REPORT

OF

THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1878, *June* 1.

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SINCE the date of my last Report to the Board of Visitors, 1877, May 13, the lapse of twelve lunations leads to 1878, May 2. I am induced by this circumstance to close the present Report on May 2, describing the state of the Observatory for that day, and adverting to the transactions which have occurred between the two Reports. The different subjects are treated in the usual order.

I. Buildings and Grounds :—

I have rarely had so little to report under this head as on the present occasion.

Of the portable huts used for the Transit of Venus: two Photoheliograph Huts are at the Cape of Good Hope and at South Kensington; and one Transit Hut, conveyed to Ascension for the use of Mr. Gill in observations of Mars for solar parallax, has been left there for the use of the Military Establishment. All others are either lodged in the Reserve Ground of Greenwich Park, or are abandoned or broken up.

The buildings, &c. are in general good order.

A small alteration has been made in the windows of the Dip Observatory; not for facilitating the dip-observations (which rely on gas-light) but for convenience of illumination on papers, &c.

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I continue to remark the approaching necessity for Library extension. Without having absolutely decided on a site, I may suggest that I should wish to erect a brick building, about 50 feet by 20, consisting of two very low stories (or rather of one story with a gallery running round its walls), so low that books can be moved by hand without necessity for a ladder. The site which appears most convenient is that at present occupied by the rubbish-yards of workmen, facing the eastern window of the Magnetic Observatory; care, however, must be taken in the selection of materials. For convenience of access to such a site, as well as to the Magnetic Observatory and other buildings, a light roof over the Magnetic Passage would be very desirable.

The railway through the town of Greenwich has been opened some months. No effect of its proximity (the distance is about 1700 feet) has been discovered at the Observatory.

II. Moveable Property:—

Allusion will shortly be made to the instruments employed in the regular course of observations. Of others I have to report:—

The telescope lent to Colonel Tennant, which had been sent by Colonel Tennant to Mr. Simms on return to the Observatory, has been received.

A large bar-magnet and a small clock which were lent to Mr. (late Sir Francis) Ronalds about thirty years since have been returned.

The Transits, Altazimuths, and Clocks employed on the Transit of Venus are stored here in an accessible state. The Equatoreals are all here, with the exception of one at the South Kensington Museum. Of the five photoheliographs: one is mounted here, and is in daily use in our heliographic observatory; one is at the Observatory of the Cape of Good Hope; one, accompanied with its special huts, &c. (but not with Transit or Altazimuth, which have been returned) at the South Kensington Museum; one is sent to the Indian Department, for observations by Colonel Tennant in India; and one is in our own shed.

In apparatus of a lower class, woodwork, &c., though small works have frequently been going on, no change worth notice has been made.

III. Manuscripts:—

The utility of an Observatory rests so completely in its manuscripts, both of observations and of calculations, that I deem it my duty to maintain a constant

watch on the security and the good order of those documents. Next in importance to these is the correspondence with men of science on all subjects bearing on our special pursuits; but there is a lower class, not to be neglected, of letters from and to persons who ask for information, or who desire judgment on their own speculations, sometimes of the most fanciful description.

I think it right to preserve all these papers, in an order which makes it possible at all times to trace out each series relating to any one subject. To some future examiner they may offer interesting evidence, both on the steps of the real progress of science and on the efforts made by the less educated classes to connect themselves with science.

The plan which has been established here for many years appears to work well, and is maintained with scrupulous regularity. The first step is a rude arrangement made every day; the last result is a series of bound volumes of carefully classed manuscripts.

The volumes are catalogued, and are annually compared with the list. All appear to be complete, excepting a copy of Bradley's original volumes, which is lent to a German astronomer, and a packet of papers relating to the Eclipse of 1860, lent to Mr. Ranyard.

IV. Library:—

In conformity with our long-established plan, efforts are continually made to keep up our library to the current state of science in those branches which engage the attention of this Observatory. Its principal supply consists, as heretofore, in the presents from observatories and academies.

The books are at present too much scattered in four different rooms, and the pressure on the shelves is becoming too great.

The books are compared annually with their Catalogue. All appear to be correct.

V. Astronomical Instruments:—

In regard to the Transit-Circle, no repetition has been made of the observations for the form of the pivots, the state of their surfaces having appeared to be most satisfactory. But in the month of December 1877, the azimuthal error of the transit had increased to 10″. A skilful workman, instructed by Mr. Simms, easily reduced the error to about 2″·5 (which would leave its mean error nearly 0), the

western Y being moved to the north so far as to reduce the reading of the transit-micrometer, when pointed to the south, from 35r·500 to 35r·000. The level-error was not sensibly affected.

No observations have been made of the flexure of the telescope. But, for inversion of the action of the spring upon the screw-threads, as well as for convenience of manipulation of the microscope-micrometers, the micrometer-heads on the three left-hand micrometers have been turned to the lower instead of the upper ends of the micrometer-boxes. At the same time, some small improvements have been made in the internal combs, and in the adjustment of the object-glass of one microscope.

The Sidereal Standard Clock preserves a rate approaching to perfection, so long as it is left without disturbance of the galvanic-contact springs (touched by its pendulum), which transmit signals at every second of time to sympathetic clocks and the Chronograph. A readjustment of these springs usually disturbs the rate. I contemplate the possibility of using the Standard Clock, leaving the pendulum free from the touch of springs, to give, from its wheel of 30 double-seconds, bi-secondly currents; which currents would regulate, on Mr. Jones' principle, the movement of a seconds' clock, by which the desired signals would be actually produced.

The clock "Hardy" frequently used with the Transit-Circle, had become exceedingly rusty, and has received extensive repair. The other clocks are in fairly good order.

The Chronograph required several small repairs of its wheel-work, which were effected by Messrs. Dent. It is now in good order.

In September last, the horizontal pivots of the Altazimuth were found to be somewhat scratched. They were burnished down by Mr. Simms.

The lower microscopes of the Altazimuth, reading its horizontal circle, have been readjusted for focus. The necessity for these repeated adjustments, always in the same direction, appears to arise from a gradual sinking of the parts which support the lower pivot.

The Sheepshanks and Shuckburgh Equatoreals are in their usual state, and are sometimes employed for extrameridional phenomena.

The Great Equatoreal has again been a little stiff in its bearing. This instrument has been more frequently employed than in former years, and is more liable than it was formerly to sustain injury from rotary friction. It was found also that the diameter of its oiling-pipes was rather too small. Larger pipes have been substituted; and blocks and other apparatus required for raising the instrument in time of need have now been prepared as part of its permanent furniture.

The Spectroscope constructed by Mr. Browning consisted of four compound prisms, each formed of three simple prisms, and two, each formed of two simple prisms; through all which every pencil of light travelled in both directions. It was furnished with proper telescopic apparatus, and had, after much trouble and expense, been brought to a satisfactory state. It is now superseded by Mr. Christie's Direct-vision Spectroscope or Half-prism Spectroscope (briefly mentioned in the last year's Report), constructed, under Mr. Christie's direction, by Mr. Hilger; formed by a combination of two compound prisms, each consisting of two simple prisms, which appears to be very effective. An accidental circumstance slightly limits the convenience of its application to our Equatoreal (but without really preventing its use for any object in our visible sky, except some stars near the pole); the eyepiece is rather long, and approaches too near to the floor of the room when employed on objects near the zenith, and too near to the equatoreal circle for close circumpolar objects. Had such a construction being contemplated as possible, it would have been very easy to plan the Equatoreal so as to avoid this difficulty; at present it is not easy to remove it.

The actinic doublet is still untouched. The slow-motion screws of the Equatoreal, the object-glass-separator, the air-pump, the photoheliograph and its micrometer, are all in good order, and require no further notice. The micrometer used for the Transit-of-Venus photographs has again been unpacked for use, as will be mentioned.

VI. Astronomical Observations:—

It appears unnecessary to repeat the statement of the continued devotion of our meridional powers to the observation of Moon, Sun, Planets, and important stars, taking no share in the zone-observation of small stars; or of our efforts to secure, when possible, observations of long series of fundamental stars, or sometimes to check the direct-transits by reflexion-transits; or of our arrangements for observing the Moon and two stars with the Altazimuth on every practicable day. I still, however, lament that our power of advantageous observation of the small planets is limited by the want of ephemerides, which I should be glad to possess for the first eighteen of those objects.

To facilitate the observations of Stars, a new Working Catalogue has been prepared, in which are included all stars down to the third magnitude, stars down to the fifth magnitude which have not been observed in the last two Catalogues, and a list of 258 stars of about the sixth magnitude of which the places are required

for the United States Coast Survey. The whole number of stars in our new working list is about 2500.

It may be here mentioned that an extensive series of observations was made, during the autumn, of about 70 stars, at the request of Mr. Gill, for comparison with Mars, Ariadne, and Melpomene.

Between 1877, May 13, and 1878, May 2, the following observations have been made:—

With the Transit-Circle:

Transits, the separate limbs being counted as separate observations	3970
Pairs of observations of the nearly vertical wires of the Collimators	294
Reciprocal observations of the nearly vertical wires of the Collimators	350
Reflexion-observations of the central wire	284
Circle-observations, each requiring a separate reading of the six microscope-micrometers	3824
Reflexion-observations of the zenith-distance wire (included in the number of circle-observations)	275
Reflexion-observations of stars (similarly included)	471

With the Reflex-Zenith-Tube:

Pairs of observations of γ Draconis, the instrument being reversed between the observations	27
Single observations	2

With the Altazimuth:

Azimuths of the Moon and Stars	791
Azimuths of the Collimating-mark	288
Zenith-distances of the Moon	406
Zenith-distances of the Collimating-mark	282

In reference to the number of complete observations of the Moon in both elements, as depending on the Mean Solar Time of the Moon's Transit:—

Between 21^h and 22^h there were 5 observations.
Between 22^h and 23^h „ 2 „
Between 23^h and 24^h „ 2 „
Between 0^h and 1^h „ 0 „
Between 1^h and 2^h „ 3 „
Between 2^h and 3^h „ 4 „

The whole number of places of the Moon observed with the two instruments were:—

With the Transit-Circle, 104, or 8·7 per lunation.

With the Altazimuth, 171, or 14·3 per lunation.

The Moon's diameter has been measured:—

With the Transit-Circle, twice in R.A., 7 times in N.P.D.

With the Altazimuth, 10 times in Azimuth, 56 times in Z.D.

The Great Equatoreal, the Sheepshanks Equatoreal, and the Altazimuth, have been employed, sometimes singly, sometimes simultaneously, for occasional extra-meridional observations.

These are,—

In occultations of Stars by the Moon, 3 disappearances, 3 reappearances.

In the movements of Jupiter's Satellites, 7 phenomena of various classes.

With the Great Equatoreal,—

Twenty-nine sketches of Mars were obtained near his opposition, forming a complete record of the appearances of that planet during the entire rotation.

One measure and seven estimates were made of the position and distance of the outer satellite of Mars, and two estimates for the inner satellite.

Saturn was carefully examined on five nights, but always in unfavourable state of atmosphere. Several positions of his satellites were measured; Rhea on four nights, Dione and Tethys on three, Titan on one. On one evening, the position and distance of Enceladus were estimated.

For observation of the Transit of Mercury on May 6, occurring during the preparation of this Report, ample preparations were made. The sky however was heavily clouded, and the ingress of Mercury was not seen at all. After a time, the planet was seen upon the sun's disk for several minutes, but no observations of important character could be made.

VII. Reduction of Astronomical Observations:—

The following report applies to the state of reductions on May 2:—

For Meridional Transits:

Clock-times of transit over the true meridian after all corrections for instrumental errors, &c. are prepared, to	1878, April 29
Clock errors and rates are determined, and corrections are applied to form apparent right-ascensions from observation, to .	April 26
Star-reductions are computed and applied to the apparent right ascensions of stars, so as to exhibit the mean right ascension on 1878, January 1, to	April 26

For transits of the Sun, Moon, and Planets, mean solar times are prepared, to . . . . . 1878, April 26
Corrections for defective illumination are computed and applied to April 26

The usual investigation of personal equations has been made from the transits of 1877; the change for each observer is very small.

For Meridional Circle Observations:

The means of micrometer-readings are taken, and the usual corrections are applied forming apparent zenith-distances, to . 1878, April 27
Refraction, parallax, and colatitude, are applied to . . . April 20
Star-reductions are computed and applied so as to form mean N. P. D. for January 1, to . . . . . April 3
Corrections for defective illumination are corrected and applied to April 20

The corrections for R—D have been investigated and applied, and the correction to co-latitude and the numbers which define the obliquity of the ecliptic and the place of the equinox have been investigated. The co-latitude found is 38°. 31′. 21″·52; the corrections to the obliquity and equinox of the Nautical Almanac are small.

The computations of the geocentric and heliocentric errors in the places of the planets given by the various tables in use are advancing.

The computations for the *Nine-Year Catalogue* of 2263 stars, including some supplementary investigations, were completed in the course of 1877, and the Introduction has been prepared and sent to the printer. The Catalogue is drawn up in the same form as previous Catalogues, the only noteworthy alterations being the addition of another decimal place to the R.A.'s and Annual Precessions in R.A., which are carried to $0^s{\cdot}001$ and $0^s{\cdot}0001$ respectively. The Right Ascensions are thus made to correspond more nearly with the North Polar Distances as regards the degree of accuracy exhibited. For the determination of the systematic errors in Right Ascension, depending on the assumed places of the Clock-Stars used, a comparison has been made of the R.A. of Clock-Stars found from groups which extend over 12^h at least with those of the Catalogue, and also a comparison of the R.A. of Circumpolar Stars above and below the Pole. For the first-named discussion, new ledgers of R.A., from groups of 12^h and upwards, were formed for the 208 Clock-Stars, of which 3130 observations were available, and the mean places deduced for 1872 were assumed as Standard, and corrections to the Nine-Year Catalogue were tabulated according to R.A. and N.P.D. respectively. From these, mean corrections have been deduced by a graphical method, ranging from $+0^s{\cdot}014$ about 23^h to $-0^s{\cdot}011$ about 9^h as depending on the R. A., and from $-0^s{\cdot}005$ at 50° to $+0^s{\cdot}003$ at 100° and upwards as depending on the N. P. D. In preparing the Assumed Mean Right Ascension of Clock-Stars for use in 1878, these corrections have been applied to the places of the

Nine-Year Catalogue, so that in future the assumed places of Clock-Stars will virtually depend on groups of 12^h and upwards. The R. A.'s of Clock-Stars in the First and Second Seven-Year Catalogues have also been compared with the Standard 12^h Groups, the result being to show that the errors of the assumed places of Clock Stars, originally derived from Pond's observations, have been carried through the successive catalogues, though gradually diminishing in amount. For the First Seven-Year Catalogue the corrections range from $+0^s{\cdot}041$ about 23^h to $-0^s{\cdot}044$ about 8^h; and for the Second Seven-Year Catalogue from $+0^s{\cdot}023$ about 23^h to $-0^s{\cdot}037$ about 8^h. With regard to the Circumpolar Stars, the Mean Excess of R.A. above the pole over R.A. below the pole, reduced to Equatoreal interval, ranges from $+0^s{\cdot}020$ at 23^h to $-0^s{\cdot}010$ at 3^h, rising again to $+0^s{\cdot}027$ at 6^h and falling gradually to $0^s{\cdot}000$ at 14^h to 19^h. The mean excess from the whole of the observations is $+0^s{\cdot}010$. The North Polar Distances have been corrected for error of the Microscope-Micrometer screws for the years 1868 to 1875; the observations in 1876 do not require any such correction, as new screws were applied at the beginning of that year. A correction of $-0''{\cdot}20$ has also been applied for error in the assumed Co-latitude, $38°.31'.21''{\cdot}60$, a new determination based on all the observations of Circumpolar Stars having given the value $38°.31'.21''{\cdot}40$. In this investigation 5976 observations above pole and 2685 below were discussed, and the result has been adopted as the basis of the N. P. D.'s of the Catalogue.

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

The following is the state of reduction of the Altazimuth-observations:—

For azimuths, true azimuths are formed by combination of mean of microscopes, correction for level, collimation, and azimuth-zero, to	1878, April 2
For zenith-distances, true Greenwich zenith-distances, corrected for refraction, are formed, to	April 2
Corresponding tabular azimuths and zenith-distances are formed, to	April 2
Apparent errors of Moon's tabular R. A. and N. P. D. are computed, to	April 2
Apparent errors of Moon's tabular Longitude and Ecliptic N. P. D. are computed, to	April 2

The observations of the Moon with both instruments agree in exhibiting a rapid increase in the errors of the Lunar Tables.

The observations of Occultations of Stars by the Moon are completely reduced.

VIII. Spectroscopic and Photographic Observations :—

During the past year the Sun's chromosphere has been examined with the Spectroscope on 79 days (on 2 of these through part of the circumference only); prominences were seen on 58 days. The Sun was usually enveloped in mist or light cloud when no prominences were seen, and it is therefore not safe to infer their complete absence on such occasions, as their brightness is generally much inferior to that of the chromosphere. All the observations, however, tend to show that the Solar prominences have been few in number and insignificant in size for many months. The Ten-prism Spectroscope was employed for this work up to the end of July last, when it was superseded by the new Half-prism Spectroscope, with the result of a marked increase in the proportion of days on which the Chromosphere could be satisfactorily examined. The Half-prism Spectroscope has also been employed in the examination of the spectrum of the Sun-spot of October 25—November 6, and in the measurement of several fine absorption-lines near G, with reference to the existence of bright lines in that part of the Solar spectrum.

The observations of displacement of the lines in the spectra of Stars suffered some interruption from the various small alterations consequent on the substitution of the Half-prism Spectroscope for that formerly used, and there was further interruption during the oppositions of Mars and Saturn. From these various causes, the observations were not brought into regular train till the middle of last November. One hundred and thirteen measures have been made of the displacement of the F line in the spectra of 20 stars as compared with that of hydrogen; and 92 measures of the displacement of the *b* lines in the spectra of 16 stars as compared with that of magnesium; 21 observations of 6 of these stars having been made with the full dispersive power of the spectroscope (giving a spectrum of 75° from A to H, equivalent to 15 simple prisms of 60°). Of these stars, 9 had not been observed before for motion in the line of sight. Numerous comparisons of the F and *b* lines in the spectra of the Moon and of the Sky, with those of hydrogen and magnesium, have been made regularly as a check against instrumental error.

The Single-prism Spectroscope has been employed in the examination of the spectra of Mars, Uranus, and of the Eclipsed Moon, as well as of one or two variable stars; and a small Half-prism Spectroscope has been used for spectroscopic observation of Comet *b*, 1877 (Winnecke's), and of the rainband in the sky-spectrum to which Prof. Piazzi Smyth has called attention. Further observations of the spectrum, referred to in the last Report as occasionally intruding into that of Hydrogen, have led to its identification with the spectrum of Zinc, which is used in the preparation of the gas.

Photographs of the Sun have been taken on 156 days, and 283 of these have been preserved for measurement. The photographs show a complete absence of spots on 66 days, and on 26 of these there are neither spots nor faculæ.

IX. Reduction of Spectroscopic and Photographic Observations :—

All observations with the Spectroscope have been completely reduced; the position-angles of prominences being converted into Heliographic N.P.D.; and the displacements of lines in the spectra of stars being reduced so as to exhibit the concluded motion in miles per second, after applying a correction for the Earth's motion.

The areas, position-angles, and distances from the Sun's centre, of Sun-spots and faculæ, have been measured to the end of 1877, and in duplicate to 1877, July 5.

The correction of the position-angles and distances for the effects of refraction and distortion, and their conversion into Heliographic Longitude and Latitude, have been pushed forward as rapidly as circumstances would admit after the measurements had been completed. As there is a considerable accumulation of arrears since 1873, which will require many months for their reduction, it has seemed desirable to commence with the year 1876, with the view of including in the volume for 1876 the complete deductions from the measures of Sun-spots and faculæ in that year, if they can be prepared for press in time, leaving the complete results for the years 1873 to 1875 to be included in the next volume; the areas, as distinct from positions, having been already printed in the volumes for 1874 and 1875.

X. Magnetical and Meteorological Instruments :—

The principal instruments have required little beyond the usual cleaning, and there are but few changes to record under this head.

A new axis has been applied to one of the dipping needles.

From some cause, which has not yet been perfectly traced, the indications of one of the Earth-Current Wires, "North Kent—Blackheath," are accompanied with abnormal fluctuations which greatly vitiate the results.

The time of revolution of the cylinder on which the indications of the dry and wet-bulb thermometers are photographically registered, has been increased to 52 hours,

a change rendered necessary by the occasional overlapping of the two records; opal screens have been fixed on the Standard Barometer, to protect the instrument from the radiation of the gas-lamps, which are however only turned up at the time of reading; and new scales have been supplied to the Deep-sunk Thermometers, reference marks having been previously scratched on the glass stems. It is proposed to screen the Standard Thermometers from the radiation of the ground, by fixing a small board below their bulbs.

A cistern has been mounted and some experiments with the Thomson registering Electrometer have been made, but it has not yet been brought into a proper state for continuous record. The glass insulators of the old electrometer apparatus cracked last autumn, and have not been renewed.

XI. Magnetical and Meteorological Observations:—

The self-registering magnetometers, barometer, thermometers, and anemometers, have given a continuous record of the magnetical and meteorological elements, with very few failures from accidental causes throughout the year. Their indications are checked by eye observations taken four times a day, and by occasional determinations of dip, deflexion, and zero of the declination-theodolite. The moment of inertia of the deflecting magnet, employed in Deflexion-Observations, has been redetermined from careful measurements made by Mr. Simms. The result agrees closely with the adopted value.

All the thermometers in ordinary use were compared with the Standard in January last.

The observations of atmospheric electricity have been discontinued since the autumn, pending the introduction of the new electrometer.

With reference to the general system of observation, we have been in friendly communication with the Meteorological Office.

XII. Reduction of Magnetical and Meteorological Observations:—

The theodolite observations of the Upper Declination-Magnet, giving absolute magnetic declinations, are reduced to the end of 1877; eye-observations of scale of Horizontal-Force-Magnetometer to the present time; and of Vertical-Force-Magnetometer (for which the value of the dip is required) to the end of 1876. On

the photographic sheets the time-scales for Declination, Horizontal Force, Earth-Currents, and Thermometers are complete to the end of 1877; those for the Vertical Force to the end of 1876. The base-line values for the Declination and Horizontal Force are formed for 1877, but not yet laid down on the sheets. The Dip-observations are reduced to the present time, and the Deflexion-determination of absolute horizontal magnetic force to the end of 1877.

The following are the principal results for magnetic elements in the year 1877 :—

Approximate mean westerly declination . .	18°. 57′.
Mean horizontal force	3·901 (in English units). 1·799 (in Metric units).
Mean dip	67°. 38′. 46″ (by 9-inch needles). 67. 39. 54 (by 6-inch needles). 67. 40. 40 (by 3-inch needles).

The Magnetic Reductions for the years 1865 to 1877, alluded to in the last Report, are now in hand.

In the reduction of the ordinary meteorological observations we have, since 1878, January 1, employed the corrections for diurnal range of barometer and thermometers given by the reduction of the twenty years' photographic records, 1849–1868. In future the Photographic Meteorological Records will be reduced each year as part of the current work, on the same system as the Magnetic Records, the back years being brought up as opportunity offers.

The mean temperature of the year 1877 was 49°·4, being the same as the average of the preceding 36 years; the months of greatest deviation were January and February, respectively 4°·2 and 4°·3 above the average, and May and September, respectively 3°·9 and 4°·4 below. The mean of January and February taken together was exactly the same as the mean of March and April together, viz., 43°·1. The highest temperature was 88°·2 on July 31, and the lowest 23°·5 on March 1.

The mean daily motion of the air in 1877 was 313 miles, being 34 miles greater than the average. In February and November, the movements were respectively 87 and 88 miles above the average. The greatest day's motion was 893 miles on January 30, and the least 67 miles on December 20.

The vane of Osler's anemometer made, in the year 1877, eight complete revolutions in the positive direction N, E, S, W, N.

On April 10 last, a very heavy fall of rain took place. Between April $10^{d}.5^{h}$ and April $11^{d}.2^{h}$, $2^{in}\cdot824$ was recorded, and 75 per cent. of this, or $2^{in}\cdot12$, fell in the eight

hours between $13\frac{1}{2}^h$ and $21\frac{1}{2}^h$; and on May 7, 1 inch of rain fell in 50 minutes, of which $\frac{1}{2}$ inch fell in 15 minutes.

XIII. Printing and Distribution of the Volume of Greenwich Observations:—

The Astronomical part of the volume for 1876 is completely printed, with the exception of the Introduction, and of the Spectroscopic and Photographic Results. The manuscript of the latter has been somewhat delayed, in order that the measures of positions of spots might be incorporated with those of areas, but it will very shortly be ready for the printer. The Nine-Year Catalogue, forming Appendix I., is printed as far as 16^h, and the Introduction is in the printer's hands. Appendix II., consisting of the continuation of the Numerical Lunar Theory, is printed as far as page 239; closing Symbolical Variations on the disturbed side, and exhibiting the formulæ of Solar Perturbing Forces.

The Magnetical Results for 1876 are printed, and the Meteorological Results are in the press; the manuscript of the Introduction has not yet been sent to the printer.

The whole of the manuscript of the three principal sections of the Astronomical part of the Volume for 1877 has been sent to H.M. Stationery Office, but no proof sheets have yet been received.

The extent of the impression of the Volume for 1876 is the same as that for 1875, with the exception of the Nine-Year Catalogue, of which it is proposed to print 500 copies for separate distribution, in addition to 300 included in the Volume. As usual there will be 150 separate copies of Astronomical Results, and 250 each of Magnetical and Meteorological Results and of Numerical Lunar Theory.

The Great Meteorological Reductions, including the discussion of the Photographic Barometer Records 1854–1873, of the Photographic Thermometer Records 1849–1868, and of the observations of Deep-sunk Thermometers 1847–1873, are in the hands of the printer. The illustrative plates have been engraved, and the Barometer section is already printed.

XIV. Chronometers, Time Signals, Regulations of External Clocks, Operations for Longitude:—

The number of chronometers now in our hands is 178, of which 145 (107 box-chronometers, 28 pocket-chronometers, and 10 deck-watches) are the property of the

Government, 4 belong to an Italian man-of-war, having been sent for a short rating, and the remaining 29 box-chronometers belong to various chronometer-makers, being placed here for the annual competitive trial. These latter are compared daily; the other chronometers, except in special cases, only once a week. Every chronometer is tested in a temperature approaching to 100° Fahrenheit; Government chronometers for a period of at least three weeks; competitive chronometers twice for periods of four weeks each.

The supplementary compensation continues to be applied with success to Government chronometers which offer facilities for its introduction, and a marked improvement in the performance of chronometers returned after repair by the makers appears to have resulted from the increased attention now given to the compensation. Of the 29 competitive chronometers, 25 have the supplementary compensation.

In the competitive trial of last year, a slight falling off in the criterion of merit given by the mean "trial numbers" of the first six chronometers is shown, as compared with the two preceding years. The first chronometer however is a good one, fully up to the average.

A competitive trial of chronometers has been instituted at Hamburgh; and the general form of proceeding, and the arrangement of Report, are precisely copied from those at Greenwich. Reports also of a somewhat different class of time-keepers, and in a rather less elaborate form, are issued from Neufchatel.

There have only been two failures from accident in the automatic drop of the Greenwich time-ball; on 4 days the ball was not raised on account of high wind. The Deal time-ball was not dropped at 1^h on 8 days, through failure of the telegraphic connexion; on 25 days the current was weak and the assistance of the attendant was required to release the trigger; on 3 days high wind prevented the raising of the ball. On the 8 days of failure of the ball-drop at 1^h, a black flag was hoisted, and the ball was dropped again at 2^h.

The Westminster Clock was cleaned by Messrs. E. Dent & Co. last autumn, the clock being out of use from August 21 to October 11. Since this cleaning, the clock has gone with a remarkably steady rate, though sometimes affected by high wind. During the period to which this Report refers, the Westminster Clock has been 3^s in error on 7 days, and 2^s on 26 days. On the greater number of days the error has been under 1^s.

The daily dissemination through the country of accurate time-signals, originating from this Observatory, continues to advance, without any important alteration of principle.

XV. Personal Establishment:—

No change has been made in the persons or the employments of the Establishment.

The important duties of Chief Assistant are intrusted to Mr. Christie. During my presence, every operation is concerted with him; and in my absence he is invested with the fullest powers. One of his daily duties is to examine all observations before calculations are made upon them.

The business of the Astronomical Department is distributed among Messrs. Dunkin, Lynn, Criswick, Downing, and Thackeray; the mere observations being principally made by the four gentlemen last mentioned, each of them taking his turn in the observations made with every instrument. Besides these established Assistants, there is also a fluctuating body of Supernumeraries, whose engagement, stipend, and discharge, rest entirely with me; and some of these, whose ability has been properly proved and formally certified, are occasionally employed as observers. For other works:—Mr. Dunkin directs the supernumeraries who reduce transit-observations and orbital deductions, &c., and superintends the reading of proof sheets, and also maintains general discipline among all supernumeraries; Mr. Lynn, with one or two supernumeraries, takes charge of the adjustments of the Altazimuth and reduces the observations made with it; Mr. Criswick, with one supernumerary, manages chronometers, time-signals, matters of stationery, and quarterly accounts; Mr. Downing has library, manuscripts, business with H. M. Stationery Office, and distribution of printed works; Mr. Thackeray, with one supernumerary, attends to the Chronograph, and to Zenith Distances observed with the Transit-Circle.

The duties of the Magnetical and Meteorological Department employ Mr. Ellis and Mr. Nash, with (usually) two supernumeraries. At the present time, while the advanced reduction of the magnetical observations 1865–1877 is yet unfinished, four supernumeraries are constantly engaged.

The Spectroscopic and Photographic Department, and the general care of the S.E. Equatoreal, are confided to Mr. Maunder, with one or two supernumeraries.

A gate-porter, watchman, and labourer are attached to the establishment; and an unattached clerk of works is regularly employed.

Reports of all transactions within the Observatory, of every kind, are periodically brought for my inspection.

XVI. Extraneous Work:—

I first advert to the reduction of observations of the Transit of Venus:—

At the date of the last Report, the determination of the longitudes of the British Stations was not quite complete (that of Kerguelen being then imperfect). But, under a demand from the House of Commons, a strong effort was made to finish all introductory calculations; and to effect computations of Solar Parallax, by comparing all eye-observations of ingress of Venus among themselves, and all eye-observations of egress of Venus among themselves. The operation was in fact entirely conducted by Captain Tupman, though always under my cognizance. It soon became evident that the different stages of phenomena at the ingress must be most accurately discriminated, and this was done by Captain Tupman with great care, and I believe with great general success; although Captain Tupman himself has been induced lately to modify his interpretation of the observers' language in one or two instances. The same remarks apply to the recorded observations at egress. Then it became evident that in one instance there was indubitably an error of 1^m of time, and suspicions arose of a similar error in other observations. In an observation at another station, not included in the British "five," the more serious error of 30^s has been found.

Finally, a Report was made to the Government on July 5, giving as the mean result for Mean Solar Parallax $8''\cdot76$; the results from ingress and from egress, however, differing to the extent of $0''\cdot11$. A more complete calculation by myself, including in one series the observations both at ingress and at egress, and recognizing the possible errors of R.A. and N.P.D., gave sensibly the same mean result for Parallax. This is liable to no error except from the interpretation of observers' language, to which I have alluded. All has subsequently been re-examined by Captain Tupman; different interpretations have, in a few instances, been put on the records; several observations from colonial stations have been combined; instead of using different phases in the observations (both of ingress and of egress), attempts have been made to ascertain the one phase of "contact of limbs;" the notes of a few unpractised observers have been rejected; and the result for parallax has been increased to $8''\cdot82$ or $8''\cdot83$.

The numerous photographs taken at the various stations had been carefully measured by Mr. Burton, and have since been re-measured by Captain Tupman; and (by photographs of Mr. De La Rue's scale of equal parts) the measure of photographic distortion had been well ascertained. But the results from photography have disappointed me much. The failure has arisen, perhaps sometimes from irregularity of limb, or from atmospheric distortion, but more frequently from faintness and from want of clear definition. Many photographs, which to the eye appeared

good, lost all strength and sharpness when placed under the measuring microscope. It was once remarked to me "You might as well try to measure the zodiacal light." A final result 8″·17 was obtained from Mr. Burton's measures, and 8″·08 from Captain Tupman's.

I next allude to the progress made in the Numerical Lunar Theory.

The developments of the effect of every possible error (expressed as a Symbolical Variation) in the co-efficients and arguments of the assumed lunar ordinates, upon every term in the three fundamental expansions of—(1) Areas in the Ecliptic, (2) Radial Forces in the Ecliptic, (3) Forces normal to the Ecliptic,—have been computed and printed. The corresponding Solar Perturbing Forces have been computed entirely for the first of these (care being taken to extend the decimal calculation further for those terms whose effect may probably be increased in solution of the equations, a process in which many figures are almost necessarily wasted), and partially for the second and third. Until all have been completed, I cannot draw any positive inference from the comparison of these terms with those of the ordinate-expansions; but a cursory collation of those relating to the Areas led me to suppose that there might be some error in the computations of the Annual Equation and related terms. A most jealous re-examination has however detected nothing, and has confirmed my belief in the general accuracy of the numerical computations. I dare not yet venture to assume an error in Delaunay's theory; but I remember that the Annual Equation gave great trouble to the late Sir John Lubbock, and that he more than once changed his conclusions as to its true value.

XVII.—General Remarks:—

In my last Report to the Board, I alluded briefly to the increasing demand for extension of our buildings; and in a preceding section of the present Report, I have called attention more particularly to the want of Library-room, and to the way in which it might be supplied. If my proposal on this matter is satisfactory to the Visitors, I would ask their support in applying for the sanction of the Government, so that the work might proceed with the building season of next year. Such an erection would not only relieve us from the necessity of placing books in several small and inconvenient corners, but it would set at liberty at least one room which might be used for computers or persons engaged in any other literary employment incident to the Observatory.

If this addition be made to our buildings, and if no remarkable increase be made in the number or magnitude of our instruments, I believe that the Observatory may go

on for many years without requiring any extension of its boundary. But if a very large equatoreal or other instrument of unusual dimensions were to be erected, we must either stilt the building on the New South Ground, or we must destroy the Magnetic Observatory or its dependencies. Whatever is done, I hope that the genuine "Flamsteed Hill," the place of the labours of Flamsteed and Bradley,—a site which, though limited, possesses very great advantages,—will never be abandoned.

On other points relating to the buildings, I abstain at present from offering any remark.

I alluded also to the questions connected with our printing. Every novelty in the Observatory increases the amount of printing; and our annual volume now contains very nearly one thousand large and closely-printed pages. (The Paris *Observations* for 1867 contains 400 pages.) I by no means wish to make, at present, any modification in this important matter; but I should be glad to be guided by the opinion formed by Members of the Board after careful personal inspection. There lack not Members who individually can speak with authority on Gravitational Astronomy, on Observing Astronomy, on Magnetism, on Meteorology, on Solar Photography, on Spectroscopy; and if the Board should decide to refer me to those gentlemen for instructions, each in his own province, we should probably arrive at a satisfactory conclusion.

A precept was lately issued by the Lords Commissioners of H.M. Treasury to the effect that no printing of a work should be begun until the whole of the manuscript had been communicated to the Controller of H.M. Stationery Office; and great fears were entertained that this arrangement might seriously retard the publication of the Greenwich Observations. I have however reason to hope that the Observations will be excepted from the action of the rule, and that the printing will go on as heretofore.

G. B. AIRY.

Royal Observatory, Greenwich,
1878, *May* 20.

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