REPORT

OF

THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1888 *June* 2.

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The Report here presented refers to the period of 356 days from 1887 May 21, to 1888 May 10, and exhibits the state of the Observatory on the last-named day.

I. Buildings and Grounds, Moveable Property, and Library :—

The building operations for extension of the Computing Rooms and erection of a dome 18 feet in diameter were commenced on November 7 and completed by April 21, with the exception of the new dome made by Sir Howard Grubb, which is now nearly finished. The Assistants and Computers of the Astronomical Branch were, in the meantime, transferred to the Octagon Room, where temporary arrangements had been made for carrying on the office work. New desks and shelves for books have been fitted up in the Computing Rooms and sinks for photography have been fixed in the Dome Room, the north portion of which is to be partitioned off as a photographic dark room. A fire-place with provision for ventilation has also been fixed in the Astronomer Royal's Official Room. The increased space available in the new rooms and the ready means of communication between the upper and lower rooms are felt as a great convenience, and as the Spectroscopic and Photographic Branch has been transferred to the Upper Computing Room, the whole of the astronomical establishment is now brought together. It is intended to mount the Cooke 6-inch equatoreal, with the photoheliograph tube attached, on the new pier as soon as the 18-foot dome is completed.

The alterations required in the Safe Room in connexion with the work on the new rooms and pier necessitated the removal of Bradley's North Quadrant, which has been placed in the Transit-Circle Room. The South Quadrant which is mounted on the east face of the pier has not been disturbed.

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A new flue with independent outlet has been fitted to the chronometer oven to carry off the fumes from the gas jets. The South-east dome has been warmed during the winter months by means of heated air from the stove in the Chronometer Room, as explained in the last Report.

As regards moveable instruments, three transits, an altazimuth, a photoheliograph, and two clocks (Dent 1916 and 2013) are at the Cape Observatory ; a photoheliograph and the mountings of two others (without the tubes), an equatoreal (Simms' No. 2), a transit, and an altazimuth have been lent to the Science and Art Department, the three last-named for exhibition at Bethnal Green Museum ; a photoheliograph tube is in India ; an altazimuth has been transferred to the Royal Naval College and the Lee 6-inch equatoreal to the Hong-Kong Observatory, and a clock (Dent 2011) is at Kew Observatory. The Hodgson 6-inch object glass, lent to the Elder Brethren of the Trinity House for photometric experiments, and the micrometer for measuring the Transit of Venus photographs, lent to Capt. Darwin, have been returned. The telescope of the Simms' equatoreal No. 1 and a small portable equatoreal mounting were used by Mr. Turner for observations of the Solar Eclipse of August last in Russia.

The Cooke 6-inch equatoreal has been mounted temporarily in the South Ground since the beginning of last June for observation of occasional phenomena, a portable transit hut, with canvas flap on its roof, being used to protect it from the weather.

The annual comparison of the books and manuscripts with the catalogue has been made. The three books missing last year have not been found, and another book, a pamphlet, and a bound manuscript volume are also missing. It is possible that the last named has been mislaid in the moving of books and manuscripts out of the Computing Rooms for the building operations. Dr. Auwers has a copy of Maskelyne's printed observations on loan.

The subject of approaching railways has again, after a lapse of many years, engaged our serious attention. Early in March notice was received from the Home Office of a proposal to carry a railway (in extension of the authorized Bexley Heath Railway) in a tunnel across Blackheath, the nearest point being 840 yards from the Observatory. As there was reason to believe that this railway might injuriously affect the Observatory, preliminary observations of the effect produced by trains on the existing Greenwich-Maze Hill Railway were at once commenced, the observations being made on six nights with the transit-circle and the disturbance in the image of the wires, as seen by reflexion from the trough of mercury, being noted. It resulted from these experiments that trains on this railway caused great disturbance during their passage, not only on the section between Greenwich and Maze Hill, the nearest point of which is 570 yards from the transit-circle, but also on the line beyond Greenwich on the London side and beyond Maze Hill on the Woolwich side. The distances of the Greenwich and Maze Hill stations from the Observatory are about 970 and 670 yards

respectively. There was also evidence of disturbance caused presumably by trains on the Lewisham, Blackheath and Charlton line, at a distance of about a mile from the Observatory, but we could only infer the times of passage of these trains from the published time-tables.

In order to establish conclusively the connection between definite disturbances and trains, arrangements were made to note the times of arrival and departure of trains on the Greenwich line and at Blackheath, facilities for doing this having been courteously given by Mr. Myles Fenton, the Manager of the South-Eastern Railway. Observations were made on this plan on five nights, one observer being stationed at the transit-circle to record all disturbances of the reflected image, while another observer travelling up and down the Greenwich line, and a third observer at Blackheath noted the times of arrival at and departure from the stations. It was found that the disturbance was very great during the passage of trains between Greenwich and Maze Hill, the reflected image being invisible while the train was in the tunnel, at a minimum distance of 570 yards, and that there was considerable disturbance during the passage of trains through the Blackheath-Charlton tunnel, at a distance of a mile, the reflected image becoming occasionally invisible. As the tunnel of the proposed railway would be similar in character to this, but at half the distance, it was concluded that it would cause so great a disturbance as to make delicate observations impossible. On my notifying this to the Admiralty, the bill was opposed on the part of the Government, and as a consequence of this the clauses authorizing the construction of the railway across Blackheath were abandoned.

I may here mention that the extension of the London, Chatham, and Dover Railway from Blackheath Hill to Greenwich, which was authorized in 1881, is now in course of construction. I hope that, though the terminus of this line is distant only 620 yards from the Observatory, the tremor from trains will not have sufficient time to produce the full accumulated effect in the short interval between Blackheath Hill station and the terminus. But if at any future time a further extension of this line should be proposed, the question would require very careful consideration in the interests of the Royal Observatory.

II.—Astronomical Observations :—

Transit-Circle.—The errors of level and azimuth having become inconveniently large, the Y's were readjusted after having been taken out and thoroughly cleaned. The azimuth error has been altered by shifting the eastern Y (by means of its adjusting screws), and the level error by placing a sheet of tinfoil under the western Y. The mean azimuth error has thus been altered from + 9″ to about — 2″, and the mean level error from — 5″ to about + 4″. After the cleaning of the Y's it was found that the

instrument had been shifted bodily westwards, the clearing away of the accumulation of oil and dirt having apparently allowed the plate against which the end of the eastern pivot bears to go further home. This is believed to have been the position which the instrument originally occupied. The plates which were formerly placed under the microscopes to allow of their being brought to focus have now been removed, these plates having presumably been required in consequence of the shift of the whole instrument eastwards in course of years. The object-glasses of the transit-circle and collimators were thoroughly cleaned at the beginning of this year, and the apparatus for illuminating the wires has been cleaned and readjusted.

The errors of the steel micrometer screws applied to the microscopes of the transit-circle at the beginning of 1886 were investigated in September and October last by means of the south collimator, 20 sets of measures of the value of each revolution, and 10 of each third of a revolution from -1^r to 6^r being made. The resulting apparent errors are so small that they may safely be neglected.

The Personal Equation Instrument was used in 1887 to obtain a long series of observations by 5 observers on the variation of personal equation with rate and direction of motion. The results which have been discussed by Mr. Turner (Monthly Notices, R.A.S., 1887 November) show that this variation is very small except in the case of one observer whose personal equation is large. The differences in the absolute personal equations of the several observers thus determined for equatoreal stars accord well with the relative personal equations (referred to a standard observer) from transits of clock stars, and the variations due to direction of motion also agree closely with those deduced from transit-circle and altazimuth observations with the reversion-prism. The whole number of complete transits observed with the personal equation instrument was 954 on 39 days, involving about 1400 bisections for adjustment of the contacts, two bisections of the artificial star being made before the series of transits and two after for contact at each of the nine wires. The instrument was dismounted for the winter, and has now been re-mounted for an investigation of personality in the observation of limbs.

The regular subjects of observation with the transit-circle are the Sun, Moon, planets and fundamental stars, with other stars from a working catalogue, which includes all the stars in Groombridge's Catalogue and in the Harvard Photometry not observed at Greenwich since 1867. It is intended to add stars from Piazzi's Catalogue, as the observations of the stars in the working list are cleared off. A new list has been prepared of about 1300 stars to be observed by reflexion, selected with a view to proper distribution in zenith distance from those observed since 1882, when the new mounting of the collimators rendered it possible to extend such observations to considerable zenith distances. The Annual Catalogue of stars observed in 1887 contains about 1900 stars.

The following statement shows the number of observations made with the Transit-Circle in the period of 356 days ending 1888 May 10 :—

Transits, the separate limbs being counted as separate observations	5304
Determinations of collimation error	294
Determinations of level error	351
Circle observations	5067
Determinations of nadir point (included in the number of circle observations)	331
Reflexion-observations of stars (similarly included)	503

About 350 transits (included in the above number) have been observed with the reversion-prism, to determine personality depending on the direction of motion.

The very bad weather in the first four months of this year has seriously affected the number of observations with the transit-circle.

As regards the computations :—

The transits are completely reduced (so as to exhibit mean R.A. 1888 Jan. 1) to May 5, means of wires and limbs being taken to May 9. The copy for press is complete to March 1, except the notes, which are written to the end of 1887.

The investigation of personal equations in eye and ear transits, as well as in chronographic, has been completed for the year 1887, the results for the regular observers being closely accordant with those found in previous years. The practice of observing two clock-stars on each night by the eye-and-ear method has been maintained.

The circle observations are completely reduced (so as to exhibit Mean N.P.D. 1888 Jan. 1) to May 5, and the copy for press is prepared to the end of 1887.

The correction for discordance between the nadir observation and the mean of results from reflexion observations of north and south stars is insensible in 1887, the mean for the year being + 0″·006, with considerable fluctuations in the individual months.

Five determinations of the astronomical flexure of the transit-circle have been made since the last Report, the resulting values being + 0″·12, + 0″·02, − 0″·11, + 0″·28, and + 0″·13. No correction for flexure as distinct from the R—D correction, has been applied since 1879.

The correction for R—D, the error of assumed colatitude, and the position of the ecliptic have been investigated for 1887. The ledgers of mean R.A. and N.P.D. of

stars for 1887 are completed and the geocentric and heliocentric errors for the planetary results of 1887 are in hand.

The value of the correction for discordance between reflexion and direct observations of stars is $-\ 0''{\cdot}032 + 0''{\cdot}696 \sin$ Z D., being sensibly the same as the mean for the four years 1883-1886, $+\ 0''{\cdot}692 \sin$ Z D., which has been adopted for the Ten-Year Catalogue.

The value found for the colatitude from the observations of 1887 is $38°.\ 31'.\ 21''{\cdot}63$, differing by $0''{\cdot}27$ from the assumed value; the correction to the tabular obliquity of the ecliptic is $-\ 0''{\cdot}19$; and the discordance between the results from the summer and winter solstices is $+\ 1''{\cdot}64$, indicating that the mean of the observed distances from the pole to the ecliptic is too small by $0''{\cdot}82$. The results of the ecliptic investigation for 1887 differ from those of former years, mainly through the substitution of the freely exposed thermometer in the front court for the ordinary exterior thermometer in the observations of the Sun, as explained in the last Report. More care has also been taken to equalise the internal and external temperatures by leaving the shutters open for some time before observing. The mean excess of the reading of the front court thermometer over that of the exterior thermometer at the time of observation of the Sun ranged from $+\ 1°{\cdot}1$ in December to $+\ 4°{\cdot}8$ in June, and the consequent increase in the correction for refraction from $+\ 0''{\cdot}21$ in May to $+\ 0''{\cdot}59$ in October.

The mean error of the Moon's tabular place (computed from Hansen's lunar tables with Newcomb's corrections) is $+\ 0^s{\cdot}059$ in R.A. and $+\ 0''{\cdot}66$ in longitude as deduced from 110 meridian observations in 1887. The mean error in tabular N.P.D. is $+\ 0''{\cdot}18$, indicating that, as in the case of the Sun, the mean of the observed N.P.D.'s is too small. It is to be noted that no change has been made as regards the thermometer used for observations of the moon at night, the front court thermometer being used only for observations in the daytime.

The computations for the Ten-Year Catalogue are in the following state :—

The annual results for R.A. and N.P.D. have all been corrected for reduction to the mean formula for R − D, and also for index error of the thermometer (from 1877 January 1 to 1879 April 3), and have been entered in the Catalogue sheets as far as R.A. 15^h (2340 stars). The precessions and secular variations have also been computed and entered to R.A. 15^h. The mean R.A. and N.P.D. for the epoch 1880·0 have been computed as far as R.A. 12^h, Auwers' proper motions being used throughout wherever available, supplemented by Argelander's as given in Vol. VII. of the Bonn Observations.

In order to obtain further information on the distribution of temperature in the transit-circle room as affecting the refraction correction, three thermometers were mounted at the beginning of this year in the horizontal shutter-opening in the middle and at the N. and S. angles respectively. These have been read 127 times, simultaneously with the interior, exterior, and front court thermometers, particulars as to the shutters open on each occasion being also noted.

Altazimuth.—The total number of observations made in the period of 356 days ending 1888 May 10, is as follows, the observations having been as usual restricted to the first and last quarters in each lunation, except during the winter when, in the absence of suitable objects for equatoreal observations, the Moon was observed throughout the lunation.

Azimuths of the Moon and stars	354
Azimuths of the azimuth mark	114
Azimuths of the collimating mark	116
Zenith distances of the Moon and stars	209
Zenith distances of the collimating mark	116

In consequence of the building operations for the extension of the Computing Rooms the collimating mark was dismounted on November 9, and the view of the azimuth mark has been obstructed by the new building from the beginning of December. Since then the collimation and azimuth errors have been determined entirely by observations of high and low stars. It is proposed, when the work on the new building is completed, to select two azimuth marks, one distant and the other sufficiently near to be seen in the foggy weather of the winter months. For distinct vision of the latter a lens of very long focus would be required, and it would thus be available strictly as a collimating mark.

The altazimuth observations are completely reduced to March 21, so as to exhibit errors of Moon's tabular R.A., N.P.D., longitude and ecliptic N.P.D., and the copy for press has been prepared to the same date.

The following table shows the number of days on which complete observations of the Moon were obtained with the transit-circle and altazimuth respectively ;—

Moon's Time of Meridian Passage.	Transit-circle.	Altazimuth.
1^h to 2^h mean solar time . . .	0	2
2^h to 3^h ,, . . .	0	6
3^h to 4^h ,, . . .	4	8
4^h to 5^h ,, . . .	2	7
5^h to 6^h ,, . . .	3	5
6^h to 9^h ,, . . .	19	7
9^h to 12^h ,, . . .	20	8
12^h to 15^h ,, . . .	20	2
15^h to 18^h ,, . . .	23	8
18^h to 19^h ,, . . .	5	6
19^h to 20^h ,, . . .	4	6
20^h to 21^h ,, . . .	0	7
21^h to 22^h ,, . . .	0	1
22^h to 23^h ,, . . .	0	1

The whole number of places of the Moon observed with the transit-circle is 110 or 9·2 per lunation, and with the altazimuth 74 or 6·2 per lunation.

The Moon's diameter has been measured with the transit-circle 4 times in R.A. and 9 times in N.P.D., and with the altazimuth 4 times in Z.D.

Clocks and Chronograph.—These are all in good order. The Sidereal Standard stopped on October 15, through thickening of the oil. It was cleaned by Messrs. E. Dent & Co., and brought into use again on November 7.

Reflex Zenith Tube.—Since the date of the last Report 21 double observations of γ Draconis have been made and completely reduced.

The discussion of the results of the transits observed in the years 1883 to 1885 for determination of the temperature correction is unsatisfactory, there being difficulty in determining the effect of an error in focal adjustment from these observations.

Equatoreals.—The Lassell equatoreal is in good order. The photographic camera was dismounted at the beginning of this year and the small plane mirror inserted for eye observation. The driving clock has required some small repairs. The dome, 30 feet in diameter, is in excellent order and it has been found that it can be turned completely round (through 360°) in 30 seconds by one person.

No progress has been made since the date of the last Report in the construction of the new 28-inch refractor, owing to difficulty in obtaining the crown disk. The flint disk made by Messrs. Chance seems to be satisfactory, but up to the present neither that firm nor M. Feil's successor has succeeded in making a crown disk.

The South-east, Sheepshanks, Cooke, and Shuckburgh equatoreals are in good order.

The Sheepshanks equatoreal was completely dismounted and thoroughly cleaned last June, the object glass was re-centred and the slow motions were repaired and improved for adaptation of the instrument to stellar photography under Mr. Criswick's supervision. A 4-inch photographic object-glass by Dallmeyer, belonging to one of the photoheliographs, was mounted at the end of June in a light wooden tube and firmly attached to the side of the telescope tube and parallel to it, to carry out experiments on the extent of field available on plane and curved plates respectively, the latter being moulded by Messrs. Chance to a radius of 22 inches, corresponding to the curvature of the field, if the circle of least confusion be taken for the image. Forty-one photographs have been taken of the Pleiades and other objects with different exposures and in different parts of the plate, 13 of these being on curved plates. In these experiments the Sheepshanks refractor was used as directing telescope, the image of a star being kept on its cross-wires during the exposure of a plate by means of the slow motions. The plates measure $6^{in.} \times 6^{in.}$, representing $5\frac{3}{4}° \times 5\frac{3}{4}°$, and it is found that on the flat plates the star images are sensibly circular to a distance of

nearly 2° from the centre of the field, while micrometric measures of these plates show that for some distance beyond this limit the relative places of stars can still be measured with an accuracy exceeding that of meridian observations and with no sensible systematic error depending on magnitude or duration of exposure. Comparison of the results on flat and curved plates respectively indicates that the advantages of using the latter are doubtful. As the Dallmeyer object glass is peculiar in having the flint outside it was reversed in the cell in the course of the experiments and some photographs were taken with it in this position, the flint being inside. It appeared on comparing the results that a somewhat better field is obtained with the flint outside. A photographic object glass of 6 inches aperture and 6 feet focal length, made by Sir H. Grubb for experiment, was mounted at the end of April in place of the 4-inch object glass, and some trial photographs of stars have been taken with it.

Since the date of the last report 24 occultations of stars by the Moon (13 disappearances and 11 re-appearances) and 18 phenomena of Jupiter's satellites have been observed with one or more of the equatoreals or with the altazimuth. The occultations and phenomena of Jupiter's satellites are completely reduced to the end of 1887. Special arrangements were made for observing occultations during the total eclipse of the Moon on January 28, observers being stationed at nine instruments, but clouds covered the Moon almost continuously during totality, so that the smaller instruments were useless. In glimpses of clear sky the disappearances of 6 stars and the re-appearances of 8 were observed with the larger instruments, three of these by three observers and three others by two observers. In three cases the disappearance and re-appearance of the same star were observed. Various devices were adopted with a view to facilitating the observation in rapid succession of the faint stars occulted during the eclipse. In the case of two instruments the eye-piece was mounted excentrically at the distance of the radius of the Moon's image from the axis, so that without disturbing the position of the telescope any point of the limb could be brought into the centre of the field. For setting the position-circles rapidly in the dark, cardboard circles with notches at important points or with the figures indicated with luminous paint, were found very useful.

Comets have been observed with the Sheepshanks equatoreal on 12 nights and with the altazimuth on one night, the observations being thus distributed :—Comet *e* 1887 on 3 nights, Comet *f* 1887 on 1 night, Comet *a* 1888 on 9 nights. All the observations of comets have been completely reduced.

III.—Spectroscopic and Photographic Observations :—

The spectroscopic observations of motions of stars in the line of sight have been continued during the past year, 273 measures of the displacement of the F line in the spectra of 40 stars and 60 of the *b* line in 16 stars having been made since the last report, besides comparisons with the spectra of the Moon, Mars, or the sky, as a check on the

general accuracy of the results. The recent observations of Algol confirm the previous results indicating orbital motion, but further observations are required to establish the fact. At the request of Mr. Lockyer the spectra of α Orionis, α Herculis, γ Cassiopeiæ and β Lyræ have been examined on several occasions. Comet a 1888 has been spectroscopically observed on 3 nights, the spectrum being chiefly continuous and the three usual cometary bands very faint. The spectroscopic observations of all kinds are completely reduced.

In the period of 356 days ending 1888 May 10, photographs of the Sun have been taken at Greenwich on 205 days, and of these 398 have been selected for preservation, besides 9 photographs with double images of the Sun for determination of zero of position.

For the year 1887 Greenwich photographs are available on 188 days and photographs from India or Mauritius filling up the gaps in the series on 173 days, making a total of 361 days out of 365 on which photographs have been measured in this year.

The Sun has been free from spots on 106 days in the year 1887, and the areas of both spots and faculæ have diminished since the date of the last Report. With the exception of a fine group seen during three rotations in May, June, and July, and of three other groups, one in July and two in December, all of these being in the southern hemisphere, there has been a complete absence of conspicuous spots. The entire spotted area has rarely amounted to 1–2000th of the Sun's visible hemisphere, and the mean is less than one-sixth of that recorded in 1883, being intermediate between those for the years 1875 and 1876.

The photographic reductions for 1887 are completed and the copy for press is prepared.

The Greenwich photographs have been measured in duplicate as far as 1888 Feb. 5, and the measures have been completely reduced so as to exhibit heliographic longitudes and latitudes and areas of spots and faculæ.

The photographs from India and Mauritius have been received from the Solar Physics Committee as far as Feb. 29 and Jan. 9 respectively. The Indian photographs have been measured as far as 1888 Jan. 13 and completely reduced to the end of 1887. The Mauritius photographs have all been measured and completely reduced.

In view of the diminution of the current work as the minimum of Sun spots approaches, the further discussion of the results of former years has been commenced and arrangements have been made through the Solar Physics Committee to complete the Greenwich results as far as practicable by the measurement of photographs taken elsewhere, particularly at Ely and Cambridge, U.S. From the beginning of 1882 the photographic record is practically complete, the measurement of Indian photographs to fill up gaps in the Greenwich series having been undertaken from 1881 Dec. 22. The further discussion of results has, therefore, been commenced from that

date, and the projected areas of spots (uncorrected for foreshortening) have been formed to 1885 May 29, and from the beginning of 1886 to the end of 1887. The ledgers in which the areas and positions of the spots of a group are collected and the mean area and position of the group, deduced for each day and for the whole period of visibility, have been formed for 1886 and 1887, and their completion for the years 1882 to 1885 will now be taken in hand. Two new forms have been prepared to exhibit the distribution of spotted area on each day for every degree of latitude and for every 10° of longitude, mean results being taken for each rotation and for each year.

IV. Magnetic Observations :—

The only important change in the magnetic instruments is the substitution, since October last, of a wooden bar loaded with lead, of the same size and weight as the declination-magnet, for the brass bar hitherto used for determination of the torsion of the suspending skein, a very weak trace of magnetism having been detected in the brass bar.

The continuous register by photography of the changes in magnetic declination, horizontal force and vertical force has been maintained, the absolute values of the magnetic elements being determined from time to time by eye-observation of declination, dip and deflexion, to give the means of obtaining the values for the reference lines from which ordinates on the photographic sheets are measured for each hour.

The earth-current wires, which were damaged by the snowstorm of 1886 December 26, were not completely repaired till August 1887, when it was found that the earth-plate at Angerstein Wharf had been stolen, another earth-plate being then supplied. A renewal of the earth-current wires concurrently with the telegraph wires on this portion of the South-Eastern Railway was arranged, in concert with Mr. Leonard, but this has not been carried out owing to a rise in the price of copper. Five measures of resistance of the earth-current wires have been made since the last Report, but the results are not satisfactory, owing presumably to the bad condition of the wires. On the line from Angerstein Wharf to Ladywell, $7\frac{1}{2}$ miles in length, the measures of resistance range from 220 to 285 ohms, and on the Blackheath to North Kent East Junction line, 5 miles long, the measures range from 230 to 262 ohms. Under these circumstances it seems hopeless to attempt to express the measures of ordinates on the earth-current sheets in terms of the electrical units until the conditions of the circuits have been improved. A further difficulty arises in discussing the small diurnal inequality on the earth-current registers in consequence of the circumstance (to which attention was first drawn by Mr. A. J. S. Adams of the Post Office Telegraphs) that there is a slight dislocation in the Angerstein Wharf-Ladywell trace shortly after sunset with sudden return to the original position shortly before sunrise, representing an increased current from Ladywell to Angerstein Wharf, or a diminished potential

at Angerstein Wharf during the night hours. Possibly this may be connected with the electric lighting in the vicinity of the earth plate. It appears to have commenced in 1883, becoming more pronounced in 1884. It may be mentioned here that Mr. A. J. S. Adams spent some time at the Observatory last autumn copying earth-current traces for the years 1884, 1885, and 1886.

From the beginning of 1888 the magnetic and meteorological photographic registers have been taken in duplicate, two sheets being placed on each cylinder. It is found that a good trace can be obtained on the under sheet by means of the light transmitted through the upper. The duplicate series will be available for loan to magneticians or meteorologists who wish to discuss the Greenwich records.

The Richard thermograph in the magnet-basement answers its purpose well. It is satisfactory to note that its indications support the general accuracy of the temperatures for each hour inferred in former years by interpolation from the eight daily eye-observations.

The magnetic reductions are completed to the following stages :—

The eye-observations of the upper declination magnet, and of the horizontal and vertical force magnets, are completely reduced to the end of 1887. The time-scales for declination, horizontal force, and vertical force are complete to the end of 1887, and the base-line values, deduced from the eye-observations, are entered on the photographic sheets for horizontal and vertical force.

The hourly ordinates of the photographic curves are read out to the end of 1887 for horizontal and vertical force, and the time-scales for earth-currents are laid down. The dip observations are completely reduced to the present time, and the deflexion observations for absolute measure of horizontal force to the end of 1887. The temperature of the magnet basement at every hour has been read off from the sheets of the Richard thermograph to the end of 1887.

The following are the principal results for the magnetic elements for 1887 :—

Approximate mean declination . .	17° 47′ West.
Mean horizontal force . .	3·9419 (in British units) 1·8175 (in Metric units)
Mean dip	67° 25′ 45″ (by 9-inch needles) 67 26 20 (by 6-inch needles) 67 27 13 (by 3-inch needles)

In the year 1887 there were only three days of great magnetic disturbance, but there were also about twenty other days of lesser disturbance for which tracings of the photographic curves will be published, as well as tracings of the registers on four typical quiet days.

The results of the Greenwich determinations of declination, horizontal force, and dip, from 1841 to 1884, which, as mentioned in the report for 1886, were communicated

to M. Moureaux of the French Magnetic Observatory, Parc Saint Maur, have been discussed by him in connexion with the preparation of a new magnetic chart of France.

V. Meteorological Observations :—

All the meteorological instruments are in good order. The Osler pressure chain broke in the long tube on Nov. 2, and owing to difficulties in removing the portion in the tube, it was not renewed till Nov. 30. The driving clock of the new thermograph had, as mentioned in the last Report, given much trouble, and was eventually sent to Mr. Kullberg in May 1887 for improvement of the mechanism. Many small changes were made and a new pendulum was provided. The new thermograph was brought into use again on Oct. 11, the old thermometer apparatus, which has not been dismounted, being used in the interval.

The registration of atmospheric pressure, temperature of the air and of evaporation, direction, pressure and velocity of the wind, rainfall (at various heights above the ground), sunshine, and atmospheric electricity has been maintained as usual, special attention having been given during the past year to the temperature of the air as indicated by thermometers under different conditions of exposure. With this object the readings of the thermometers in the Stevenson screen and on the roof of the Magnet House have been continued and the results compared with those of the standard thermometers on the rotatory stand. The observations in 1887 of the thermometers on the Magnet House roof confirm those made in the previous year in giving generally a smaller diurnal range than those on the rotatory stand, the day temperatures in summer being lower, especially on very hot days. The readings of the thermometers in the Stevenson screen appear on the whole to fall between those of the roof-thermometers and those of the standard-thermometers.

The instruments formerly used for observation of atmospheric electricity were exhibited in March last at the Royal Meteorological Society's exhibition of instruments connected with atmospheric electricity.

The meteorological reductions are in the following state :—The observations of barometer, thermometers, anemometers, rain gauges and sunshine recorder (corrected where necessary, for instrumental error) are reduced up to the present time. On the photographic sheets all the time-scales are laid down to the end of 1887 and the hourly ordinates are read out for the dry and wet bulb thermometers to the end of 1887. The hourly ordinates for the electrometer are read out to April 1887, and the table of principal changes in the direction of the wind is prepared to June 1887.

The mean temperature of the year 1887 was 47°·8 being 1°·5 below the average of the preceding forty-six years. The highest air temperature in the shade was 92°·2 on July 4 and the lowest 15°·5 on January 2. The mean monthly temperature in 1887

was below the average from January to June and from September to December, and above in June, July, and August. In March it was 4°·1 below the average, in July 4°·3 above, and in October 5°·0 below.

The mean daily motion of the air in 1887 was 275 miles, being 9 miles below the average of the preceding twenty years. The greatest daily motion was 829 miles on March 23, and the least, 59 miles on November 16. The only recorded pressure exceeding 20 lbs. on the square foot was 20·5 lbs. on April 6.

During the year 1887 Osler's anemometer showed an excess of about 17 revolutions of the vane in the positive direction N., E., S., W., N., excluding the turnings which are evidently accidental.

The number of hours of bright sunshine recorded during 1887 by Campbell's sunshine instrument (Prof. Stokes's improved pattern) was 1401, which is about 190 hours above the average of the preceding ten years. The aggregate number of hours during which the sun was above the horizon was 4454, so that the mean proportion of sunshine for the year was 0·315, constant sunshine being represented by 1.

The rainfall in 1887 was 19·9 inches, being 4·8 inches below the average of the preceding forty-six years.

Good progress has been made with the barometer reductions, 1874–1876, and thermometer reductions, 1869–1876, to fill up the gap in the Greenwich series. The hourly ordinates of barometer and dry and wet bulb thermometers have been read out from the photographic sheets and checked for the whole period. The means have been taken for the barometer and examined for the three years, 1874–1876, with the exception of 8 months in 1875. The means for the dry bulb thermometer have been taken and examined for four years, 1870–1873, with the exception of 3 months in 1871 and 5 months in 1873, for which special examination was required. No means have yet been taken for the wet bulb thermometer.

The barometer results for 1876 (diurnal inequalities in each month) have been supplied to Mr. F. C. Bayard at his request.

Daily readings of the dry and wet bulb thermometers at 7 a.m. for the period 1885 Jan. 1 to 1886 June 30, together with the corresponding direction and force of the wind, have been communicated to Mr. Obach, in connexion with a discussion of the amount of heat abstracted from the human body by cold baths at different seasons.

VI. Printing and Distribution of Greenwich Publications :—

The volume of Greenwich Observations 1885 and the separate copies of the Results were not distributed till last October, although the whole was passed for press before

the end of May. It is understood that the official order for binding was delayed till October through inadvertence.

The printing of the volume for 1886 has fallen somewhat into arrear, notwithstanding every effort on our part, owing to a change in the printer. Good progress has however been made lately by the new printer, and the whole of the volume is now in type, with the exception of the last two and a half sheets of the Astronomical Introduction, the last sheet of the Magnetical and Meteorological Introduction, and the Title Pages and Indexes. Some advance copies of the Spectroscopic and Photographic Results for 1886 have been received. These contain, in addition to the usual observations, Ledgers of Areas and Positions of Sun-spot Groups, and Total Projected Areas of Sun-spots and Faculæ for each day.

As regards the volume for 1887 the proof sheets of the whole of the Altazimuth section have been received. The MS. of the Spectroscopic Observations is in the printer's hands, and the MSS. of the Transits and the Meridian Zenith Distances are ready to be sent off.

VII. Chronometers, Time Signals, and Longitude Operations :—

The number of chronometers now being tested at the Observatory is 154 (111 box chronometers, 19 pocket chronometers, and 24 deck watches), all of which belong to the Navy. The chronometers for the annual competitive trial, which is now held in the latter half of the year, will not be deposited at the Observatory till June 18.

In the year 1887 the average daily number of chronometers being regularly rated was 224, the total number of chronometers received was 717, the total number issued was 642, and the number sent for repair was 315.

Since the date of the last report two competitive trials of chronometers and the annual trial of deck watches have been completed, besides a trial of ten chronometers for the Austrian Government. In the supplementary trial of chronometers, terminating in June last, the first seventeen chronometers were all good and the general standard of excellence was very high, though the somewhat shorter duration of the trial prevents a strict comparison of trial numbers with those in the annual trials. The first chronometer in the annual trial, 1887, was very good indeed, and the next four appear to be fine chronometers. The performance of the first six was decidedly above the average of recent years, though the trial was somewhat more severe than usual as regards range of temperature, the extremes being 37° and 100° Fahrenheit.

For the annual trial of deck-watches, 1887 Nov. 26 to 1888 Feb. 11, 21 watches were entered, and of these nine were purchased for the Navy, the first three being classed "A" or equal in performance (on the 11 weeks' trial) to an average box chronometer.

All pocket chronometers and deck-watches on trial for the Navy, whether for purchase or after repair, are now tested in different positions as well as in the oven.

At Capt. Wharton's request some experiments were made in the latter part of 1887 on a chronometer, the rate of which appeared to be affected by the motion of the ship. It was found that the rate of this chronometer with the gymbals free was different from that with the gymbals fixed, two other chronometers which were tested in the same way for comparison showing no such defect.

In March and April the chronometer books kept at the Admiralty were again compared with those of the Observatory, and the discrepancies rectified.

There has been no failure in the automatic drop of the Greenwich time-ball, but on four days the ball was not raised on account of the violence of the wind.

The automatic drop of the Deal time-ball failed on six days owing to interruption of the telegraphic connections, and on two days high wind prevented the raising of the ball. There has been no case of failure of the 1 p.m. signal to the Post Office Telegraphs.

The return signal from the Devonport time-ball clock (corrected daily by the help of a time-signal from Greenwich) failed on 30 days, 7 of these being Sundays. The apparent error of the signal was under $0^{s}\cdot2$ on 72 per cent. of the days of observation, under $0^{s}\cdot5$ on 88 per cent., between $0^{s}\cdot5$ and $1^{s}\cdot0$ on 9 per cent., and exceeded 1^{s} on 3 per cent. It seems probable that on several of the days when the error exceeded 1^{s} a false signal was observed. A monthly report of the observed times of the return signals is now forwarded regularly to the Hydrographer, and a telegram is at once sent to Devonport whenever the signal is $0^{s}\cdot5$ or more in error.

There have been 23 failures in the automatic signals from the Westminster clock since the date of the last Report. The error of the clock was insensible on 25 per cent. of the days of observation, 1^{s} on 38 per cent., 2^{s} on 20 per cent., 3^{s} on 15 per cent., and 4^{s} on 2 per cent.

Provision has been made in the estimates for the expense of a re-determination of the difference of longitude between Greenwich and Paris, and I have been in correspondence with the French authorities on the subject. The regretted death of General Perrier occurred before any definite plan had been settled, but his successor, M. le Commandant Bassot, has taken the matter up warmly in concert with Admiral Mouchez, and the French Bureau des Longitudes has approved the scheme, which is to include a determination of the longitude of Dunkirk. Three French delegates (M. Loewy, M. Bassot, and M. Defforges) propose to visit Greenwich very shortly to settle the details of the plan of operations which it is intended to carry out in the autumn. In preparation for the work, Mr. Turner and Mr. Lewis have observed for practice, by eye and ear, a number of galvanometer signals sent by another observer and automatically registered on a chronograph, 5 sets of 10 signals having been recorded on each of 7 days.

VIII. Personal Establishment :—

Mr. Wickison, who has been appointed as a Clerk for office work, entered on his duties on 1887 June 1, and has taken charge of the stores and stationery, money accounts and all payments, distribution of the Greenwich publications, and much official correspondence.

There is no change to record in the Staff of Assistants, which is thus constituted, the names in each class being arranged in alphabetical order :—

Chief Assistant—Mr Turner.

First-class Assistants—Mr. Criswick, Mr. Downing, Mr. Ellis (Superintendent of the Magnetic and Meteorological Branch), and Mr. Maunder.

Second-class Assistants—Mr. Hollis, Mr. Lewis, Mr. Nash, and Mr. Thackeray.

Mr. Turner superintends all the work of the Observatory, with full power to act in confidential and other matters during my absence. Mr. Criswick has charge of the transit reductions and miscellaneous astronomical computations, and has during the past year carried out the experiments in stellar photography with the Sheepshanks equatoreal. Mr. Downing is charged with the altazimuth and equatoreal computations, and has the care of the library and manuscripts. Mr. Thackeray undertakes the meridian zenith-distance and zenith-tube reductions and the reading out of the chronograph transits. Mr. Lewis superintends the time-department and chronometers. Mr. Maunder and Mr. Hollis have the charge of the spectroscopic and photographic observations and reductions. In the magnetic and meteorological branch Mr. Ellis superintends the whole of the work, assisted by Mr. Nash, who is specially charged with the meteorological reductions and instrumental adjustments.

Nine computers are attached to the astronomical branch, one to the spectroscopic and photographic, and four to the magnetic and meteorological.

I would take this opportunity of expressing my thanks to the members of the staff for their cordial co-operation with me in carrying on the multifarious duties of the Observatory.

A skilled mechanic has been employed continuously since July 1 on small repairs and general maintenance of the instruments, and, as this arrangement is found to work well, his employment has been definitely sanctioned by the Admiralty.

A gate-porter, a watchman, a gardener, and a foreman of works, with two carpenters and a labourer, complete the establishment.

It may here be mentioned that Mr. Turner, aided by a grant from the Royal Society for adaptation and freight of instruments, went to Russia in August last to observe the Total Solar Eclipse, but did not secure any results owing to cloud.

IX. General Remarks :—

In my last Report it was suggested that the instrumental equipment of the Observatory should be supplemented by a photographic refractor of 13 inches aperture

(equatorially mounted) to enable Greenwich, as the National Observatory, to take its share in the scheme for forming a photographic map of the heavens, and for thus extending our knowledge of the places of the fixed stars. Consequent on the resolution of the Board of Visitors at the last Visitation, I brought this question of the insufficiency of our instruments for the present wants of Astronomy to the notice of the Admiralty and of the Chancellor of the Exchequer, and the matter is still under the consideration of the Government. If the Royal Observatory is to take part in this work of carrying out one of the principal objects for which the Astronomer Royal was appointed it appears to be essential that a decision should be arrived at without delay, in view of the circumstance that 13 observatories (including those of Melbourne and Sydney in our own colonies) have already ordered their instruments, which are to be completed by the end of the present year.

Allusion was made in the last report to the increased demands made on the Observatory in recent years both by the scientific and the general public, and in view of the consequent development of work it now becomes necessary to review the position of the establishment, which was constituted many years ago, when the conditions were very different. In order to understand the difficulty of the present situation it is necessary to bear in mind the following facts:—In 1835 there were 5 Assistants (excluding the Chief Assistant) having no computers to superintend, no extraneous work beyond the care of a relatively small number of chronometers for the Navy, no magnetic and meteorological observations, no altazimuth observations, no spectroscopic and photographic observations. At the present time there are 8 Assistants (excluding the Chief Assistant) having 15 computers to superintend, and of this staff two Assistants are absorbed by the Magnetic and Meteorological Branch, one by the Altazimuth, and two by the Spectroscopic and Photographic Branch, leaving only three Assistants to do the Astronomical work, which in 1835 required five Assistants, and in addition to perform all the extraneous duties which the Astronomer Royal has felt it desirable to undertake in the public interest.

Under these circumstances it becomes a matter for serious consideration whether, unless adequate provision be made for the primary objects of the Observatory, extraneous work, such as the supply of time-signals, may not have to be dropped. The service of hourly time-signals thr ws considerable work on myself and the staff of the Observatory, and, as it is purely voluntary, it appears to me that a condition of its maintenance must be that arrangements shall be made to enable the proper work of the Observatory to be carried on and suitably developed.

W. H. M. CHRISTIE.

ROYAL OBSERVATORY, GREENWICH,
1888 *May* 11.