REPORT

OF

THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1886 *June* 5.

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THE Report here presented refers to the period of twelve months from 1885 May 21 to 1886 May 20, and exhibits the state of the Observatory on the last-named day.

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

As proposed in the last Report a line of 9-inch pipes about 155 feet in length has been laid underground for the ventilation of the Magnet basement, the depth below the surface varying from 5 feet at the lower end in the South Ground to 11 feet 6 inches at the entrance to the basement. Thus the air which is admitted (by means of two branch pipes) into the east and west arms of the basement is warmed in winter and cooled in summer by passage through a considerable extent of soil at nearly constant temperature. A drain for carrying away the waste water used in the photographic operations is laid below the line of ventilating pipes, the latter being carefully isolated from the drain pipes.

Much inconvenience has been felt from the small size of the two Computing Rooms, and though this has been partially met by removing the Spectroscopic and Photographic branch to the New Library, the air-space still seems insufficient, whilst the removal of a part of the establishment to a distant building is not

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altogether satisfactory. The lower Computing Room could be considerably enlarged by including the Quadrant Passage, and the area of the Upper Computing Room could be more than doubled by extending it over the ancient Quadrant Room.

The Transit-Circle Room and the passages in the East Buildings have been painted.

Communication by telephone has been established between the Astronomer Royal's Office and the Magnetic Observatory, a pair of telephones with battery having been supplied by the Post Office for the purpose. A speaking tube has been fixed for communication between the Upper and Lower Computing Rooms.

A portable electric lamp has been purchased for use in examining the interior of clocks and in spectroscopic observations.

The distribution of the transits, altazimuths, photoheliographs and 6-inch equatoreals, purchased for the Transit of Venus 1874, remains the same as at the date of the last Report. It is proposed to use the two Simms equatoreals, the Corbett equatoreal, a photoheliograph and two photoheliograph mountings for observation of the total solar eclipse of August next in the island of Grenada, W. Indies.

A transit hut with canvas roof was erected in the South Ground last summer for the use of Commander Moore and Lieut. Douglas of the Royal Navy, and remains available for any occasional transit observations.

The annual comparison of the books and manuscripts in the Library and Record Room with the catalogue has been made, and all have been found on the shelves, with the exception of three books, for which search is being made.

II. Astronomical Observations :—

Transit-Circle.—New screws made of steel instead of bronze have been supplied by Messrs. Troughton and Simms for the microscope-micrometers, and were brought into use on January 1.

Mr. Turner has recently investigated the discordance between observations for coincidence of the collimators made respectively through the apertures in the cube of the transit-circle and with the instrument raised. A wooden model of the cube was constructed through which the observation could be made when the transit-circle was raised, and it was thus shown that the discordance was due to the cutting off of portions of the object-glasses by the cube, and not to any effect of temperature.

In view of this result it seems desirable that the optical definition of the collimator object-glasses should be thoroughly tested.

A discussion of the collimation-observations made throughout the year 1885 with the reversion-prism shows that for the regular observers the personality depending on the apparent direction of measurement is extremely small. Any possible effect of the kind is eliminated by the method of observation adopted with the reversion-prism. The personality depending on the direction of motion, as deduced from the results of reversed and ordinary transits of clock-stars with the reversion-prism, appears to be more decided, though the amount is small except in the case of one observer.

The Personal Equation Instrument was completed last autumn, but was dismounted during the winter to preserve it from injury in the bad weather. Series of observations have been taken with it on five days, and the results appear to be very satisfactory, the accordance being as close as could be expected. The absolute personal equations thus obtained seem to show that all the observers observe too late, the differences between the several observers agreeing well with the relative personal equations found from observations of clock-stars.

The Sun, Moon, planets, and fundamental stars have been regularly observed during the past year, together with other stars from a working catalogue, containing about 2,750 stars. Good progress has been made in the observation of these stars, in view of the formation at the end of 1886 of a Ten-Year Catalogue, epoch 1880·0. The annual catalogue of stars observed in 1885 contains about 1,250 stars.

The following statement shows the number of observations made with the Transit-Circle in the twelve months ending 1886 May 20 :—

Transits, the separate limbs being counted as separate observations	5685
Determinations of collimation error	306
Determinations of level error	332
Circle observations	5133
Determinations of nadir point (included in the number of circle-observations)	318
Reflexion-observations of stars (similarly included)	530

As regards the computations,—

The transits are corrected for instrumental errors to May 9, and apparent right ascensions are formed to April 30. Star corrections have been computed to March 29 and from April 19 to May 4, but have not been applied to form mean R.A. since 1885 December 31, this part of the reductions having been delayed for the

revision of the adopted proper motions, a work which was found to be desirable and which has only been completed within the last few days. From 1886 January 1, Mr. Stone's tables have been used for computing star-corrections directly, instead of by means of star-constants, and there has been some delay in the printing of the necessary forms.

The investigation of personal equations has been completed for the year 1885. During the past year it has been the practice to observe two clock-stars on each night over the 4 or 6 outer wires by the eye-and-ear method, and over the remaining 9 or 7 close inner wires on the chronograph. The personal equations in eye-and-ear transits thus deduced are nearly the same as those for chronographic transits, except in the case of one observer, for whom the difference amounts to about $0^s \cdot 6$.

The circle observations are reduced so as to exhibit apparent zenith distance (corrected for zenith point) as far as May 15 and apparent N.P.D., corrected for refraction and parallax as far as May 9. Star corrections have been computed to March 29 and from April 19 to May 4, but, for the reason explained above, have not yet been applied since the end of 1885.

The correction for discordance between the nadir observation and the mean of the results from reflexion observations of north and south stars is $-0''\cdot27$ for 1885, as compared with $-0''\cdot36$ for 1884, and $-0''\cdot45$ for 1883. With the new steel microscope-micrometer screws the correction for the first four months of 1886 is $+0''\cdot18$.

The flexure of the transit-circle, as found by means of the collimators, is apparently small. From four determinations made on 1885 July 30, November 25, 1886 February 13, and May 11 (the reversion-prism being used on each occasion) the resulting values are $-0''\cdot08$, $+0''\cdot07$, $+0''\cdot15$, and $+0''\cdot42$, the mean of which is $+0''\cdot14$, agreeing closely with the value $+0''\cdot13$ found by nine accordant determinations in the period 1879 to 1882, and also with the mean of six determinations in 1884–5, whilst differing largely from the value $-0''\cdot49$ derived from five determinations by three different observers in 1883. No correction for flexure (as distinct from the R—D correction) has been applied to the observations since 1879.

The correction for R—D, the error of assumed colatitude, and the position of the ecliptic, have been investigated for 1885. The geocentric and heliocentric errors for the planetary results 1885 are computed, and the preparation of the ledgers of mean R.A. and N.P.D. of stars is on the point of completion.

The values of the correction for discordance between reflexion and direct observations of stars, deduced from observations in 1883, 1884, and 1885, extending over a large range of zenith distance, are remarkably accordant.

Assuming the formula $a + b \sin z$, which represents the observations satisfactorily throughout the whole range, from Z.D. 70° north to Z.D. 70° south, the results are :—

For 1883	. .	$-0''\cdot02 + 0''\cdot69$ sin Z.D.
„ 1884	. .	$-0''\cdot03 + 0''\cdot66$ sin Z.D.
„ 1885	. .	$-0''\cdot02 + 0''\cdot69$ sin Z.D.

The value found for the colatitude from the observations of 1885 is 38°. 31′. 22″·04, differing by 0″·14 from the assumed value; the correction to the tabular obliquity of the ecliptic is +0″·81; and the discordance between the results from the summer and winter solstices is −0″·98, indicating that the mean of the observed distances from the pole to the ecliptic is too great by +0″·49.

The mean error of the Moon's tabular place (computed from Hansen's Lunar Tables with Prof. Newcomb's corrections) is $+0^s\cdot02$ in R.A. and +0″·36 in longitude as deduced from 105 meridian observations in 1885. The mean error in tabular N.P.D. is −0″·58, which would appear to agree with the observations of the Sun in indicating that the mean of the observed N.P.D's is too great.

The results for the azimuth error of the transit-circle since its erection at the end of 1850, have been collected, and monthly and yearly means have been taken. These show on the whole a progressive but somewhat irregular change in azimuth, together with the well-known annual variation. The latter ranges from −4″·2 in March to +3″·4 in August, whilst the progressive change is comparatively small, being at the rate of less than +0″·25 for the first 18 years, during which the Y.'s remained undisturbed. Several changes in the adjustment of the Y.'s have been made since 1870.

Altazimuth.—The observations of the Moon with this instrument have as usual been restricted to the period from last quarter to first quarter in each lunation, the total number of observations of various kinds made in the 12 months ending 1886 May 20 being as follows :—

Azimuths of the Moon and stars	213
Azimuths of the azimuth-mark	146
Azimuths of the collimating-mark	176
Zenith-distances of the Moon	110
Zenith-distances of the collimating-mark . . .	172

The altazimuth observations are completely reduced to March 13, so as to exhibit errors of Moon's tabular R.A., N.P.D., longitude, and ecliptic N.P.D.

On October 16 all the wires were accidentally broken. New wires were inserted on the following day and their intervals determined.

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	4
2^h to 3^h „ . . .	0	6
3^h to 4^h „ . . .	3	11
4^h to 5^h „ . . .	2	9
5^h to 6^h „ . . .	4	5
6^h to 9^h „ . . .	26	5
9^h to 12^h „ . . .	24	—
12^h to 15^h „ . . .	14	—
15^h to 18^h „ . . .	12	1
18^h to 19^h „ . . .	2	5
19^h to 20^h „ . . .	4	6
20^h to 21^h „ . . .	0	4
21^h to 22^h „ . . .	0	3
22^h to 23^h „ . . .	0	1

The whole number of places of the Moon observed with the transit-circle is 90, or 7·0 per lunation.

The Moon's diameter has been measured with the transit-circle twice in R.A. and 13 times in N.P.D., and with the altazimuth once in Z.D.

The reversion-prism has been used during the past year with the altazimuth for investigation of the personality depending on the apparent direction of motion of stars or the Moon. The plan adopted has been to observe a transit over the first three wires with a certain apparent direction of motion and over the last three with the apparent direction of motion changed. A second transit is then observed with the conditions reversed, so that in each double transit there are two sets of observations over the same six wires with the apparent direction of motion different, from which a determination of the personality is obtained by simple subtraction without any calculation of intervals of wires.

The following is a statement of the number of such observations made with the altazimuth reversion-prism up to 1886 May 20 :—

	Moon.		Stars.	
	Chronographic.	E. & E.	Chronographic.	E & E.
Double transits -	195	76	265	106
Nights of observation	13	9	16	15

In these observations horizontal and vertical transits were compared as well as reversed and direct horizontal or vertical. The results show that the personality is in every case small, and that further observations are required to separate it from accidental errors of observation.

Clocks and Chronograph.—The rate of the Sidereal standard clock was much affected by exposure to cold in the course of the work on the ventilation and drain pipes in the Magnet basement, but the clock has gone very steadily since, and it has therefore been thought better not to clean it at present. The chronograph has required cleaning three times since the date of last Report.

A clock synchronized by hourly currents, on Lund's system, has been presented to the Observatory by the Standard Time and Telephone Co., and is fixed in the Astronomer Royal's Office.

Reflex Zenith Tube.—A set of new wires has been inserted, the wires having been accidentally broken. The series of transits for determination of the temperature correction has been concluded and the instrument was rotated to its ordinary position for observation of zenith distances at the beginning of April. Since the date of the last Report 39 transits of γ Draconis over the 30 wires have been observed at temperatures ranging from 52° to 72°.

Equatoreals.—A new plane mirror (silver on glass) has been obtained from Mr. Calver for the Lassell equatoreal, and a wooden screen has been fixed at the eye-end to protect the open end of the tube from the heat of the observer's body, it having been found that the definition was much affected by convection currents at the eye-end, giving rise to an apparent astigmatism which was at first supposed to be caused by tilt of the large mirror. The optical performance appears now to be satisfactory. At Mr. Common's suggestion a frictional connexion between the clock and the driving-screw has been applied so as to allow of the latter being turned in either direction (for slow motion in R.A.) without putting the clock out of

gear. Divisions to every 5^m of R.A. have been painted on the large hour-circle, and an iron handle for turning the instrument in R.A. has been fixed to it.

The South-east, Sheepshanks, and Simms' equatoreals are in good order. A sliding dew-cap has been applied to the last-named instrument.

During the past 12 months, 27 occultations of stars by the Moon (18 disappearances and 9 reappearances), an occultation of Uranus (disappearance and reappearance), and 43 phenomena of Jupiter's satellites, have been observed with one or more of the equatoreals or with the altazimuth. The occultations are reduced to the end of 1885, except the formation of the final equations, and the phenomena of Jupiter's satellites are completely reduced to March 19. Comets have been observed with the Lassell reflector or one of the other equatoreals on 29 nights during the year ending 1886 May 20, viz.: Comet *a* 1885 on 1 night, Comet *c* 1885 on 3 nights, Comet *d* 1885 on 8 nights, Comet *e* 1885 on 11 nights, and Comet *a* 1886 on 6 nights. All the observations of comets have been completely reduced to May 19.

III. Spectroscopic and Photographic Observations:—

The chromosphere and solar prominences have been observed with the half-prism spectroscope on 10 days, the pressure of the photographic reductions having, as in the preceding year, interfered with these observations.

For determination of motions of stars in the line of sight, 378 measures have been made of the displacement of the F line in the spectra of 51 stars, and 21 measures of the *b* lines in 8 stars, besides measures of the displacements of the *b* and F lines in the spectra of Mars and Venus, and of the east and west limbs of Jupiter, and comparisons with lines in the spectrum of the Moon, or of the sky, made in the course of each night's observations of star-motions, or on the following morning, as a check on the general accuracy of the results. The observations of Sirius during the past twelve months indicate, as in the last three years, a displacement of the F line towards the blue (corresponding to a motion of approach), the amount being slightly larger than in the preceding year. Spectroscopic observations were interrupted on a number of nights through deficient supply of water for the driving clock of the south-east equatoreal. After some correspondence with the Kent Waterworks Company it was arranged that the pressure in the Observatory main should not be reduced to so low a point in the evening, and no further trouble with the water supply has been experienced since. The experiments with the Reversion Spectroscope of the Oxford University Observatory (lent by Professor Pritchard) indicate that this form of instrument is well adapted for observation of displacements, provided certain improvements can be effected in

the optical and mechanical parts. The spectrum of Nova Andromedæ was examined on 6 nights, and that of Nova Orionis on 3 nights. Comet *e* 1885 was observed with the spectroscope on 2 nights, and the red star 51 Schjellerup on 1 night.

The spectroscopic observations of all kinds are completely reduced to the present time.

In the twelve months ending 1886 May 20 photographs of the Sun have been taken on 205 days, and of these 410 have been selected for preservation, besides 10 photographs with double images of the Sun for determination of zero of position. There were 12 days on which the Sun's disk was observed to be free from spots.

The areas of both spots and faculæ have shown a marked diminution in 1885 as compared with 1884, the mean daily area for 1885 being in each case only three fourths of that for the previous year. The diminution in the spotted area has taken place principally in the northern hemisphere.

For the year 1885 Greenwich photographs are available for measurement on 208 days, and photographs from India and the Mauritius, filling up the gaps in the series, on 152 days, making a total of 360 days out of 365 on which photographs have been measured. The record has thus been made practically complete for 1885 by means of the Indian and Mauritius photographs.

As regards the photographic reductions:

The Greenwich photographs have been measured in duplicate as far as 1886 April 22, and the measures have been completely reduced so as to exhibit heliographic longitude and latitudes of spots and areas of spots and faculæ as far as April 19.

The photographs from India and the Mauritius have been received from the Solar Physics Committee as far as 1886 February 25, and these have all been measured and the measures completely reduced.

A table of the means of daily areas of spots and faculæ and of the mean heliographic latitude of spots has been formed for each synodic rotation of the Sun and for each year from the commencement of the Greenwich series in 1873 to the end of 1885. The results to the end of 1884 are printed at the end of the Greenwich Spectroscopic and Photographic Results for 1884.

Investigations of the personality in the measurement of areas and positions of spots and faculæ, and of the probable errors of the results have been made, a number of photographs having been specially measured for the purpose by different observers. The discussion will be printed in the Spectroscopic and Photographic Results for 1885.

IV. Magnetical Observations:—

The three magnetometers with which the changes in magnetic declination, horizontal force, and vertical force are photographically recorded, and the earth-current apparatus have been maintained in good working order, the only important interruptions of any of the registers being from 1885 June 30 to July 10 when the clock which drives the declination and horizontal force cylinder was being cleaned, and from 1886 January 5 to 14 when photographic registration in the Magnet basement was suspended during the drainage work. The identity of the earth-current wires has been recently verified and the insulation tested and found quite satisfactory.

The scale of the earth current registers is arranged so that large disturbances can be recorded within the space available on the sheet, a shunt being introduced in each circuit through which the greater part of the current flows without affecting the galvanometer. In order to determine the small diurnal inequality in earth currents, registers on a much larger scale have been taken since the beginning of 1885 on about five days in each month, by removing the shunt and thus increasing the scale about five times.

The corrections to the hourly magnetic results for change of temperature depend on eye observations of thermometers which are intermitted between 3 p.m. and 9 p.m., and between 9 p.m. and 9 a.m. following. In order to check the variations of temperature in these long intervals, a thermograph with metallic tube specially constructed by MM. Richard of Paris was placed in the basement at the beginning of February, and has been used for continuous record of temperature since that time.

As regards the magnetic reductions, the eye-observations of the upper declination magnet and of the horizontal and vertical force magnets are completely reduced to the end of 1885. The time-scales for declination, horizontal force, and vertical force are complete to the end of 1885, and the base-line values, deduced from the eye-observations, are entered on the photographic sheets.

The hourly ordinates of the photographic curves are read out to the end of 1885 for all three magnets, and the daily and hourly means are taken for declination and horizontal force. The time-scales for the earth-currents are laid down to the end of 1885. The dip observations are completely reduced to the present time, and the deflexion observations for absolute measure of horizontal force to the end of 1885.

Further experiments for determination of the temperature corrections for the horizontal and vertical force magnets by alternately warming and cooling the basement on successive days, were made in the spring of this year, a continuous

record of the temperature being obtained by means of the Richard thermograph. The following are the results thus obtained in 1885 and 1886 as compared with the previous determinations, the apparent changes for 1° of temperature being expressed in terms of the horizontal force and vertical force respectively :—

For 1° Fahrenheit increase of temperature.	1868.	1885.	1886.
Apparent decrease of horizontal force	·00018	·00026	·00021
	1882.	1885.	1886.
Apparent increase of vertical force	·00020	·00022	·00020

The following are the principal results for magnetic elements for 1885 :—

Approximate mean declination . . . 18°. 2′ west.

Mean horizontal force . . . . . { 3·9376 (in English units). 3·8156 (in Metric units).

Mean dip . . . . . { 67° 27′ 28″ (by 9-inch needles). 67. 27. 32 (by 6-inch needles). 67. 28. 27 (by 3-inch needles).

In the year 1885 there were only three days of great magnetic disturbance, but there were also about 20 days of lesser disturbance for which it may be desirable to publish tracings of the photographic curves. It is proposed to add tracings of the registers on four quiet days to serve as types of the ordinary diurnal movement at four seasons of the year, as was done for 1884.

In the Magnetical Results for 1884 a table has been added showing for declination, horizontal force, and vertical force, the difference between the greatest and least hourly mean values in each month, and also the numerical sums of the deviations of the 24 hourly values from the mean, taken without regard to sign.

The results of Greenwich determinations of absolute magnetic declination, horizontal force, and dip from 1841 to 1884 have been communicated to M. Moureaux of the Bureau Central Météorologique, Paris, for investigation of the secular changes of the magnetic elements in connection with the preparation of a new magnetic chart of France.

V. Meteorological Observations :—

All the meteorological instruments, including the Thomson electrometer for continuous record of atmospheric electricity, are in good order. Continuous registers

of barometer, dry and wet bulb thermometers, direction, pressure, and velocity of wind, rain, sunshine, and atmospheric electricity have been obtained with very few interruptions throughout the past twelve months. The barometer register was suspended from January 5 to 14 during the drainage work in the Magnet basement, and from October 22 to November 3 the continuous register with Osler's anemometer was interrupted while the driving clock was being cleaned, a partial record being however obtained by moving the sheet by hand from time to time, supplemented by frequent eye-observations.

The new photographic thermometer apparatus in the South ground has been brought into use, and from the beginning of this year a series of daily records has been obtained with it for comparison with the old apparatus. In mounting this instrument special pains have been taken to protect the thermometers from radiation without interfering with the free circulation of air.

Thermometers have been mounted in an exposed situation on the platform above the Magnet House, at a height of 20 feet above the ground for eye-observations of temperature at the regular hours and for record of daily maximum and minimum temperatures. The thermometers, which have been in use from the beginning of this year, are placed in a louvre-boarded shed or screen so constructed as to give free circulation of air with protection from radiation. A comparison of the observations obtained up to the end of April with those of the standard thermometers in the Magnet ground shows that the diurnal range of temperature for the latter is generally greater than for the thermometers on the roof of the Magnet House.

The scale for pressure of the wind for Osler's anemometer was re-determined last July. The experiments give a somewhat more open scale on the paper than the previous determination.

A new sunshine recorder of Professor Stokes's improved pattern, as adopted by the Meteorological Council, is being made for the Observatory by Mr. Lecky.

The observations of temperature of the Thames made at the Deptford Cattle Market are regularly communicated to the Royal Observatory for publication in the Registrar-General's Weekly Reports.

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 1885. The hourly ordinates are read out for the dry and wet bulb-thermometers to the end of 1885 and for the electrometer to 1885 July. The table of principal changes of direction of the wind has been prepared for 1885.

The mean temperature of the year 1885 was 48°·6, being 0°·7 lower than the average of the preceding 44 years. The highest air temperature (in the shade) was 90°·2 on July 26, and the lowest 22°·3 on Jan. 22. The mean monthly temperature was above the average in February and July, and below in January, March, May, August to October, and December. As regards the long-continuing cold weather this spring :—The mean temperature for the whole period 1886 January 5 to March 18 was 33°·8, being 5°·9 below the average; for the period February 1 to March 18, 33°·2, 6°·9 below the average; and for the period March 1 to 18, 32°·6, 8°·2 below the average. The mean temperature for the month of February was 33°·7, which thus compares with the previously recorded low temperatures for the same month in other years:—1845, 32°·7; 1853, 33°·3; 1855, 29°·1; 1858, 34°·6; 1873, 34°·3. The lowest temperature recorded this spring was 16°·5 on 1886 January 7.

The mean daily motion of the air in 1885 was 287 miles, being 3 miles greater than the average of the preceding 18 years. The greatest daily motion was 704 miles on Jan. 11, and the least 71 miles on Nov. 12 and Dec. 26. The only recorded pressure exceeding 20 lbs. on the square foot in 1885 was 22·5 lbs. on Jan. 10.

During the year 1885 Osler's anemometer showed an excess of about 32 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 by Campbell's sunshine instrument during 1885 was 1261, which is about 60 hours more than the average of the preceding eight 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 0·283, constant sunshine being represented by 1. A register of sunshine has also been regularly obtained from the beginning of June to the end of December last year with Jordan's sunshine recorder. A comparison of the results with the two instruments for the month of June 1885 shows 222 hours of sunshine registered by Jordan's recorder, and 212 hours by Campbell's.

The rainfall in 1885 was 24·0 inches, being 0·8 inch below the average of the preceding 44 years.

VI. Printing and Distribution of the Greenwich publications :—

The volume of Greenwich Observations 1883 and the separate copies of Results were distributed last September, after considerable delay at the binder's. The whole of the volume for 1884 has been passed for press, with the exception of the Transit-Circle tables at the end of the Introduction, of which the proof sheets have been revised.

The separate copies of the Magnetic Diagrams 1841–1876 by Sir G. B. Airy, forming the Appendix to the Greenwich Observations 1884, were distributed in April last.

As regards the volume for 1885, the proof sheets of the whole of the Altazimuth section, of the Spectroscopic Results, and of the Photographic Results as far as Feb. 8 have been received. The MSS. of the Transits, Meridian Zenith Distances and Photographic Results to the end of April are in the printers' hands.

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

The number of chronometers now being tested at the Observatory is 115, and of these 81 (59 box-chronometers, 9 pocket-chronometers, and 13 deck-watches) belong to the Navy, the remaining 34 being placed here for the annual competitive trial. The number of chronometers entered originally for this year's trial was 37, but three of these, which had taken a high place in last year's trial, were purchased by the Admiralty in February, and consequently withdrawn from the trial.

The first six chronometers in the competitive trial of 1885 were slightly below the average of the last ten years, as inferred from the trial numbers.

Mr. Kullberg's apparatus for automatically regulating the temperature of the chronometer oven has been in use since last November, and is perfectly successful in maintaining the temperature constant within narrow limits. A double casing packed with a non-conducting material (slag-wool) has been applied to the sides and top of the chamber, and this is found to contribute materially to constancy of temperature in the oven.

As the termination of the annual trial falls at an inconvenient part of the financial year for the purchase of chronometers, it has been decided to make the trial commence in future on the first Saturday in July, so that it would end in the latter part of January. The temperature conditions in the room will be practically the same as at present, but in reverse order, commencing with warm weather and ending with cold. The rating is to be for 29 weeks, viz., three periods of 7 weeks each in the room and two periods of 4 weeks each in the oven.

It is proposed also to have an annual trial of deck-watches for purchase by the Admiralty. The first trial is to commence on November 27 this year, and end on 1887 January 22 ; the deck-watches to be tried for two periods of 2 weeks each in the room at a mean temperature of 50° to 55°, and for one period of four weeks in different positions in the oven at a temperature of about 85°.

The automatic drop of the Greenwich time-ball failed on 2 days during the past twelve months, on one occasion through accumulation of snow on the mast, and on

another through failure in the clock-work apparatus for daily reversal of the currents through the electro-magnets. This apparatus has since been removed, and the direction of the currents is now reversed by hand once a week. On one day the ball was not raised on account of the violence of the wind.

As regards the Deal time-ball, there have been 7 cases of failure owing to interruption of the telegraphic connections, and on 3 days the violence of the wind prevented the raising of the ball. There have been three cases of failure of the 1 p.m. signal to the Post Office.

No further action has been taken as regards the establishment of hourly time-signals at the Lizard or Start, as the arrangements for preliminary trial of a collapsible cone at Devonport are not yet completed. One of the Transit of Venus clocks (Dent 2010) has been adapted by Messrs. E. Dent and Co. to give hourly time-signals, and to be synchronized by the help of an auxiliary seconds' pendulum on the plan I proposed in the last Report.

The contact apparatus of the Westminster Clock having been out of order, no signals have been received during the past twelve months. New contact apparatus of improved construction is now being fitted.

The longitude of Gibraltar was determined last year under Capt. Wharton's direction, by exchange of telegraphic signals on August 8, 9, and 12 between Greenwich and Gibraltar, the Eastern Telegraph Co. having courteously given the free use of their telegraph cable for the purpose. The signals were transmitted by relay-action from the ends of the cable to the observing stations at Greenwich and Gibraltar. Local time was determined at Gibraltar by the officers of H.M.S. "Sylvia" with the sextant, and at Greenwich by Commander Moore and Lieut. Douglas by means of sextant observations, and also by transits with the transit-circle. In connection with this determination a large number of observations of signals were made at Greenwich for determination of the personal equations of the different observers in observing telegraph signals. At Greenwich the longitude signals were observed by five observers independently. Commander Moore and Lieut. Douglas made a series of observations at Greenwich last summer for comparison of the relative value of determinations of local time made with a sextant and with a small transit instrument respectively.

VIII. Personal Establishment:—

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:—

Mr. Turner, Chief Assistant;

Mr. Criswick, Mr. Downing, Mr. Ellis, and Mr. Maunder, First-class Assistants;

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

As regards the duties of the establishment:—

Mr. Turner superintends generally all the work and has charge of the Observatory in my absence.

In the Astronomical branch, Mr. Criswick superintends the transit reductions and miscellaneous computations; Mr. Downing is charged with the altazimuth and equatoreal computations, and with the care of the library and MSS.; Mr. Thackeray undertakes the circle and zenith-tube reductions and the reading out of chronograph transits; and Mr. Lewis manages the business relating to chronometers, time-signals, money accounts, and stores.

In the Spectroscopic and Photographic branch, Mr. Maunder and Mr. Hollis superintend all the reductions.

In the Magnetical and Meteorological branch, Mr. Ellis controls the whole of the work, Mr. Nash being specially charged with the meteorological reductions and instrumental adjustments.

There are besides eight or nine computers attached to the Astronomical branch, two to the Spectroscopic and Photographic branch, and four to the Magnetical and Meteorological branch.

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

IX. General Remarks:—

The record of the past year shows that the work in all branches tends to increase. This increase could not well be resisted without impairing the efficiency of the Observatory, but year by year it causes more pressure on our limited staff, which, in addition to scientific work, is charged with the ever-increasing duties of a Government Office. In this connection I may mention that a good deal of my own time, as well as that of the Chief Assistant, has lately been occupied with various matters connected with the Navy, reference having been made to me on the subject of gun-directors, mirrors for electric search-lights, and binoculars, in all of which there are involved questions requiring careful consideration.

Commencing with the year 1885, Greenwich civil time, reckoning from midnight to midnight and counting from 0 to 24 hours, has been adopted in the Spectroscopic and Photographic Results as well as in the Magnetical and Meteorological. It is proposed to defer the introduction of this time-reckoning into the Astronomical Results till the year 1891, for which year the Board of Visitors have recommended its adoption in the Nautical Almanac. In an Observatory such as this, where

observations of various classes are carried on, there is, however, considerable inconvenience in the retention of the present astronomical day, which now involves the use of two systems of reckoning mean solar time in the same establishment.

The construction of an object-glass of 28 inches aperture and of 28 feet focal length, with suitable tube, to be mounted on the South-east Equatoreal, has been authorised by the Government, and the necessary funds have been provided in the estimates. The work has been entrusted to Mr. Grubb, with whom I have arranged the details of the tube, which is to be of special construction, adapted to the conditions of the mounting, and available for spectroscopy and photography as well as for eye-observations. Mr. Grubb proposes to provide means for readily separating the lenses of the object-glass to such a distance as will give the proper correction for photographic rays. Messrs. Chance are engaged in the manufacture of the glass for the lenses, and have already made a flint disk, which promises to be very satisfactory.

In view of the recent development of astronomical photography, I propose to have constructed, for use with the present $12\frac{3}{4}$ inch refractor of the South-east Equatoreal, a combination of a convex flint and concave crown lens, which, when placed about 2 feet within the focus, would correct the chromatic aberration of the object-glass for the photographic rays without alteration of the focal length. If this plan succeeds, the instrument would then be well adapted for photography, thanks to the firmness of its mounting and the excellence of its driving clock.

W. H. M. CHRISTIE.

Royal Observatory, Greenwich,
1886 *May* 21.