REPORT

OF

THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1859, *June* 4.

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THE Report which I have to lay before the Visitors applies to the proceedings in the Royal Observatory from 1858, May 21, to 1859, May 16, and to the state of the Observatory on the last-mentioned day.

I. Grounds and Buildings.—In the buildings of the Observatory anterior to the New South-East Dome, no change has been made and no repair has been required, that calls for the slightest remark. In the fixed building of the South-East Dome likewise no change or repair has been made; but in the rotatory Drum Dome the following work has been executed. The portion of stiff iron curb, to which I alluded in the last Report, has been fixed in its place, and it appears entirely to obviate the unfair flexure of the Dome Curb under the feet of the standards of the shutter-opening. The apparatus for fixing the Dome at four points, to prevent it from receiving oscillation from the wind, has been mounted several months, and answers perfectly well, no movement of the Dome being perceptible even in a gale of wind. It consists (at each of the four places) of a vertical lever somewhat bent, having its fulcrum attached to the inside of the Dome, and its lower point pressing almost horizontally against the external face of the fixed rack of the wall-curb; in the upper part of the nearly vertical lever is an inclined chase, in which acts the pin of a horizontal lever that is pulled down by a weight. When the weight acts on the horizontal lever, the pin slides in the chase so as to press the upper end of the vertical lever outwards, and to press the lower end strongly against the rack, and thus to exert a strong pressure at its fulcrum from inside to outside against the Dome. When the horizontal lever is raised, the vertical lever ceases to touch the rack or wall-curb, and the motion of the Dome is entirely free.

The flat roof of the Dome has shown itself perfectly trustworthy till within the last three or four weeks. Workmen lately engaged on the top have by their treading injured the zinc sheets; and the center of the flat roof having been a little depressed by the weight of the vertical-shutter and its counterpoise and other machinery, and the roof being thus perhaps rendered too flat, the rain has entered in some places. I propose to revise the covering of this roof, with the view of placing sounder metal at a higher angle of inclination.

The internal fittings required for use in observation, such as a partial amphitheatre of fixed seats on the south side, and a travelling quadrantal chair-frame (carrying a sliding chair) to traverse the rest of the floor, as in the Northumberland Equatoreal, are engaging my attention. A fixed curb parallel to the celestial equator has been established, to receive the weight of a board and chair passing through the equatoreal-frame and of the observer whom they support, when observations are made near to the Pole.

The principal want now felt in the buildings is that of a covered passage to the Galvanic Register.

The maps and plans are maintained in good order.

II. Moveable Property.—There is no remark to be made requiring the Visitors' attention. As stated in the last Report, some small things are here in charge, and some are lent or otherwise placed out of our hands. The Standards are in good condition.

III. Manuscripts.—The orderly arrangement and binding of the Observatory Manuscripts has now become matter of routine, and is continued with great regularity.

By favour of the Royal Society, I have in my custody the Book of Minutes of the Board of Visitors from its establishment to the year 1784, but I have not been able to find the continuation from that time to 1830. I should be greatly obliged by any information which would probably enable me to trace out these Minutes.

The papers of the Board of Longitude have been thoroughly revised, and are now in the binders' hands.

IV. Library.—General attention only has been given to the Library, the principal additions being the maintenance of serial works.

V. Astronomical Instruments :—

The Transit-Circle is in good order. The change of illuminating apparatus, to which allusion was made in the last Report, is very successful. No alteration has been made in any part relating to this instrument, except that for the convenience of the observers the floor of the pit has been raised a few inches, and excavations covered by hinged flaps have been made below the floor.

The Scale of the External Thermometer, on the North side of the Transit-Circle-Room, has been raised about eight-tenths of a degree, and there appears to be now no sensible error in its readings.

In the early mornings and late evenings of the summer months, inconvenience has been experienced from the circumstance that the northern Sun then shines on the External Thermometer. To remedy this inconvenience, another Thermometer has been mounted on the outside of one of the southern windows of the room, which will be in shade when the sunshine disturbs the Thermometer on the northern side.

The Reflex-Zenith-Tube continues to give perfect satisfaction. Frequent attention is necessary to correct the stretching of the straps of vulcanized caoutchouc which support the mercury trough.

The Altazimuth is in good order. In former Reports I have alluded to the growing error in the relative positions of the horizontal axis and the vertical axis, which had arisen gradually to nearly 14″. This error may have arisen from a wear of one of the horizontal pivots, or from a wear in the bearing of a horizontal pivot, or from a wear in one of the vertical pivots. It produced no injurious effect, except that it increased the trouble of numerical correction. Taking advantage of the presence of Messrs. Ransomes' skilled engineers, I have had one of the horizontal Y's scraped. The error is now a little over-corrected, amounting to 4″ on the opposite side.

The Chronographic Barrel Apparatus is in good and efficient order.

The Galvanic Apparatus within the Observatory is in good order. The only addition which has been made is the insertion in the Transit-Clock of another pair of galvanic springs, whose contact is produced by the same 60-tooth wheel which produces the contacts of the original pair of springs that make the circuit for seconds'-puncture on the Chronographic Barrel. The purpose of the new circuit is to regulate one of the clocks and to give motion to another, which are used in connexion with the new South-East Equatoreal. As one of the teeth of the 60-tooth wheel is cut away (to mark the commencements of minutes on the Chronographic Barrel), there are sent

in fact only 59 currents in every minute; and this requires a singular construction in one of the South-East Equatoreal Clocks, to be described hereafter.

In regard to external Galvanic Connexions, the wires of the South-Eastern Railway Viaduct have been thoroughly repaired, including those of the Royal Observatory; and our communication with London by that course is now good. I have not had occasion to examine the state of communication by the Admiralty Blackheath wire.

The North Equatoreal (Shuckburgh's) can be used for measure of Declinations, or as a mere equatoreal support of a telescope. It is useless for Hour Angles or Right Ascensions.

The East Equatoreal (Sheepshanks'), and the Double-image Micrometer commonly used with it, are in good condition. In order to alleviate the friction in motion in Right Ascension, I have lately introduced lever-counterpoises, but have not yet made them act entirely to my satisfaction.

The new South-East Equatoreal is now far advanced, and though I am not yet able to exhibit it in a complete working state, I trust to be able, by referring to the parts or models of parts which are visible, and by description of the principles which have guided their introduction, to make it generally intelligible. It is known to the Visitors that on three occasions of erecting large Equatoreals which were entirely intrusted to me, namely, at Cambridge, at Liverpool, and at Greenwich, I have thought it my duty carefully to examine the construction of the three principal classes of equatoreals (the old English or Shuckburgh's, the long polar axis with telescope on one side, and the German form). And I have never put out of sight the consideration that, in Observatories like this, an Equatoreal cannot be considered as a mere commodious support for a gazing-telescope, but must be regarded as a firm graduated instrument, with which Right Ascensions and Polar Distances can be determined with considerable accuracy. Remarking, then, the diameters of the graduated circles, but still more the diameters of the racked-circles and the clamp-circles, on which the steadiness of clock-movement or the firmness of clamps must depend; remarking also the engineering objections, as regards weakness and friction, to the support of an instrument which projects beyond its two bearings; I prefer the English form, and I have accordingly adopted it here, with no novelty of principle, except that the Declination-axis is so advanced in front of the center of the polar-axis, and the upper part of the polar frame is so cut away, that the telescope commands the meridian without interruption to and a little way beyond the pole. Each cheek of the Polar-axis is a skeleton prism; and, as I have shown in the description of the Northumberland Telescope, this form is braced against torsion if

each of its slides is braced. The bracing here is effected by a series of diagonal tension-bars and transversal thrusting-bars (each being drawn or thrust by its appropriate screw-motion); the long pillars and the bars being of wrought iron. The Upper and Lower Ovals which carry these are of cast iron. On the spindle of the lower oval turns freely the hour-wheel, 6 feet in diameter, on which the clock-movement acts: which hour-wheel can be clamped at pleasure to the oval, and can also (when transits are required with an unmoved telescope) be clamped to the foundation-plate. A fixed microscope views a graduation of the hour-wheel, which, in its ordinary motion, will always exhibit in the microscope the Sidereal Time: and a microscope carried by the Lower Oval views another graduation, which in the same circumstances will exhibit the Right Ascension of the celestial body under view of the telescope. These microscopes are not directed perpendicularly to the graduated limb, but at an angle of nearly 10°, the illuminator throwing its light at the same inclination on the opposite side of the normal to the limb, so that the light is specularly reflected up the microscope: a principle of illumination which I think important. The two microscopes of the declination-circle spread out nearly in the same way as those of the meridional Transit-Circle, so that though they view opposite graduations on a 5-feet circle, the two eye-pieces are only a few inches apart. The illumination of the divisions is effected as in the eye-piece for viewing the wires of the Transit-Circle by reflexion; the light enters a hole in the side of the eye-tube, where it is reflected downwards by diagonal plates of transparent glass; it falls upon the limb, whose surface is turned to a concave or dished conical form so that the axis of the microscope is perpendicular to the portion of the limb under view; and the light which has been thrown down that axis is therefore reflected specularly up the axis to the eye. For the observer's ascent to these microscopes, a swinging ladder is provided, of which the lower end rests on the floor, while the upper end is supported by a rope of adjustable length fastened to the top of the Dome. There is a 5-foot clamp-circle attached to the opposite cheek of the polar-axis, whose clamp-screw and slow-motion are acted on by long handles from the eye-end of the telescope. For convenience of setting, and for easy reading of differences of polar distance, there is a radial bar at the side of the telescope-tube, turning on a pin near the center of motion of the telescope, and having a graduation at its end near the eye-piece of the telescope; and this radial bar is bridled by an adjustable graduated sliding rod, of which the distant end is carried by a pin on one cheek of the polar-axis. The lights for all these purposes are gaslights; the upper pivot of the polar-axis is perforated, and a gas tube (connected with fixed gas tubes by a rotatory joint) is passed through the perforation, and distributes its branches where lights are required on the polar-axis; one branch passes by means of a rotatory joint through the declination-axis (which is perforated), and brings gas to a burner on the eye-end of the telescope. The communication of time is made by

a small clock with 10-inch pendulum beating seconds, near the fixed microscope of the hour-circle, and by a galvanic chronometer carried by the eye-end of the telescope; but these clocks do not give independent times: the wire of a galvanic battery, whose circuit is completed at 59 seconds of every minute of the transit-clock, is carried through a coil into which swings a bar-magnet carried by the 10-inch pendulum, and is also carried through the coils of the galvanic chronometer, (being led from the fixed support to the polar frame by means of insulated springs on the fixed support, touching insulated rings on the polar frame, and being then led in a similar manner to the telescope,) and thus the 10-inch clock is regulated, and the chronometer is moved, in exact accordance with the transit-clock. The seconds' wheel of the chronometer has only 59 teeth, and the seconds' dial has only 59 divisions, one of which counts for the two successive seconds (28 and 29): this is necessary in consequence of the loss of one current per minute in the transit-clock, as before remarked. In the 10-inch clock, which is merely regulated by the current on the principle introduced by Mr. R. L. Jones, there is no such anomaly.

Another pair of galvanic wires is brought, by insulated rings and springs, to a touch-piece at the eye-end of the telescope: these wires are connected with the pricker of the Chronographic Barrel, so that times may be registered on the same sheets as the times of observations with the Transit-Circle and the Altazimuth.

The clock-movement of the hour-circle is effected essentially by the same mechanism as that which I introduced at Liverpool. By transferring a water supply from a lower to a higher level, I have obtained a fall for driving a reaction machine (Barker's mill), revolving four times in a second. This, acting through two worms, drives the hour-circle. For its regulation, it gives motion to an axis revolving in two seconds, which acts upon a conical pendulum (carried by two pairs of springs that do the duty of a universal joint), by the remarkable contrivance called Sieman's Chronometric Governor, of which the effect is that, if there is a tendency to acceleration, the throttle-valve of the water-pipe is immediately contracted. It is necessary that the pendulum suffer a retarding force, which ought to be strictly tangential; to effect this, I have so connected a small spade with the rotatory apparatus, that the pendulum by enlarging its cone dips the spade into a trough of water. I anticipate from this a very smooth and uniform motion.

Every part of the apparatus is provided with the proper means of gearing and ungearing, oiling, &c., according to the usages of the best modern engineering. The instrument may be now considered a splendid piece of mechanism; I hope that it will ultimately be judged to be a splendid equatoreal.

The Engineers' part of the work is executed by Messrs. Ransomes and Sims of Ipswich; the graduations and the optical parts generally (except the object-glass), including also the work of the eye-end, the radial bar and bridles, and the mounting of the object-glass, by Mr. Simms of Fleet Street; the object-glass by Messrs. Merz and Son of Munich. The pendulum of the clock movement, and the 10-inch clock, were furnished and mounted by Mr. Dent of the Strand. The galvanic chronometer was made by Mr. Shepherd of Leadenhall Street.

The observing chair I propose to mount as a slider upon a vertical quadrant revolving round a point near the center of the room, the part of the floor near the south pier being furnished with theatre-seats, as for the Northumberland Telescope. For enabling the observer to observe objects near the pole, without leaning upon the polar frame, I have surrounded the Lower Oval with a curb, for supporting a board that will pass between the cheeks of the frame, on which board the observer will rest.

It is proper to mention that the focal length of the object-glass furnished by Messrs. Merz is considerably less than the length originally stated. The whole apparatus therefore is somewhat larger than is absolutely necessary. It might with some inconvenience be made to carry a telescope of above 20 feet focal length; and, if the regions near the pole were given up, it might carry one still larger.

The old instruments have not been specially examined; but are, it is presumed, in their usual state.

VI. Astronomical Observations.—The maintenance of regular Meridional Observations is considered, as heretofore, the most important duty of the Observatory. Our large clock-star-catalogue, of 193 stars, is thoroughly observed (if possible) every year. There are likewise stars which have been observed with the Moon, or in occultations, or stars which have some peculiar claims for observation. Of moveable bodies, the Moon never passes unobserved, if visible; the Sun and all planets are observed when they pass before 15^h, except on Sundays; and when the Moon passes after 15^h, any large planets passing after 15^h are observed. For transits, the chronographic method is used, except for close circumpolar stars.

Much labour is lost in searching for small planets on the meridian, in consequence of the inaccuracy of their ephemerides. I propose in future to abstain from some of these searches until I shall have good reason for trusting to the ephemerides; but I have not yet arranged details of my system.

The number of Meridional observations from 1858, May 22, to 1859, May 16, both days included, is as follows:—

Transits (two limbs, or two different systems of wires, being counted as two)	5,215
Pairs of observations of the collimators by the Transit-Circle	305
Observations of transit wires by reflexion	350
Observations of Collimator by Collimator	52
Circle observations of all kinds	5,141
Observations of wire by reflexion (included in the tale of circle observations)	324

No alteration is made in the system of adjustments.

With the Reflex-Zenith-Tube there have been made the following observations of γ Draconis: 87 pairs of observations in reversed positions, and 8 single observations.

With the Altazimuth: The total number of observed azimuths of the Moon and stars is 767; of Donati's Comet, 15; of the Collimator, 416. The total number of observed zenith-distances of the Moon is 395; of Donati's Comet, 16; and of the Collimator, 416. The complete observations of the Moon, on days when her meridian passage occurred between 0^h and 1^h solar time, are 1; between 1^h and 2^h, 3; between 2^h and 3^h, 7; between 21^h and 22^h, 5; between 22^h and 23^h, 3; between 23^h and 24^h, 1. The whole number of days of complete observations of the Moon is 195, or 15·6 per lunation. The corresponding number of complete observations on the meridian is 120, or 9·6 per lunation.

With the Double-Image-Micrometer, Mars has been measured on 2 days, Jupiter on 4, Saturn on 2, γ Virginis on 2.

Other observations are: 10 occultations of stars by the Moon, besides that of Saturn, and 57 phenomena of Jupiter's Satellites.

VII. Reduction of Astronomical Observations. — In the computation of Right Ascensions as deduced from Meridional Observations, the Apparent Right Ascensions of Center of Object, and the Mean Right Ascensions of Stars, are found to April 22; Clock-Errors and Rates being all ready to May 8. Application of Personal Equations, and Corrections for deficiency of illumination on a limb, are completed to the end of 1858. Mean Solar Times to April 22 for Meridional Observations, and to May 6

for Altazimuth Observations. In the computation of North Polar Distances, as deduced from Meridional Observations, the Geocentric Apparent N.P.D. of Center of Object are found to May 8, and the Mean N.P.D. of Stars to March 17.

The Annual Star Catalogue for 1858 requires a very little work for its completion, and the Heliocentric Errors of four small planets are not completed.

The Ledger of Stars' Mean R.A. and Mean N.P.D., the comparison of observed places and observed diameters of Sun, Moon, and Planets, (excepting as above-mentioned,) with tabular places and diameters, (the places being in all cases reduced to Longitudes and Ecliptic N.P.D.,) and the exhibition of the Heliocentric Errors of the Planets, are finished to the end of 1858.

For the Reflex-Zenith-Tube, the results are complete to the end of 1858, and the daily reductions to this day.

For the Altazimuth; the Azimuths are completely reduced to April 25, and the principal steps are finished to the present day. The same words will apply to the Zenith Distances. The Errors of Tabular R.A. and N.P.D. of the Moon are completed to March 21, and are converted into Errors of Tabular Longitude and Latitude to the same date.

The Double-Image-Micrometer Observations are completed for 1858.

The reduction of Occultations for 1858 wants only the last line in each computation for absolute completeness. Every essential part of the calculation is finished.

The following remarks suggest themselves, on examination of the results:—

The personal equations for transits in the chronographic method, referred to Mr. Dunkin as standard, range from $+ 0^s \cdot 14$ to $- 0^s \cdot 21$. For the individual observers, the results now found do not sensibly differ from those found last year, with the exception of those of one Supernumerary Computer, whose personal equation has lately been deduced from a small number of comparisons.

It is still found that the Transit-Circle and its Collimators occasionally exhibit simultaneous changes in Azimuth, as referred to circumpolar stars, which do not disturb their relative position. It is also still found that the eastern pivot rises with rising temperature.

The determination of colatitude is rather perplexing. The thermometer-readings have been most rigorously compared with the simultaneous readings in the Magnetical and Meteorological Department, and their agreement is precise, yet the winter observations still give a rather larger colatitude than the summer observations: and a gradual change seems to be going on from year to year, the greatest colatitude being that of 1854. The following table exhibits the results obtained since the introduction of the Transit-Circle:—

	From Polaris.	From all Circumpolar Stars.
1851 . . .	38. 31. 21·94	38. 31. 21·95
1852 . . .	21·92	21·94
1853 . . .	22·10	22·06
1854 . . .	22·16	22·10
1855 . . .	22·11	21·91
1856 . . .	21·89	21·83
1857 . . .	21·60	21·80
1858 . . .	21·58	21·76

The consistency in the progress of these numbers might seem at once to indicate the effect of some physical law; yet a fraction of a second is a small quantity, so small that it may even depend upon a change in the observer's habit as to the mode of applying his eye to the eye-piece, &c. I am unwilling yet to assert that a real change of latitude is certain.

The Azimuth-zeros of the Altazimuth still fluctuate with changes of temperature, and the relative position of the Altazimuth and its Collimator does not appear to be affected by the changes. The azimuths are referred, in every possible case, to stars observed on the same night, and the results thus deduced from observation are extremely good.

VIII. Printing of Astronomical Observations.—The volume for 1857 has been distributed lately. It had been out of my hands several months; the delay of publication arose, I believe, from some arrangements in the Stationery Office.

The state of printing of the volume for 1858 (now in hand) is nearly as follows. The Transits with the Transit-Circle are printed to August 3; the Zenith Distances with the Transit-Circle to August 25, and the Azimuths with the Altazimuth to September 18. The number of copies worked off is 350; with an addition of 150 copies for the last section embracing the Results of Observations.

I have lately examined the lists for distribution of Observations, of the Royal Society and the Royal Astronomical Society, and I think that they may with advantage be extended. If it is agreeable to the Visitors, I will as soon as possible take steps for such increased distribution, including the back volumes of Observations as far as I can furnish them. The distribution cannot be effected without some expense to the Observatory; but I conceive that this is not to be mentioned in comparison with the expansion of the field of utility of the Observatory, and the gratification to the scientific foreigners who are scarcely able to obtain possession of the Observations in any other way.

IX. Magnetical and Meteorological Instruments.—The free 2-foot magnet with collimator and concave mirror, and the bifilar magnet with plane and concave mirror, (the concave mirrors forming spots of light on the photographic paper covering a revolving barrel), and the absolute-force-apparatus, are in good order.

In the late winter, the vertical-force-magnet (which rocks on knife-edges) gave me some alarm, by exhibiting for the daily magnetic curve a form approaching much more nearly to a straight line than it had usually given; and in particular wanting altogether the remarkable sharp bends at certain hours of the day which we know to be characteristic of the vertical force. I took the magnet from its box, and most scrupulously examined its knife-edges, and I was not satisfied with their grinding and polishing. I placed them in the hands of Mr. Simms, in whose admirable workmanship I have the highest confidence, but in whose skill in the preparation of knife-edges in particular I had learned to trust from his refitting of the pendulums used by me in the Harton Experiment. The knife-edges of the Vertical Force Magnet were returned in a beautiful state. In the meantime, the agate planes on which the knife-edges rock had attracted attention; and as Messrs. Ransomes' engineers, then employed at the Observatory, had a proof-plane, I was able to examine the flatness of the agates. They were found to be far from correct. These being also adjusted by Mr. Simms, the instrument was re-mounted, and I have had the satisfaction of seeing that it again presents us with curves of the well-known form. We have no difficulty in fixing precisely on the time when the indications began to be faulty.

In regard to the dipping-needles, I am still very much perplexed. We have several needles, apparently well made, used with great care, each one giving results as consistent among themselves as the deductions of other observers which have reached me; and yet the means of the different needles are discordant by more than a quarter of a degree. Professor Hansteen, the best authority of continental Europe, strongly objects to a reduction of the dimensions of the needle, like that which has lately been

introduced in England. As soon as I have leisure, however, whether the dimensions adopted be large or small, I propose to alter the arrangement in the following way. There is no reason whatever for confining the mounting of a stationary needle to the same dimensions as are proper for that of a travelling needle. I propose therefore to have a proper rotatory frame with long axis in a pedestal, and long microscopes for reading, and a revolving gaslight. I think that the observations may thus be delivered from some causes of uncertainty which now attach to them.

The Meteorological Instruments;—barometers; wet, dry, maximum, and minimum thermometers, some for eye-reading, and some for photographic registration; the deep-sunk thermometers; the maximum and minimum thermometers in the Thames; the Osler's and Whewell's anemometers; the electric wire and electrometers; are in good order. In the radiation-thermometer we have made a decided improvement by inclosing its bulb in an exhausted glass globe.

X. Magnetical and Meteorological Observations.—The instruments above-described have been used in the ways which their different structures require, so as to furnish continuous registration of their different phænomena, checked at proper intervals by eye-observations. The deep-sunk thermometers are read daily; the electrometers occasionally. No observations have been made beyond the limits of this rule.

XI. Reduction of the Magnetical and Meteorological Observations.—First, for the eye-observations. The equivalents and temperature-corrections are applied to the declination and horizontal force magnet, to the present time; and to the vertical force magnet to the end of 1858. The Zero of Theodolite is prepared only to the end of 1858, so that the declination-observations are completely reduced only to that time. The deflexion and vibration observations are reduced in part to the present time, and completely to the end of 1858. Ordinary meteorological observations are reduced to the present day.

Secondly, for the photographic sheets. The sheets are fitted with the proper system of time-scales and new base-lines, and the ordinates of the curves are translated into numbers and inserted in the sheets for press, to the end of 1858.

At the time of my writing, only a few notes are required to fit the whole for the press.

The reductions present no point of special interest. The mean westerly magnetic declination for 1858 is about 21°.29′.30″, having gradually diminished about 5′ in the year. The mean dip with large needles is 68°.26′·3, and with small needles 68°.20′·7; the change from 1857 (as inferred from observation with the same needle) is insignificant.

The vane of Osler's anemometer had on the whole turned 25 times in the year, in the direction N.E.S.W.N.

The following is the state of the further Reductions from 1848 to 1857.

For Declination and Horizontal Force (the time-scales for Solar Hours having been previously laid down on the photographic sheets, and the new base-lines drawn), the time-scales for lunar hours have been laid down, and the ordinates of the photographic curve, previously smoothed by a pencil line drawn through them by hand, have been transferred to sheets; and their monthly means or lunation-means (as the case requires) have been taken in the directions of vertical and horizontal lines on the sheets, for solar or lunar days and for solar or lunar hours; and the whole process has been approved; for the solar part to the end of 1857, and for the lunar part to the end of 1856.

For Vertical Force, the Solar Means are approved to 1850; no Lunar Means are yet formed; but a great quantity of work is done in the preceding steps of both departments.

No step has yet been taken in reference to the correction for Temperature; this will require my careful consideration.

XII. Printing of Magnetical and Meteorological Observations.—No part for 1858 is yet printed, although (as I have already remarked) the whole copy is all but ready for press. The number of copies usually printed is 600, of which 350 are bound with the Astronomical Observations. Two copies of Secondary Photographs are prepared to the end of 1857.

XIII. Chronometers, Communications of Time, &c.—The number of Chronometers now in the Chronometer-room is 129. All are compared, daily or weekly, with a Galvanic Clock that is sympathetic with the Motor Clock, which is adjusted most accurately every day, to Greenwich Mean Solar Time. This is the same Clock which drops the Time Ball and gives signals to London and Deal.

The new Chronometer Oven has been in perpetual use, and numerous faults of adjustment which had escaped the notice of chronometer-makers have been detected I think it probable that we must soon increase the dimensions of the Oven.

The business of valuation and repairs of Chronometers, and of their receipts and issues, rests, as heretofore, with me.

The Post Office Clocks are duly regulated, and the Time Ball at Deal is dropped by direct current, as formerly.

I have called the attention of the Government to the advantage of daily time-signals at Portsmouth and Devonport. Another exhibition of signals also, of a more extensive kind, has been proposed. It was first suggested, I believe, by the Board of Trade, that a signal should be exhibited every hour at one of the principal headlands of our southern coast, for the benefit of ships passing down the Channel; and in the first instance the Lizard Point was named. It appeared to me that the Start Point would be preferable; and with this modification, after having examined the locality, I submitted a detailed plan to the Admiralty. Considerations unconnected with the abstract value of the scheme induced the Lords Commissioners of the Admiralty to defer it for the present; but the matter will be kept in view, for further consideration.

XIV. Personal Establishment.—The personal establishment has been altered by the resignation of one of the Assistants; the lower vacancy created by the promotions consequent on his departure has not yet been filled up. The First Assistant, Rev. R. Main, represents me in all confidential matters, and exercises general superintendance, as bearing full powers from me, over operations of every kind; he occasionally observes, principally with the extrameridional instruments. Mr. Dunkin has special charge of the Altazimuth; and gives attention to the Transit-Circle and Reflex-Zenith-Tube. Mr. Breen, during his tenure of office, had the direction of supernumerary computers, and the general care of computations and printing. Since his resignation, Mr. Lynn has filled his place. Mr. Ellis and Mr. Criswick have under their care the matters which concern time, chronometers, galvanic operations, and external time-signals. There are four (or lately five) supernumeraries, who perform a considerable part of the calculations. The observations with the various instruments are distributed, by weekly arrangement sanctioned by me, among the Assistants; occasionally, and more particularly in the present deficiency of one Assistant, the observations are made by a Supernumerary. In the Magnetical and Meteorological Department there are two regular Assistants, Mr. Glaisher (Superintendent) and Mr. Downs, and three Supernumeraries.

The appointment of Supernumeraries and of Assistants, and the advance of Assistants, has lately been made after examination, not competitive, but for trial of competency.

XV. Extraneous Works.—The Lunar Reductions with amended elements (especially Parallax) for correction of observations from 1831 to 1851 are now completed.

Since the last meeting of the Board, I have, as opportunity presented itself, personally revised all parts of the calculation, and several systematic faults were thus discovered and are corrected. I trust that the calculations as they will now be exhibited are free from important error. The final equations for correction of the Orbital Elements are in my hands, waiting only my attention for their solution. The copy for press of some parts, which were not strictly ready for the printer, is now in hand. The Introduction is written. It is, I think, matter of congratulation to the Observatory and to Astronomy, that there are now exhibited the results of uninterrupted Lunar Observations extending through more than a century, made at the same place, reduced under the same superintendence and on the same general principles, and compared throughout with the same theoretical tables.

The printing of these Reductions will occupy a much less space in proportion to the number of years over which they extend than the former "Reductions of Lunar Observations," even although the Altazimuth observations from 1847 to 1851 are included. After examination of the number of lines, I estimate that they will occupy a quarto volume of 220 pages, or about one-fourth the size of one of the two quarto volumes of the former "Reductions." The Board of Visitors may perhaps think fit to recommend to the Lords Commissioners of the Admiralty to sanction the immediate printing of this work.

Under this head, I trust that I may be permitted to allude to another work, not executed at the Observatory, but in which nevertheless the results of former works executed at the Observatory have tacitly exerted an important influence.

It is known to the Visitors as matter of history that when Professor Hansen had so far completed his Lunar Theory as to contemplate the numerical exhibition of its results, he was led, by communication of the principal inferences from the "Reduction of Greenwich Lunar Observations from 1750 to 1830," to the discovery of the two equations of long period in longitude and of some equations in latitude, the most remarkable perhaps that theory has ever explained. It is known also that the correction of Orbital Elements deduced from those Reductions has served as basis for Hansen's Tables. Finally it is known that by the liberal and honourable patronage of the British Government, assistance was given for the preparation of the Tables, and that the expense of their publication and distribution was entirely supported by our country. I mention these matters merely to explain that everything relating to the success of those Tables must have interest for this Board.

In the last autumn, after correspondence between the Superintendent of the Nautical Almanac and myself, and application for funds to the Board of Admiralty, to which

their Lordships responded with the liberality that they have invariably exhibited in regard to matters of this class, a strict comparison of Hansen's Tables with the Greenwich observations of late years, both meridional and extrameridional, was commenced. The same observations had, in the daily routine of the Observatory, been compared with the Nautical Almanac or Burckhardt's Tables. The result for one year only (1852) has yet reached me, but it is most remarkable. The sum of squares of residual errors with Hansen's Tables is only one-eighth part of that with Burckhardt's Tables. When it is remembered that in this is included the entire effect of errors and irregularities of observation, we shall be justified in considering Hansen's Tables as nearly perfect. So great a step, to the best of my knowledge, has never been made in numerical physical theory.

I have cited this at length, not only as interesting to the Visitors from the circumstance that we have on our side contributed to this great advance, but also because an innovation, peculiar to this Observatory, has in no small degree aided in giving a decisive character to the comparison. I have never concealed my opinion that the introduction and vigorous use of the Altazimuth for observations of the Moon is the most important addition to the system of the Observatory that has been made for many years. The largest errors of Burckhardt's Tables were put in evidence almost always by the Altazimuth observations, in portions of the Moon's orbit which could not be touched by the meridional instruments; they amounted sometimes to nearly 40″ of arc, and they naturally became the crucial errors for distinction between Burckhardt's and Hansen's Tables. Those errors are in all cases corrected with great accuracy by Hansen's Tables.

XVI. General Remarks.—With the inauguration of the New Equatoreal will terminate the entire change from the old state of the Observatory. There is not now a single person employed or instrument used in the Observatory which was there in Mr. Pond's time, nor a single room in the Observatory which is used as it was used then. In every step of change, however, except this last, the ancient and traditional responsibilities of the Observatory have been most carefully considered: and, in the last, the substitution of a new instrument was so absolutely necessary, and the importance of tolerating no instrument except of a high class was so obvious, that no other course was open to us. I can only trust that, while the use of the Equatoreal within legitimate limits may enlarge the utility and the reputation of the Observatory, it may never be permitted to interfere with that which has always been the staple and standard work here.

At present I have no definite proposal to make regarding the additional personal assistance that will probably be required. I have not lost sight of the necessity of arranging this, and am not entirely unprepared as to the decision to be made if absolutely required at this moment; but I prefer to wait for a time, until, after occasional use of the instrument, we shall be enabled to judge better of our needs and of the mode of supplying them.

G. B. AIRY.

Royal Observatory, Greenwich,
1859, *May* 21.