—As regards magnetical instruments, the three magnetometers (with collimator or plane mirror for eye-observations, and with concave mirrors for forming spots of light on revolving barrels covered with photographic paper for self-registration), and the absolute force apparatus, are in good order. The adjustments of the horizontal force magnetometer have lately been disturbed by a clumsy workman.

The dipping-needles are still a source of anxiety. The form which their anomalies appear to take is that of a special or peculiar value of the dip given by each separate

needle. With one of the 9-inch needles, the result always differs about a quarter of a degree from that of the others. I can see nothing in its mechanical construction to explain this, and I have been driven to the following conjecture. The theory of determination of dip rests on the assumption that, when the magnetism is reversed by double touch, the magnetic axis will be the same as before. Now it is conceivable that the magnetizable particles of steel may consist of two series, of which one is prepared to take one kind of magnetism and the other to take the other kind; and that the axes of these two series may not be parallel. I am supported by Professor Faraday in the idea that this is not impossible; and, if the conjecture have any foundation, we are never certain of having a dipping-needle free from special error.

The stationary support for a dipping-needle, to which I alluded in my last Report, is in the course of construction by Mr. Simms.

Among the matters which attract the attention of practical telegraphists are the spontaneous currents through their wires, which are almost every day perceptible, and are not unfrequently so powerful as to render their instruments useless. These violent currents always occur at the times of magnetic storms; but it is extremely difficult to extract from the accounts, even the careful ones, of telegraph-clerks, such an idea of the phases of the currents as will make them comparable with the phases of magnetic storms. It may be worth considering whether it would ever be desirable to establish in two directions at right angles to each other (for instance, along the Brighton Railway and along the North Kent Railway) wires which would photographically register in the Royal Observatory the currents that pass in these directions, exhibiting their indications by photographic curves in close juxtaposition with the registers of the magnetic elements.

The Meteorological Instruments of the usual classes, some for eye-observation and some for photographic self-registration, applying to atmospheric pressure, temperature, and moisture; to temperature of the Thames; to temperature of the ground; to wind; and (less perfectly) to electricity, are in their usual working order.

X. Magnetical and Meteorological Observations.—It appears sufficient to state that the instruments to which I have referred are kept in use as constantly as is practicable. The self-rg st ering constructions are incessantly at work, with such eye-observations as are required to fix their zeros. In order to obtain with greater accuracy the temperatures of the magnetometers, additional readings of the thermometers are taken on one day in each week. The magnetic dip is usually observed twice or three times in each week; the observations for absolute measure of horizontal force are made once in each month. The thermometers in the ground are read once each day. The

thermometers in the Thames register the maximum and minimum temperatures, and are read every day.

I have nearly completed the arrangements which will enable me to send a daily reading of the principal instruments to M. Leverrier's Bulletin.

XI. Reduction of Magnetical and Meteorological Observations.—As regards eye-observations of magnets, equivalents and corrections for temperature are prepared for declination and horizontal force to the present time, and for vertical force to the end of 1859. The Dips are reduced to the present time; the Theodolite observations, giving the astronomical zero for Magnetic Declination, are ready to the end of 1859; the reduction of the Deflexion-observations (for absolute measure) in the year 1859 is only in progress. Ordinary meteorological observations are completely reduced.

As regards the photographic sheets, time-scales and base-lines are completely finished to the end of 1859, and the numerical values of the ordinates of the curves for the declination and horizontal force are read out to that time; those for vertical force are begun.

The mean magnetic declination for 1859 is about 21°. 23′. 30″ (being 6′ less than that for 1858). The mean dip is about 68°. 25′· 3, sensibly the same as in 1858. But this is derived from discordant needles, of which one gives a number as high as 68°. 35′· 5, and another as low as 68°. 19′· 5. The same needles gave in 1858, 68°. 37′· 2 and 68°. 19′· 4.

The vane of Osler's anemometer turned, on the whole, in the year 1859, 14 times in the direction N., E., S., W., N. This number is much smaller than the corresponding numbers in the last few years; it appears to show that, with a general tendency of the changes of the wind to follow the diurnal course of the Sun, the extent to which they do really follow it is greatly influenced by non-periodic causes.

The further Reductions of Magnetic Observations from 1848 to 1857, are in all important respects finished, as regards reference both to Solar Hours and to Lunar Hours. The results are now being collected in Tables, for my examination. I alluded in my last Report to the consideration that would be required for determining the temperatures of the Horizontal Force and Vertical Force Magnets at every hour. The daily readings of the Thermometers had not in general been sufficiently frequent to enable me to draw temperature-curves. Fortunately, however, in the year 1848 there was a sufficient number of thermometer-observations taken under exactly the same

circumstances of fires, personal attendance, &c., as in later years; and these have enabled me to complete in a satisfactory way those parts of the curves which were otherwise insufficiently defined.

XII. Printing of Magnetical and Meteorological Observations.—No part for 1859 is yet printed, the manuscript being not quite ready for Press; the whole, however, will soon be ready. The number of copies printed for the year 1858 is 600, of which 250 are for separate circulation, and 350 are bound with the Astronomical Observations.

Two Secondary Photographs have been taken from each of the Declination and Horizontal Force Registers, but none from the Vertical Force, for the year 1858.

XIII. Chronometers, Communications of Time, &c.—In consequence of an unusual demand for Chronometers by the Admiralty, the number of chronometers on daily rating during the past spring has been great beyond all precedent. The largest number in our hands at one time was about 210. The number at present on hand is about 140. A few of these are compared only once a week, but the far greater part are compared every day. The standard of comparison is the Motor Clock, which gives general time-signals, drives the Sympathetic Clocks, and drops the Time-Signal-Balls at Greenwich, London, and Deal.

The Chronometer-Oven has been much enlarged, and (by a peculiar method of arrangement) about forty chronometers can now be placed in the Oven, and can be compared with the clock, without removal of any part of their boxes. All chronometers are now, as matter of routine, rated, during a part of their stay here, at an elevated temperature.

The estimation of the merits of chronometers offered to the Government on competition or for purchase is made by me, and the superintendance of repairs of Government chronometers rests with me. In general, all Government chronometers pass through the Observatory before being issued to the Royal Navy.

Although our galvanic currents to Deal have been, during the almost complete failure of our underground galvanic wires, exceedingly feeble, still there has always been a signal sufficient to enable the Superintendant at Deal to drop the Time-Ball with accuracy. The regulation of the Post Office Clocks has, however, failed almost completely. I expect that all will shortly be restored to their original perfection.

No further step has been taken by the Admiralty for the exhibition of Daily Time-Signals at Portsmouth and Devonport, or of Hourly Time-Signals at the Start Point. All these schemes are, in my opinion, important; and I propose, when opportunity presents itself, again to urge them.

No measures have been taken in the last year for further determination of longitudes (as referred to Greenwich) in Britain or on the Continent. Our wire-communications however now enable us to reach (I believe) every point. Considering how small is the expence of such determinations; and how great is their value, either as furnishing an independent basis of comparison with the Trigonometrical Survey, or as giving the elements of measure of an Arc of Parallel; it appears desirable that they should not be allowed to escape our attention. I lately circulated among the Visitors an exposition of Mr. Struve's views of the steps, in this direction, which it appeared desirable to take in Britain for the promotion of European Geodesy; and I ask leave to submit them to the special attention of the Visitors.

XIV. Personal Establishment.—The personal establishment remains, essentially, as at the last visitation; Mr. Main, as First Assistant, holding confidential powers and exercising general superintendance, and observing occasionally; Mr. Dunkin chiefly managing the Altazimuth; Mr. Ellis and Mr. Criswick principally taking charge of time and galvanism in all their branches; Mr. Carpenter being employed with any of the instruments, calculations, or office-work; and Mr. Lynn directing supernumerary computers, and taking general charge of computations and printing. The number of supernumeraries employed in the Astronomical Department has sometimes amounted to six; and even with these we have not perfectly kept down our work. The system, however, of employing supernumeraries under the direction of Regular Assistants, is far the most effective and the cheapest that can be used; and I trust that, when myself or the establishment have been loaded with work of foreign character, as during the last few months, I may always be permitted to avail myself of this method of restoring order in our office-work.

In the Magnetical and Meteorological Department there are two Assistants; Mr. Glaisher (who ranks as Second Assistant of the Observatory) and Mr. Downs. There are usually three supernumeraries.

All candidates for admission or promotion are subjected to an examination of competency.

XV. Extraneous Works.—The printing of the "Reduction of Greenwich Lunar Observations from 1831 to 1851" has been terminated some time since, and I know not what cause has prevented the circulation of the printed copies. In a communication to the Royal Astronomical Society, I have deduced from these the correction to the Elements of the Moon's Orbit. The paper is, in fact, a supplement to a former paper on similar corrections deduced from the "Reduction, &c. 1750 to 1830," and contains the whole of the inferences from the reductions extending over the entire period 1750–1851. I may here properly mention, that an important error (in reference to the Constant of Lunar Parallax) was discovered in the former Reductions, and that its correction removed a discordance which had caused me great anxiety. The excellence of the observations throughout the period (1831–1851) embraced by the later Reductions gives extraordinary value to their results.

The comparison of Hansen's Lunar Tables with the Greenwich Observations, which at the last Visitation had been completed for one year only, has now been finished for the twelve years 1847–1858. The results for the whole period agree entirely, in their general spirit, with those for the year 1852 cited in the last Report. The greatest difference between the merits of Burckhardt's and Hansen's Tables appears in the Meridional Longitudes 1855, when the proportion of the sum of squares of errors is as 31 (Burckhardt) to 2 (Hansen). The nearest approach is in the Altazimuth Latitudes 1854, when the proportion of the sum of squares of errors is as 12 (Burckhardt) to 5 (Hansen).

Several months ago, I communicated to the Royal Astronomical Society a method, founded as I conceive on correct principles, for determining the Linear Motion of the Solar System. The philosophical importance of the subject appeared to justify me in recognizing it as a worthy object for the energies of the Observatory; and I have therefore had the proper Skeleton Form prepared, and from time to time have employed a Computer on it. I intend to keep it in view till it is completed. The method is applicable, without tentative process or reference to former conclusions, to any number of Proper Motions; and I shall apply it to all the best modern determinations of that element.

Our optical knowledge has been made serviceable to the Admiralty in the examination of a great number of Navy Telescopes. I fully believe that this reference to the Observatory will have the effect of considerably improving the construction of those instruments.

My own time has been very much occupied in rendering some assistance to different Departments of the Government, on subjects entirely foreign to the Observatory. From

the nature of these, it was impossible to devolve them upon the Assistants or Subordinates of the Observatory, and the whole burthen has fallen personally on myself. The least agreeable and by very far the heaviest of these relates to the steps for carrying out the Act for Measures for the Sale of Gas; a lighter and much more acceptable business, of which I have no reason to complain, has been a small degree of co-operation with the Royal Commission for Lighthouses, &c. But though the direct action of these employments has been felt by myself only, their indirect action has been propagated downwards through the whole *personnel* of the Observatory; and they have tended, with the other works which I have mentioned, to retard our ordinary progress, and sometimes to make me wish for unusual aid.

Some steps have been taken by me for organizing, with the assistance of the Admiralty, an expedition of amateur observers to the North of Spain, for observation of the approaching Total Eclipse.

XVI. General Remarks.—In looking prospectively to the occupations of the Observatory, I see much to keep us in vigorous action, especially for a short time to come, but nothing which in my opinion renders it necessary yet to contemplate a permanent enlargement of our staff. The Eclipse will derange us a little. The Visitors are probably aware that I have pointed out the approaching opposition of Mars as partly favourable (not the most favourable of all) for Equatoreal-observations tending to the measure of the Sun's Parallax, and if possible some attempts will be made to use it for that purpose. Should the Longitude-Observations to which I have alluded be put in train, they will throw some labour upon us. All these, however, are transient works. If the time-signals at Portsmouth, Devonport, and the Start, be brought into action, the superintendance of these will produce additional office-work, which, however, may be provided when the necessity for it shall arrive.

In regard to the work for the New Equatoreal, present circumstances have suggested a course of employment which may, I think, be followed with advantage; namely, a systematic scrutiny, with careful drawings, of the disks of planets. Although this will occupy much of the observing time of one Assistant, yet it is so easy to supply meridional observation at a cheaper rate than that of adding a permanent Assistant to the Observatory establishment, that I do not at present contemplate the latter course. If, however, it should be found necessary, presuming on the goodwill which has been expressed both by the Visitors and by the Board of Admiralty, I should with confidence look to the assent of the Government to my application for that additional aid.

G. B. AIRY.

Royal Observatory, Greenwich,
1860, *May* 24.

ADDRESS OF THE ASTRONOMER ROYAL TO THE MEMBERS OF THE BOARD OF VISITORS OF THE ROYAL OBSERVATORY.

It is known to several of the Visitors that, in the autumn of 1857, Mr. Struve visited this country on his way from France. His chief business had been to visit the Central Offices of Survey of the principal Continental States, and to endeavour to make arrangements for effectually carrying out the observations (where needed) and the computations, for exhibiting the comparison of measure with theory in one or more extensive arcs of parallel. In prosecution of this purpose, Mr. Struve had been permitted personally to lay his views before the Emperor of the French. Mr. Struve had examined the state of calculations in the British Survey Office (at that time unpublished), and was preparing to take further steps, when he was struck with the serious illness from which he has yet but imperfectly recovered.

In the want of reports from Mr. Struve, I have been unable to take any distinct step for furthering his proposals. But I have lately ascertained from Mr. Otto Struve that the measures which Mr. Struve was desirous to suggest, as regards the proceedings in the British Survey, are mainly the following:—

1. That the junction between the British and the French or Belgian triangles should, if necessary, be repeated.

2. That a new determination of the longitude of Valentia by the galvanic telegraph might be recommended; especially as, on the former occasion, personal equations were determined only at the end of the operations, and observers were not interchanged.

3. That the longitude of the extreme eastern station of the British triangles should be fixed by galvanic telegraph.

4. A scrupulous examination of the principal triangles might be made, and perhaps the measures might be repeated wherever that examination should indicate a weakness.

5. If necessary, a new comparison of the units of measure employed on the different base lines might be made.

And I now submit these suggestions of Mr. Struve to the consideration of the Visitors.

The points in which the Royal Observatory is practically concerned are Nos. 2 and 3 alone. In considering these, it might also be well to take into consideration whether the determination of the astronomical longitude of other points of the British Triangulation should be recommended.

G. B. AIRY.

1860, *May* 12.