REPORT

OF

THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1875, *June* 5.

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THE present Report refers to the condition of the Royal Observatory on 1875, May 20; and gives an account of its general transactions through the period of twelve and a half lunations, included between the New Moon of 1874, May 15, and the Full Moon of 1875, May 20; the arrangement under different heads being the same as in past years, with the exception of the addition of sections for Photography and Spectroscopy.

I. Buildings and Grounds :—

By occasional repairs, paintings, and small alterations, into which I need not enter, the buildings, &c. have been kept in general good order, and properly adapted to their current wants. The following, however, are more distinct changes.

For viewing the Collimator of the Altazimuth, in a new position, by the telescope of the Altazimuth (as will be hereafter described), the circular wall which supports the wall-curb of the South Dome has been raised about three inches. No change is made in the exterior wall, except that the perforation is higher than before.

For the service of the Clock Movement of the Great Equatoreal, as will be hereafter explained, a water-cistern has been established in the highest part of the Ball-Turret, and is supplied with water by ordinary ball-service from the Kent Water Works. The height of the cistern from the ground exceeds 40 feet, but the pressure of water in the supply pipes at the ground-level is about 100 feet, and there is, therefore, no difficulty of supply. Care has been taken to increase the protection against frost, and to give means of emptying the cistern. As the rising supply-pipe passes close to the door of the Octagon Room, a hose has been laterally attached which can discharge water into the room.

For better examination of the solar photographs introduced in the operations of the Photographic Department, by light of the sky reflected upwards from a horizontal mirror, a sheet of plate-glass was inserted in one of the windows of the Lower Computing Room. It soon became evident, however, that greater space was required for that Department, and I have now appropriated to it a room, formerly considered as the room of the Superintendent of the Magnetical and Meteorological Department, but used practically as a place for deposit of the stores of that Department. Perhaps a plate-glass window may be found necessary there.

A water-sink has been established at the head of the stairs to the South-East Dome, close to the door of the observing room of the Great Equatoreal, for use in the photographic employment of that instrument. A small fire-hose is attached to its supply-pipe.

I have inadvertently omitted to state in former Reports that there are on the Observatory Grounds three fire-plugs, always charged with water at a pressure of about 100 feet, and that the Observatory is provided with 220 feet of large fire-hose. The Assistants are periodically exercised in the use of the hose.

The removable buildings, the instruments, and the stores, of the Transit-of-Venus Stations A (Egypt), C (Rodriguez), and D (New Zealand), have now been returned to the Observatory. One Transit-hut (for examination of personal equations) and one Altazimuth-hut (for practice of the officers of the Arctic Expedition) have been again planted in the South Ground. Other of the building-frames and stores are at present lying in the South Ground; and one large collection, by permission of the Department of Works and Parks, is placed in the Reserve Ground of Greenwich Park.

A carefully constructed scale of equal parts, 15 feet in length, employed by Mr. De La Rue in Kew Park, for examination of photographic distortion, and lent by him for present use at the Royal Observatory, has been suspended at the north-east angle of the Octagon Room. The photographic hut of Station A has been placed, by permission of the Superintendent of the Royal Naval School, in the grounds of that school, for photographic examination of the scale.

Two piers have been built in the South Ground for mounting two transit instruments belonging to the Admiralty, for practice of the Officers of the Arctic Expedition.

For many years past, reports on the progress of the proposed Railway through Greenwich have been matters of great interest to the Board. At present I have merely to state that the works of the railway have really advanced from the east through the northern grounds of the Naval School, at a distance from the Observatory which leaves no fear of sensible tremor; and mention of it may well be omitted from all future reports.

II. Moveable Property :—

Our moveable property of general character is in its usual good state, and requires no special notice. A portrait of Graham has, by the kindness of Dr. Henry Lonsdale of Carlisle, been added to the collection in the Octagon Room.

For observation of the Transit of Venus, there were issued from the Observatory (besides various instruments constructed for the Transit and considered to belong to the Observatory, though not yet borne on its Catalogue), the large portable Altazimuth with axial view, and several telescopes. The Altazimuth has been received, but has not at the time of my writing been examined; the telescopes are not yet received.

III. Manuscripts :—

The bound manuscripts have all been placed upon the slate-shelving (including the new shelves of which mention was made in the last year's Report), and arranged under my own eye. All are labelled, and the letters of the classes and the Nos. of the shelves are marked on them; but we have not had leisure to inscribe the Nos. of the individual books.

The binding of manuscripts of every department is continued, as often as the manuscripts in each department accumulate in sufficient numbers to form a volume. At the present time the binding is somewhat in arrear; the excessive pressure of work, arising from the arrangements for the Transit of Venus, having absorbed much of our time.

From the same cause the annual examination of bound manuscripts, in comparison with the Catalogue, has not yet been completed.

IV. Library :—

Mr. Criswick having been charged with the superintendence of the Time Department, the Library has been placed under the care of Mr. Downing.

The books have been compared with the Catalogue; two books appear at present to be missing.

The number of books has been considerably increased by presents from foreign countries; partly, I think, in consequence of the facilities now given by foreign book-post; partly from the enormous activity in the publication of unreduced meteorological observations in the utmost detail. I doubt whether the value of the Library is much increased by the works last mentioned.

Among the duplicates, to which I alluded in the last Report, are some bound copies of works of standard character, of which a list has been made, with the view (under the sanction of the Admiralty) of distributing them gratuitously. A portion of these have been presented to the Cambridge Observatory. It seems doubtful whether the mass of unbound pamphlets are worth preservation.

V. Astronomical Instruments :—

The Transit-Circle is in good working order, and has required very little attention during the past year. As regards observations of R.A., it demands no further remark.

The correction of $+0^{r}\cdot019$ or $+0''\cdot28$ has been applied to the readings for coincidence of the nearly vertical wire of the North Collimator with that of the South Collimator, when taken through the pierced cube of the Transit-Circle, as explained in the last Report.

No new determination of the coefficient of flexure has been made since the date of the last Report.

A new and stronger recording-apparatus has been applied to the Zenith-distance-micrometer; that first made having been injured by a blow.

From 1875, January 1, the circle-reading for the Nadir-point observation has been taken with the circle-reading $179°.\ 35'. + 3^{rev.}$ (approximately) instead of $179°.\ 40'. + 0^{rev.}$ (approximately); which brings the image of the wire more nearly into the center of the field of the telescope, and the divisions of the circle more nearly into the middle of the field of the microscopes; the system previously used having

made the observation largely dependent on the value of the telescope-micrometer-screw, and on the correction for runs, as referred to the center of the field. When the change was made it was found that the discordance between the Zenith-points deduced from the Nadir-observation and those obtained from the mean of North and South Stars changed from $-0''\cdot7$ to $+0''\cdot6$; an alteration of $1''\cdot3$. This result naturally threw doubt on the value of the telescope-micrometer-screw, but a careful redetermination of this gave a result almost identical with that previously found. As there appeared to be no probability of so large an error in the adopted division-errors of the circle, observations of the Nadir-point were made with the same division in different parts of the field of the microscopes; and at the same time the runs of the screws were taken for readings at the zero and half a revolution on each side of it. In both cases considerable discordances were found, indicating an inequality in different parts of the threads of the micrometer-screws. It is suggested by Mr. Simms that this is probably the effect of wear; and this idea seems admissible, when we consider that the screws have been turned nearly one hundred thousand times, with more frequent bearing at the middle of run than at the ends. As a check on these results, observations of the nearly horizontal wire of the South Collimator were made, in which the same interval of its micrometer-screw was measured in terms of the screws of the micrometer-microscopes at each revolution in the field of view. They are yet scarcely complete, but they seem to show clearly that the apparent measure of a definite arc varies according to the position, in the microscopes' field of view, of the space traversed by the micrometer-wires; increasing from one side of the field to the other. It appears not improbable that we may be compelled to introduce new micrometer-screws.

It is to be remarked that the adopted Zenith-Points are free from systematic error, the Nadir observation having been regularly corrected for discordance, as found from the observations themselves, so that the result for Zenith-Point really depends on observations of stars alone which are distributed over the whole range of the micrometer-screws. But it is possible that the results for N. P. D. of special stars may require special corrections.

The adjustment of the apparatus for correcting the barometric inequality of the Sidereal Standard clock appears now to be complete; and the arc of vibration is very steady.

The Chronograph is in good order, and it has not been found necessary to clean it during the past year.

The Altazimuth is in excellent condition. The counterpoises of the horizontal axis were removed last October, and the instrument has been used since that date without

them, the object being to insure the stability of that axis. To protect the supporting bars of the upper pivot from the radiation of the axis-lamp, which was found to produce a sensible effect on the position of the vertical axis, tin covers have been made for the iron rods forming the upper triangle. The value of the level-divisions was tested on November 20 by Mr. Simms' level-prover, the result being that the readings of the Zenith-Distance-levels require a correction of $+\frac{3}{40}$ to reduce them to seconds of arc, whilst those in azimuth are sensibly correct.

A new set of webs was inserted on August 21, and two others were subsequently renewed; the intervals were determined by transits of stars.

In order to determine the Collimation-error independently of stars, the positions of the collimating-mark and lens have been altered, so as to produce a reversed-telescope in a horizontal direction. For this purpose it has been necessary to raise the dome three inches, and view the mark through a hole in its curtain. The collimating-mark is to be fixed to the chimney of the Upper Computing Room. As this place is somewhat difficult of access, an apparatus consisting of a galvanic battery and small induction-coil, whose spark will light the gas-lamp, is to be provided by Messrs. Comyn, Ching, and Co.

I have had it in contemplation to determine the error of level of the horizontal axis by use of a collimator passing downwards through the wall of the room, at an angle (approximately) of 45° with the vertical; but no step has yet been taken for carrying out this idea.

The Sheepshanks and Shuckburgh Equatoreals are in their usual condition, and are available for observation of occultations and phenomena of Jupiter's satellites.

The Great Equatoreal is in a very satisfactory state. Various small alterations and additions have been made to it to adapt it to the Spectroscopic and Photographic work, for which it has chiefly been used during the past year. Amongst these may be mentioned a new dew-cap and cover to the object-glass, indexes to the slow-motion rods, a sliding counterpoise on the telescope to balance the Spectroscope, a small photographic camera, a cupboard for chemicals, moveable steps to the observing-chair, and a stage for observing objects near the pole, which was used for Coggia's Comet of last year.

Mention has already been made of the cistern in the Ball-Turret for supply of the Water-clock, the necessity for which arose from the following circumstance:—The Water-clock was supplied by a small pipe, about 80 feet in length, connected with the 3-inch Observatory main (which passes through the Park), at a distance of about 250 feet from any other branch pipe. In spite of this distance I have seen that, on stopping the water-tap in the Battery-Basement under the North-East Turret, the pressure in the gauge of the Water-clock has been instantly increased by more than

40 lbs. per square inch. The consequent derangements of the water-clock in its now incessant daily use became intolerable. Since the independent supply was provided, its performance has been most satisfactory.

A moveable weight has been adapted to the pendulum for changing readily from Sidereal to Mean Solar time.

For photographing the Moon, &c. I have sketched a slipping-piece to give a motion to the photographic slide in any desired direction and with any required speed, keeping the Moon stationary on the plate. This apparatus has not yet been constructed.

The Spectroscope has received some additions and alterations, which have been suggested by practical experience. Some trouble was at first experienced from false light, but this has now been entirely got rid of by suitable adjustment; and the only defect appears to be a want of coincidence between the foci in the two planes parallel and perpendicular to the slit, the surfaces of the prisms being all slightly cylindrical. This is a fault which exists in all spectroscopes of which I have been able to obtain information, and, though trifling in amount where small dispersive power is used, it becomes important with a large number of prisms (the errors being all in the same direction), and interferes seriously with the definition of the solar prominences. Although a great improvement has been made by re-working the prisms, it has not yet been found practicable to get rid altogether of this defect; it has therefore been corrected by inserting a cylindrical lens in the Collimator-Telescope near the slit, a delicate adjustment being made by varying the distance of the lens from the slit.

The plan originally adopted, of comparing the spectra of stars with that of a vacuum tube placed in the course of the rays within the telescope, having been found to give unsatisfactory results; two comparison prisms have been fixed in front of the slit in connexion. with a collimating lens, by which an image of the comparison-light is thrown on the slit immediately above and below that of the star, in such a way that the cone of rays from this image fills the whole object-glass, and is thus subject to identically the same conditions as the star's light.

A new micrometer has been made for the Spectroscope by Messrs. Ladd and Hilger, that originally applied being a very old one, which was found to be defective. A small telescope has been adapted by Mr. Simms, by means of which the dispersion of a half compound prism can be used, giving a spectrum of $3\frac{1}{2}°$, applicable to faint objects. For such cases also the original Star-Spectroscope, made by Mr. Simms, has been fitted with a slit, which permits the use of a comparison-spectrum.

Mr. Spottiswoode has kindly placed his powerful Automatic Spectroscope at my disposal during the adjustment of the Royal Observatory Spectroscope, it being very desirable to have some standard of comparison by which to test our instrument.

A Sprengel air-pump has been made, with Mr. Crookes' friendly co-operation, by Mr. Hicks of Hatton Garden, who has applied some improvements introduced recently by Mr. Crookes.

The Reflex-Zenith-Tube is in a satisfactory condition.

The Kew Photoheliograph is in an efficient state. A spiral spring has been adapted by Mr. Simms to the instantaneous slide, in place of caoutchouc, which gave much trouble from its breaking.

Instead of the Kew Photoheliograph, I propose to mount the Transit-of-Venus-Photoheliograph returned from Egypt, as soon as its optical distortion has been determined from photographs of Mr. De La Rue's scale.

An instrument has been prepared and brought into use for measure of the areas of the solar spots in the photoheliograms, by comparison with squares engraved on the field-plate. The photographic plate is placed above a mirror, by which the light of the sky is reflected to the eye.

VI. Astronomical Observations:—

The Moon every day, and the Sun and large planets every week-day, have been subjects of regular observation on the meridian; the small planets have been observed, as usual, only in the first half of the lunation; having been, however, very rarely visible, in consequence of the cloudy state of the sky in the last winter and spring. (The observations of other objects have suffered in the last six months from the same cause.) The stars observed have been fundamental stars, and other stars described in the Reports for 1872, 1873, 1874.

In order to eliminate (as far as practicable) systematic errors in the determination of positions of fundamental stars, the rule has been adopted, since the beginning of this year, of rejecting the R. A. of all Clock stars, as determined from observation, when the group does not extend over six hours at least; the more limited groups being used only for determining clock-error. At the same time, in order still further to link together stars differing in R. A. by twelve hours, the assiduous observation of pairs of Circumpolar Stars above and below the Pole has been continued on the system introduced in 1872.

Many of the stars in the old Working Catalogue having been sufficiently observed, a new one has been prepared, containing, in addition to the Clock stars, about 1,500 stars of which further observations are required. Many of these, however, require only a single observation. This list will probably last till the next General Catalogue is formed, perhaps at the end of 1877.

The Moon, with stars for instrumental zeros, has been observed with the Altazimuth on every available opportunity; when a Low Star could not be observed, the Collimator was used. A few stars were observed in zenith-distance for zenith-point during the alteration of the Collimating-mark.

The following is a statement of the number of observations made from 1874, May 15, to 1875, May 20:—

With the Transit-Circle:

Transits, the separate limbs being counted as separate observations	3,780
Pairs of observations of the nearly vertical wires of the Reversed Telescopes	305
Reciprocal observations of the nearly vertical wires of the Reversed Telescopes	350
Reflexion-observations of the central wire	436
Circle-observations, each requiring a separate reading of the six microscope-micrometers	3,636
Reflexion-observations of the zenith-distance wire (included in the circle-observations)	428
Reflexion-observations of stars (similarly included)	452

With the Reflex-Zenith-Tube:

Pairs of observations of γ Draconis, the instrument being reversed between the observations	55
Single observations	3

With the Altazimuth:

Azimuths of the Moon and Stars	834
Azimuths of the Collimating-mark	72
Zenith-distances of the Moon	373
Zenith-distances of the Collimating-mark	198
Zenith-distances of Stars	40

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

On days when the Moon passed between 21^h and 22^h Mean Solar Time	4
" " between 22^h and 23^h	0
" " 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	3

The following comparison shows the number of places of the Moon observed with the Transit-Circle and Altazimuth respectively:—

With the Transit-Circle, 108, or 8·6 per lunation.

With the Altazimuth, 189, or 15·1 per lunation.

Observations of 7 disappearances and one re-appearance of stars occulted by the Moon, and of 36 phenomena of Jupiter's satellites, have been made, in some cases by two observers with different instruments; the Great Equatoreal and the Sheepshanks Equatoreal have been generally used for these observations. Two drawings of Coggia's Comet of last year were made with the Great Equatoreal.

A series of measures of cusps were made with the Great Equatoreal during the Eclipse of the Sun last October, from which the corrections to the Moon's tabular R. A. and N. P. D. were found; the corrections to the diameters of the Sun and Moon being assumed from the results of the Eclipse of 1870, which was much more favourable for the determination of these elements.

VII. Spectroscopic and Photographic Observations:—

With the Spectroscope the solar prominences have been mapped on 28 days only; but the weather of the past winter was exceptionally unfavourable for this class of observation; and, before the appointment of a computer as Photographic Assistant, Mr. Maunder's time was much occupied with photography, so that the best hours of the day were sometimes lost. After mapping the prominences, as seen on the C line, the other lines, especially F and *b*, have been regularly examined, whenever practicable. Great care has been taken in determining the position, angle, and heights of the prominences in all cases. Hitherto there has not been much opportunity of examining Sun-spots with the Spectroscope, but a few observations of this kind have been made. At Prof. Clerk-Maxwell's request, some measures of the breadth of different Fraunhofer lines have been made, but nothing of value in this direction can be obtained unless the Sun is high and the air very pure.

In all this work, the power of readily changing the number of prisms employed has been found very useful, as it is impossible to use high dispersive power with advantage when the sky is hazy.

The spectrum of Coggia's Comet was examined at every available opportunity last July, and compared directly with that of Carbon Dioxide, the bands of the two spectra being sensibly coincident. Decided polarisation in a plane passing through the Sun was found in the coma as well as in the tail of this comet, a double-image-prism being used for this observation.

Fifty-four measures of the displacement of lines in the spectra of 10 stars, as compared with the corresponding lines in the spectra of terrestrial elements (chiefly hydrogen), have been made, but some of these appear to be affected by a constant error depending on faulty adjustment of the Spectroscope, though special attention was given to this point. I hope that the method of comparison now adopted will be free from this source of error. The spectra of several chemical elements have been examined with a view of detecting changes in the breadth and relative intensities of the lines at different temperatures of spark; in particular, the spectrum of lead has been carefully observed, both when the spark is taken in air and in hydrogen, and changes have been remarked which confirm the results obtained by Dr. Huggins, as to the behaviour of the line in the lead-spectrum, which he has used for comparison with the nebulæ. The spectra of various compounds of carbon have been directly compared, and the positions and breadths of the bands and lines carefully measured.

Photographs of the Sun have been taken with the Kew Photoheliograph on 186 days; and of these 377 have been selected for preservation. Transits of the Sun over the cross-wires are taken about once a fortnight for determining the inclination of the wires.

The Moon, Jupiter, Saturn, and several stars (including the Pleiades and some double stars) have been photographed with the Great Equatoreal, with fairly satisfactory results, though further practice is required in this class of work.

VIII. Reduction of Astronomical Observations:—

The following table exhibits the various stages of the reductions on May 20:—

For Meridional Transit Observations:

The observed transits are cleared of instrumental errors, and clock-times of transit over the true meridian are exhibited, to .	1875, May 9.
Apparent right-ascensions from observation are formed by application of clock-errors and rates, to	May 8.
Stars' corrections are computed, to	May 20.
Mean right-ascensions of Stars from observation, reduced to 1875, January 1, are formed by combination of the two last-mentioned elements, to	May 8.
Mean solar times of observation of Sun, Moon, and Planets are prepared, to	April 24.
Corrections for defective illumination of Moon's and Planets' limbs are applied, to	May 8.

The Personal Equations of the observers who have taken transits in the year 1874 have been investigated in the usual way; the methods of observing of the principal observers are almost identical with those found in 1873.

The consideration of the observation of Circumpolar Stars of large N. P. D. above and below the Pole, to which allusion has been made, introduces no new process in the reduction of star-places; its results will be found in subsequent comparison of the places of the Circumpolar Stars above Pole and below Pole, as deduced by the usual reductions. That comparison is not yet made for 1874.

For Meridional-Circle-Observations:

Means of microscope-micrometers are taken, and corrected for telescope-micrometer, errors of graduation, flexure, inclination of wire, and zenith-point, exhibiting apparent zenith-distances, to . . . . . 1875, May 9.

Refraction, parallax, and colatitude are applied to form true geocentric north polar distances, to . . . . . May 9.

Stars' corrections are applied, forming mean north polar distances on 1875, January 1, to . . . . . April 16.

Corrections for defective illumination of Moon's and Planets' limbs are applied, to . . . . . May 9.

The refractions used are the same as those employed since the beginning of 1868.

The corrections for R—D and for error of assumed latitude have been computed for 1874; those for the position of the Ecliptic, and the geocentric and heliocentric errors of the planetary tables, are far advanced for 1874.

The variable term of the R—D correction does not sensibly differ from that found in 1873.

The result for co-latitude, 38°. 31′. 21″·35, supports that obtained last year; it is the smallest yet obtained.

The observations of γ Draconis with the Reflex-Zenith-Tube are completely reduced to the end of 1873.

The Altazimuth observations are reduced to the following stages:—

In azimuth, the means of microscopes are corrected for level, collimation, and zero of azimuth, (forming true azimuths), to 1875, April 6.

In zenith-distance, true Greenwich zenith-distances are formed, to . . . . . April 6.

Corresponding tabular azimuths and zenith-distances are computed, to . . . . . April 6.

Apparent tabular errors of Moon's R. A. and N. P. D. are computed, to . . . . . April 6.

Apparent tabular errors of Moon's Longitude and E. N. P. D. are computed to . . . . . April 6.

The Occultations of Stars by the Moon are completely reduced.

The observations of Coggia's Comet with the South-East Equatoreal are reduced, to the exhibition of apparent places deduced from the observations.

The observations of the Solar Eclipse of 1874 are reduced, exhibiting the corrections to the tabular place of the Moon's center.

IX. Reduction of Photographic and Spectroscopic Observations :—

The complete discussion of the photographs can hardly be undertaken till the results of several years' work have been brought together and grouped in such a manner as to exhibit the decennial and other curves of frequency of spots. There is, however, a considerable amount of preliminary reduction which may be carried on as current work, and this has been brought to the following state, the instrument for measuring areas of Sun spots having been brought into use on 1875, January 13 :—

All groups of Sun spots have been numbered, and the date of their first and last appearance entered up to the present time.

Areas of spots have been measured to Photograph 334 on 1874, July 17.

All observations with the Spectroscope, whether of Solar prominences, of Stars, or of Metals, have been entered up to the present date; and the measures of displacement of lines in the spectra of stars have been completely reduced.

X. Printing and Distribution of Astronomical Observations :—

The whole of the volume for 1873 is now printed, with the exception of the Introduction, which we have not yet been able to prepare fully for press. The impression consists of 300 copies of the "Observations," including a revised edition of the "Regulations of the Royal Observatory;" with 150 separate copies of the "Astronomical Results," 250 of the "Magnetical Results," and 150 of the "Regulations."

Two sheets of the volume for 1874 have been received. An abundant supply of manuscript has been sent to the Queen's Printing Office.

XI. Magnetical and Meteorological Instruments :—

On a few very hot days, as usually happens, it was found impracticable to keep the temperature of the Magnetic Basement down to the usual level; but during the rest of the year it has been maintained with little variation. The walls of the Basement have in the course of years become sensibly warmer, and the general temperature of the room has slightly risen.

The Upper Declination-Magnet has received no change; it is in good order.

The Lower Declination-Magnet is in perfect condition.

The same favourable remark applies to all the other instruments. The Vertical-Force-Magnet and the Dip-instrument, as well as the other magnetic instruments, were carefully examined by Mr. Simms at the end of 1874.

The Earth-current-wires were identified on 1875, May 3, and their insulation was then found to be perfect.

All the meteorological instruments (including the public barometer, near the front gate,) are in good order. I have reason to expect, from the kindness of the Kew Committee and the Superintendent of the Meteorological Office, a new Standard Thermometer.

XII. Magnetical and Meteorological Observations :—

The self-registering instruments have been maintained, as usual, in constant action; and an uninterrupted record of the magnetic elements, of earth-currents, and of atmospheric changes, with most insignificant exceptions, has been obtained.

The zeros of the photographic curves have been determined, as in our long-established system, by readings of the magnetometers taken four times a day; a circumpolar star has been observed with the theodolite for Zero of Azimuth at convenient times, usually once or twice a month, and a fixed mark more frequently; the dip two or three times a week; and deflexions for absolute measure of Horizontal Magnetic Force once a month.

The barometer and thermometers are read at certain hours of the day, for comparison with the photographic curves. The anemometric instruments require no such comparison, if care be taken to place their sheets properly.

XIII. Reduction of Magnetical and Meteorological Observations:—

The theodolite-observations of stars (giving astronomical zeros for the Declination-Magnet), the theodolite-readings of the Declination-Magnet, and the telescope-observations of the Horizontal-Force-Magnet, are reduced to the present time; those of the Vertical-Force-Magnet to the end of last year. These determinations give the zeros for the ordinates of the photographic curves.

The whole of the time-scales are complete for the Declination, Horizontal Force, and Vertical Force, for 1874; the new base-lines for the Declination and Horizontal Force are laid down on the photographic sheets to the end of 1874; and those for the Vertical Force to April 1874. The ordinates of the curves are measured for the Declination to the end of 1874, and for the Horizontal Force to August 1874; no measures of the Vertical-Force curves have as yet been made for 1874.

The number of disturbed days in 1874 is only 5. This number is found by adopting the scale of disturbance which I have used in the Philosophical Transactions. For these days the ordinates are to be measured for all the salient points of the curves; no further reduction of these numbers has been made since 1857. For the other days, pencil curves are being drawn, smoothing down the principal inequalities; and their ordinates are being measured for every hour; these measures will be used to form tables of diurnal and other inequalities to the end of 1874.

The absolute measures of horizontal magnetic force are prepared to the end of 1874; the dips, as usual, are reduced to the last observation.

The following are the principal results for 1874:—

Mean westerly declination	19°. 29′.
Mean horizontal force	3·892 (in English units). 1·795 (in Metric units).
Mean dip	67. 41. 59 (by 9-inch needles). 67. 43. 48 (by 6-inch needles). 67. 45. 0 (by 3-inch needles).

No measures have been made, and no theoretical results deduced, from the ordinates of the photographic curves given by the earth-current wires in their present position.

The following is the state of the meteorological results:—Corrections for instrumental errors are applied to the eye-observations, and the dew-point and degree of

humidity are computed, to the present time; time-scales and new base-lines to the Barometer traces are laid down to the end of 1874.

The vane of Osler's Anemometer made, in the year 1874, 20 complete revolutions in the positive direction N, E, S, W.

It will be remembered by the Visitors that an extensive reduction of the Photographic Meteorological Records from 1848 to 1868 was commenced a few years ago. Among the infinite number of ways in which the different phænomena of meteorology may be combined, I selected for present examination the hourly photographic readings of the Dry and Wet Thermometers, arranged to exhibit diurnal inequality of those two instruments; as grouped by months, as grouped by high and low temperatures, as grouped by high and low barometer, as grouped by clear and cloudy skies, and as grouped by directions of the wind. This work is completed, and the abstracts for press are only waiting my examination. To this was added a deduction of the diurnal inequalities of the barometer from the hourly photographic readings from 1854 to 1873; this work is about half done. A limited discussion of the readings of the deep-sunk thermometers from 1846 to 1873 is completed.

XIV. Printing and Publication of Magnetical and Meteorological Observations :—

The Magnetical and Meteorological Results for 1873 are printed. The number of copies is 550, of which 300 are bound in the volume of Greenwich Observations, and 250 are reserved for separate distribution.

In the Magnetical section, detailed measures of the ordinates of the photographic curves are given on three days of unusual disturbance. They are expressed in terms of the Metric Absolute unit, as well as on the old system. For the rest of the year, only the mean diurnal inequalities of the three magnetic elements for each month are printed. The deflexion-observations and the elements of their reductions, and the result of every dip-observation, are also given.

The Meteorological portion contains the results (but not in a detailed form) of the daily readings, of barometer, wet-bulb and dry-bulb thermometers, maximum and minimum thermometers, anemometers, and pluviometers, besides observations of cloud and weather, and records of the temperature of the Thames water and of the soil at various depths.

The daily results are communicated, at the earliest appropriate time, to M. Le Verrier's daily Bulletin and Monthly Report; to the Chief Signal Officer of the

United States War Department; to the Registrar General; to the Meteorological Office; and to various Daily Newspapers.

XV. Chronometers, Time Signals, Regulation of External Clocks:—

The number of chronometers now in the Chronometer Room is 143, consisting of 133 box-chronometers, 3 pocket-chronometers, and 7 deck-watches. Of the box-chronometers, 49 are the property of chronometer-makers, who have placed them on the annual competitive trial; all the others are the property of the Government. The competing chronometers, and others which seem to require it, are compared with one of the sympathetic clocks of the Mean-Solar-Standard-system every day; all others every week. Every chronometer undergoes trial, at least for one period of three weeks, at temperature approaching 95°; some are exposed for cold to the open air; but no artificial cold is ever used. All new chronometers are tried with the XII. hour N, E, S, and W.

The stock of chronometers is usually kept up by purchases of the best chronometers from the competitive trial, at premium-prices submitted by me to the Board of Admiralty. Sometimes chronometers are purchased, on trial, from Navy officers. On some few occasions (as the Chinese war) large numbers have been bought hastily; and in the spring of this year, 22 chronometers being demanded for the Arctic Expedition, 73 chronometers were immediately put on trial for selection of 22 to fill the place of those required.

One solar and one sidereal chronometer are now withdrawn from the general stock, for the service of the Observatory.

This may be a convenient place for mention of a supplemental mechanism which I have myself introduced into some chronometers. I have long remarked that, in ordinary good chronometers, the freedom from irregularities depending on mechanical causes is most remarkable; but that, after all the efforts of the most judicious makers, there is in nearly every case a perceptible defect of thermal compensation. There is great difficulty in correcting the residual fault, not only because an inconceivably small movement of the weights on the balance-curve is required, but also because it endangers the equilibrium of the balance. To remedy this, I have introduced small supplementary weights carried by means of a supplementary bar (rotating with stiff friction on the balance-staff), at whose ends are very light springs, carrying the supplementary weights, and constantly pressing them to the interior of the balance-curve. When the supplementary bar is so turned that the supplementary weights are near

the end of the balance-curve, the compensation is large; when they are near the root of the balance-curve, it is small. The movement from one state to the other is so simple that probably an Assistant of the Observatory will be able to manage it; and it does not interfere with equilibrium. This arrangement has received the approval of some able chronometer-makers, and may perhaps with advantage be adopted generally.

The error-numbers of the chronometers in the competitive trial of 1874 are somewhat greater than those of several years past. The difference, however, is small; about one-tenth part of the whole.

The interruptions in the daily drop of the Greenwich Time-Ball from high wind have been only 6 in number.

The Deal Time-Ball was not raised (on account of the violence of the wind) on 5 days; and was not dropped or was erroneously dropped on 7 days, from an omission of connexion of the wires. On 45 days the current failed to release the trigger without assistance from the attendant, principally from a defect in the wire within the town of Deal, for which a new one has now been substituted. The Ball Tower at Deal has undergone some repairs.

The general system of time-signals, originating at this Observatory and disseminated by the Post-Office-Telegraph through the whole of England, and to Scotland and Ireland, was so fully described in my last Report that I need not to enter into it further at this time. I shall only remark that the system continues to spread, and that it appears to be now a valuable National Institution.

It has been explained in former Reports that Sidereal clocks in the Observatory (as far as necessary) are connected galvanically; that all the Mean Solar clocks are connected galvanically; and that, after due comparison of clocks of the two classes, all the latter are brought to accurate time by galvanic action on the pendulum of one. Advantage is taken of the same principle when any occasional wants arise; as for hourly signals to the Magnetic Observatory, signals at every second to one of the Transit-of-Venus huts, &c.

The Lombard-Street-clock has been maintained in all the accuracy that is required for post-office purposes, with scarcely a failure; and the Westminster clock has been so well regulated, under the check of automatic report to this Observatory, that on 83 per cent. of the days of the year its error is below one second.

Proposals have been made for galvanic determination of the longitude of the Dublin Observatory, and the operation is delayed only for convenience in the arrangements to be made in Dublin.

The principal galvanic operation of the year has been, however, that connected with the Egyptian stations for the Transit of Venus. On the part external to England I

shall speak hereafter; at present I allude only to the English part. By the assistance of the Post-Office, uninterrupted metallic communication was made between this Observatory and the telegraph station of the Eastern Telegraph Company at Porth Curno, a small bay a few miles east of the Land's End. Mr. Ellis proceeded to this station, carrying proper chronometers, and signals were made to and from the Observatory, and were observed at both ends. On the same evenings, signals were passed between Porth Curno and Alexandria, and were observed at both stations. These two series of observations, though made by the same person at Porth Curno, and strictly part of the same system, were entirely independent; as, for the safety of the submarine wires, it is not considered prudent to connect them with open-air wires on land.

XVI. Personal Establishment:—

A general change in the duties of the observers has been rendered necessary by the resignation of Mr. Glaisher at the end of 1874. The actual arrangement is the following:—

Mr. Christie, Chief Assistant, and, in the absence of the Astronomer Royal, representing him with full powers.

Mr. Dunkin, Superintendent of Supernumerary Computers, more especially of those who are employed on meridional reductions and on the more advanced inferences from observation.

Mr. Ellis, Superintendent of the Magnetical and Meteorological Department in all its branches.

Mr. Lynn, Superintendent of the Altazimuth, and the reduction of observations made with it.

Mr. Criswick, Superintendent of the Time Department generally, of Stationery Stores, and of Money Accounts.

Mr. Downing, charged with the management of the Chronograph, and acting as Librarian and distributor of printed works.

Mr. Thackeray, employed on Circle Observations, but scarcely yet charged with a department.

Mr. Nash, Assistant in the Magnetical and Meteorological Department.

Mr. Maunder, Superintendent of the Photographic and Spectroscopic Department.

No astronomical observations are made by Mr. Dunkin, Mr. Ellis, or Mr. Nash, and only a limited number by Mr. Christie and Mr. Maunder.

Seven young men are employed as supernumerary computers in the Astronomical Department (sometimes giving assistance for the Transit of Venus), one in the

Photographic, and three in the Magnetical and Meteorological; (in addition to three, of whom I shall make further mention). The stipends of these computers, which are left to my discretion, are varied from month to month as occasion requires. A small addition is always granted when they have shown themselves competent to make trustworthy observations; and by this regulation a number of unattached observers are always ready, of whose assistance I am often glad to avail myself.

A labourer, a gate-porter, and a watchman complete our establishment. But practically we are never without carpenters in our employ, and one of these becomes virtually clerk of works.

All observations are reported to me daily; and Reports on the state of reductions are furnished when I think it necessary to call for them. The daily work of every supernumerary computer and of every workman comes before me in a detailed Weekly Report.

XVII. Extraneous Work:—

The first subject to which I have to advert is the observation of the Transit of Venus.

The parties from Egypt (A) and Rodriguez (C) are returned, with their instruments, &c.; and the instruments, &c. are returned from New Zealand (D). I am in continual expectation of the arrival of the other parties.

With regard to Egypt, the first point to be insured was the determination of the longitude of some one station. The submarine telegraph is, for commercial use, broken up into several parts. I have had experience of the troubles incident to the use of a broken line, and I determined to rely on purely astronomical methods, unless we could transmit signals in an unbroken line from Cornwall to Alexandria. This was no easy matter; the line is longer by several hundred miles than any other submarine line which has been so used; and the wire, as I understand, is smaller in section than any other long wire. I cannot say how much I am indebted to the assistance of the Eastern Telegraph Company, of their officer at Porth Curno, and of C. F. Varley, Esq., who aided us with his counsel, and who lent us (for experiment) his great resistance-apparatus, imitating the effect of a submerged wire, and other apparatus. In the actual operation, Mr. Ellis at Porth Curno received signals from Greenwich and sent signals to Alexandria; Mr. Hunter received them at Alexandria, and sent signals to Captain Orde Browne's observatory on the Mokattam Hills above Cairo (to which the Khedive had constructed a telegraph for the use of the Expedition); and communication was thus made both ways between Greenwich and Mokattam on the

same night. This was repeated four times. I shall not delay further than to remark that I believe the eye-observations and the ordinary photographs to be quite successful; that I doubt the advantage of the Janssen; that one of the double-image-micrometers (an old one, very ill made, in whose construction I had no part, and which I had not seen) seems to have failed; and that the Zenith-Telescope gives some trouble. The Suez station, I expect, will well connect us with the stations in the Indian and African seas.

At three stations at C, Rodriguez, and three at E, Kerguelen, the observations appear to have been most successful. At B, Sandwich Islands, two of the stations appear to have been perfectly successful (except that I fear that the Janssen has failed), and a rich series of lunar observations for longitude is obtained. At Rodriguez, besides our own lunar observations, we have good communication by chronometers with Lord Lindsay's stations. At Kerguelen I believe that the longitudes of the foreign stations will depend on ours. At D, New Zealand, I grieve to say the observations were totally lost, entirely in consequence of bad weather. The arrangements made by Major Palmer for establishing his own stations, for organizing the whole country into an assembly of observers, and for removing every obstacle that could be foreseen, were most admirable, and might well be taken as a model for future operations. But in the whole length of the southern island not an observation was made, except an imperfect series by the American party at its southern extremity.

There has been little annoyance from the dreaded "black drop." Greater inconvenience and doubt have been caused by the unexpected luminous ring round Venus.

From mechanical or optical causes which Captain Abney has not yet overcome, we have not yet perfectly succeeded in the observations for examining photographic distortion.

Mr. Simms is preparing, under my direction, an instrument for measuring the distance of the center of Venus upon the photographs from the center of the Sun.

The second matter is the progress of my proposed New Lunar Theory.

Basing my application upon the Resolution of the Board of Visitors at their last meeting, I submitted to the Admiralty, and through them to the Treasury, a request for assistance in carrying on this work. After necessary explanation, the Treasury sanctioned the expenditure of a sufficient sum in the then current financial year, and permitted the insertion in the Navy Estimates of a statement for grant to cover expenses during the present financial year. Three computers are now steadily employed on the work.

It will be remembered by the Visitors that the detail and mass of this work are purely numerical; every numerical co-efficient being accompanied with a symbolical correction whose value will sometimes depend on the time, but in every case is

ultimately to be obtained in a numerical form. Of these co-efficients, extracted (for convenience) from Delaunay's results, there are 100 for parallax, 182 for longitude, 142 for latitude; the arguments being preserved in the usual form. On the left side of the three equations all the raisings of powers, multiplications, and differentiations, are performed; using for the last unit 10^{-7}, and, where co-efficients are diminished by differentiation, using a more advanced figure (this last operation not quite perfect at the present moment). On the right side or side of perturbing quantities the powers of the Sun's distance, &c. are introduced, but the functions of angular distance between Sun and Moon are not formed. Of the symbolical corrections, which for the co-efficients are introduced step by step, nearly one-half are prepared; those for arguments (which are very much simpler) are not yet touched. The oblateness-terms admit of being treated almost independently, and I had myself advanced considerably with them, but a sudden influx of business compelled me to lay them aside, and I have not yet returned to them.

XVIII. General Remarks :—

The Report which I have now read is the fortieth of its class which I have had the honor to lay before the Board of Visitors. During the time to which they apply, the constitution of the Observatory, personal and material, has been greatly changed. Only one Member of the Board of Visitors, I believe, remains as witness of my first proceedings. There is not now a single Assistant, or a single instrument in use (for even Shuckburgh's Equatoreal is not employed as a graduated instrument), of those which formed the Establishment of 1835. The contemplation of this long period and of these changes induces me to look both backward and forward on the objects of the Observatory and the mode of carrying them out.

The Observatory was expressly built, for the aid of Astronomy and Navigation, for promoting methods of determining Longitude at Sea, and (as the circumstances that led to its foundation show) more especially for determination of the Moon's motions. All these imply, as their first step, the formation of accurate Catalogues of Stars, and the determination of the fundamental elements of the Solar System. These objects have been steadily pursued from the foundation of the Observatory; in one way, by Flamsteed; in another way, by Halley, and by Bradley in the earlier part of his career; in a third form, by Bradley in his later years, by Maskelyne (who contributed most powerfully both to Lunar and to Chronometric Nautical Astronomy), and for a time by Pond; then with improved instruments by Pond, and by myself for some years; and subsequently, with the instruments now in use. It has

been invariably my own intention to maintain the principles of the long-established system in perfect integrity; varying the instruments, the modes of employing them, and the modes of utilising the observations by calculation and publication, as the progress of science might seem to require.

While instruments of the same class, but of increased power, have been substituted for those which I found here, three novel constructions have been introduced; the Lunar Altazimuth, the Reflex-Zenith-Tube, and the Chronograph; and, for a special investigation, the Water-Telescope (now dismounted). I omit mention of auxiliary instruments. To utilize the observations, the numerical reductions for each current year have always been maintained in the most perfect state that I could devise. From these, elaborate star-catalogues (now in frequent demand) have been formed from time to time. And, for connecting the observations of the moveable bodies of our system in a complete and homogeneous series, beginning at 1750, first the Planetary Observations and secondly the Lunar Observations of my predecessors have been reduced, and orbital elements have been corrected. The Lunar Reductions are probably the greatest single work ever undertaken in Astronomy.

This portion of our labours may be considered as applying to the combined subjects of Astronomy and Navigation. But there are also, peculiar to Astronomy, the photo-heliography and spectroscopy lately introduced. And, peculiar to Navigation and related subjects, there are the investigation of the laws of magnetic disturbance in iron ships, and the correction of the compass by methods now used in the commercial navies through the world; the maintenance of magnetic observations; the incessant attention to chronometers; the extensive dissemination of accurate time-signals; and the daily dropping of a time-ball at Deal.

The subject of Meteorology, which has been followed for many years, is scarcely connected with the two great heads of Astronomy and Navigation, and hardly deserves the name of a science. It is, however, in great popular request.

Mechanical self-registration of some meteorological phænomena was introduced by me shortly after the commencement of my residence. Since that time the practical arts of Photography and Galvanic Communication were invented, and they were quickly made available in many of our operations.

In this increase of occupations, the annual expenses of the Observatory have increased, but in a much lower proportion than the work done.

Experiments have been made, bearing on cosmical physics, by Maskelyne for the attraction of Schehallien, and by myself for the vibrations of pendulums in mines. Preparations have been made for observations of Eclipses and of the Transit of Venus. Assistance has been rendered to the Government in training officers for such services as tracing National Boundaries, &c., and in reference to National Standards.

The Lunar Theory, though most intimately connected with the highest interests of Astronomy, scarcely presents itself to me as a work of the Observatory.

Turning now from the past to the future, I see little in which I could suggest any change. If it should ever be necessary to make any reduction, I should propose to withdraw Meteorology, Photoheliography, and Spectroscopy; not as unimportant in themselves, or as ill-fitted to the discipline of the Observatory, but as the least connected with the fundamental idea of our establishment. In the nature of addition, I will indicate one practical point. I much desire to see the system of time-signals extended, by clocks or daily signals, to various parts of our great cities and our dockyards, and above all by hourly signals on the Start Point, which I believe would be the greatest of all benefits to nautical chronometry.

Should any extension of our scientific work ever be contemplated, I would remark that the Observatory is not the place for new physical investigations. It is well adapted for following out any which, originating with private investigators, have been reduced to laws susceptible of verification by daily observation.

The National Observatory will, I trust, always remain on the site where it was first planted, and which early acquired the name of "Flamsteed Hill." There are some inconveniences in the position, arising principally from the limited extent of the hill, but they are, in my opinion, very far overbalanced by its advantages.

G. B. AIRY.

Royal Observatory, Greenwich,
1875, *May* 27.