REPORT

OF

THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1897 *June* 5.

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The Report here presented refers to the year from 1896 May 11 to 1897 May 10, and exhibits the state of the Observatory on the last-named day.

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

The building of the North wing and Central Dome of the Physical Observatory was finished in 1896 September, with the exception of the vane on the Central Dome, which was completed last March, but the office furniture was not all supplied till April, and it has therefore been necessary to postpone the occupation of the rooms till the present time. An observing floor and gallery have quite recently been fitted up in the Dome to facilitate work with the new Thompson Equatorial, now mounted there. The completion of the Physical Observatory by the building of the East and West wings has been further delayed, though provision was made for commencing the work in the last financial year. It is hoped that it will now be taken in hand, the necessary funds having been provided. Until this building is completed the arrangements for the accommodation of the staff and of the photographic and other records are necessarily provisional.

The selection of a site in Greenwich Park for the Magnetic Pavilion has given much trouble, owing to the difficulty of finding a suitable position free from any suspicion of disturbance from iron. It has been found necessary to select a site at a greater distance from the Observatory than was originally contemplated, and, after a series of observations had been made at different stations, mainly to determine the disturbing effect of the mass of iron in the Reservoir to the South of the Observatory, a site which appears to be in every respect suitable has been found on the East side of the Observatory at a distance of between 300 and 400 yards. [This site has been approved by H.M. Office of Works, since the date of this Report.]

The observing floor and moveable roofs over the collimators of the new Altazimuth, the supplementary chronometer oven, and the water tank on the flat of the lobby of the 36-foot dome for the supply of water to the driving-clock of the Great Equatorial, which were in progress at the time of the last Report, were completed in September.

Provision has been made in the Navy Estimates for extending the electric light installation to the completed portion of the Physical Observatory and to the new Altazimuth Pavilion.

The construction of the proposed balcony to give an all-round view of the sky from the building in which the 28-inch telescope is mounted has now been sanctioned.

The principal moveable instruments are thus distributed :—

At Greenwich—

Transits B, D, E, and the transit with axis view.

Altazimuth D.

Equatorials (6-inch).—Cooke No. 2; Simms No. 1; Hodgson and Corbett. (The telescopes are mounted respectively on the Thompson and 28-inch Equatorials.)

Photoheliographs.—No. 3, complete, mounted on the terrace roof of the South wing of the Physical Observatory for daily photography; the tube of No. 2, and the driving clock (in use for the Personal Equation Machine).

Detached Telescopes (on tripod stands).—One 4-inch (Simms No. 1), two 4-inch (R.O. Nos. 1 and 2), two $3\frac{1}{2}$-inch (R.O. Nos. 3 and 4).

Two Hilger Chronographs.

A single prism Spectroscope.

On loan—

Transits.—A, at the Cape Observatory; C, at Montreal.

Altazimuths.—A, at the Science Schools, South Kensington; B, at the Cape Observatory; E, at the Royal Naval College, Greenwich.

Equatorials.—Lee (6-inch) at Hong Kong Observatory; Simms No. 2 (6-inch), lent to the Science and Art Department.

Photoheliographs.—No. 1, complete, at the Cape Observatory; No. 5, complete, and No. 2 (without the driving clock), lent to the Science and Art Department; the object-glass of No. 2 lent to Professor Turner for observation of the Solar Eclipse of 1896 August 9; No. 4, complete, at the Madras Observatory.

Detached Telescope.—Simms No. 2 (4-inch) lent to Mr. Maunder for the Solar Eclipse of 1898 Jan. 22.

Clocks.—Dent No. 1916, and Dent No. 2013, at the Cape Observatory; Dent No. 2011, at the Kew Observatory; Dent No. 2010, at Devonport; and Arnold 2, at the University Observatory, Oxford.

Anemometer.—Whewell's Anemometer, formerly (1843–1862) mounted above the roof of the Octagon Room of the Royal Observatory, lent for exhibition at South Kensington Museum.

The Spectroscope lent to Mr. Maunder for the Solar Eclipse of 1896, and the Hilger Chronograph lent to the Oxford University-Observatory have been returned.

The annual comparison of books in the Libraries with the catalogue has been made, and 9 books are reported missing. Two of the books reported missing last year have since been found. It is probable that some of the books now missing have simply been misplaced, the shelves being in a very crowded state.

II.—Astronomical Observations :—

Transit-Circle.—The Sun, Moon, planets, and fundamental stars have been regularly observed on the meridian as in previous years. The number of observations made from 1896 May 11 to 1897 May 10, is as follows :—

Transits, the separate limbs being counted as one observation	11,963
Determinations of collimation error	305
Determinations of level error	673
Circle observations	10,421
Determinations of nadir point (included in the number of circle observations)	643
Reflexion observations of stars (similarly included) . .	509

The annual catalogue of stars observed in 1896 contains 3454 stars.

Some of the wires of the transit-circle were found broken on July 9 and again on March 8, and new wires were inserted by Messrs. Troughton and Simms.

As regards the computations :—

The transits are completely reduced (so as to exhibit Mean R.A. 1897·0) to March 28. The whole of the copy for press of the transits for 1896 is in the printer's hands.

The investigation of personal equations is completed for 1896. In January 6 sets of observations were made with the personal equation machine for determination of personality in observations of limbs of the Sun and Moon, and these observations as well as the 29 sets made last year are fully reduced.

The circle observations are completely reduced to March 30. The whole of the copy for press of this section for 1896 is in the printer's hands.

The apparent correction for discordance between the nadir observations and stars observed by reflexion for 1896 was found to be $-0''\cdot44$. The results of previous years are as follows :—

1888	$-0''\cdot12$	1892	$-0''\cdot25$
1889	$+0''\cdot07$	1893	$-0''\cdot34$
1890	$+0''\cdot08$	1894	$-0''\cdot27$
1891	$+0''\cdot07$	1895	$-0''\cdot31$

The increase in this discordance in 1896, following on the systematically negative values since 1891, led to a re-examination of the screws of the microscope-micrometers, of the screw of the telescope-micrometer, and of the errors of those divisions of the circle which are used in observations of the nadir, with a view to the discovery of the source of this discordance.

The microscope-micrometers showed signs of wear, but the reversal of three of the screws has successfully eliminated the effect of wear from the mean of the six microscopes. The errors of the mean readings, as determined in 1886 when the screws were new, in 1893, and in 1896 November are as follows :—

Error of the Mean of the Six Screws in	Revolutions of the Screw.							
	9^r	0^r	1^r	2^r	3^r	4^r	5^r	6^r
	$''$	$''$	$''$	$''$	$''$	$''$	$''$	$''$
1886	$-0\cdot13$	$-0\cdot07$	$+0\cdot03$	$-0\cdot06$	$+0\cdot06$	$0\cdot00$	$-0\cdot06$	$+0\cdot10$
1893	$-0\cdot29$	$-0\cdot11$	$-0\cdot11$	$+0\cdot03$	$-0\cdot03$	$0\cdot00$	$-0\cdot09$	$-0\cdot11$
1896	$-0\cdot14$	$-0\cdot02$	$-0\cdot10$	$+0\cdot02$	$-0\cdot02$	$+0\cdot10$	$-0\cdot04$	$-0\cdot19$

It appears that the errors are practically insensible for the range of screw (0^r to 5^r), to which the observations are ordinarily confined.

The screw of the telescope-micrometer showed considerable wear. This screw is most frequently used near the reading 20^r, the large majority of bisections made with the micrometer lying between 18^r and 22^r; though for a considerable number of observations, especially of reflexion observations, for which the telescope is clamped before the star is in the field, a wider range of the screw is used. When the screw was new in 1891 it was sensibly uniform, and the value of one revolution was found to be $37''\cdot05$.

Corrections to this adopted value were determined as follows :—(i.) The values of the 8 revolutions (approximately $5'$) from 12^r-20^r, 16^r-24^r, 20^r-28^r were measured on the circle, the instrument being pointed on the nadir or one of the

collimators. (ii.) The intervals 12^r-16^r, 16^r-20^r, 20^r-24^r, 24^r-28^r were compared with a definite length ($6^r{\cdot}0$ of the micrometer screw) on the south collimator. (iii.) The intervals 16^r-18^r, 18^r-20^r, 20^r-22^r, 22^r-24^r were similarly compared. (iv.) The single revolutions between 16^r and 24^r were similarly compared.

The combination of these observations gave the following corrections to be applied to the adopted equivalents of the readings of the screw :—

12^r	16^r	17^r	18^r	19^r	20^r	21^r	22^r	23^r	24^r	28^r
$+1''{\cdot}39$	$+0''{\cdot}80$	$+0''{\cdot}52$	$+0''{\cdot}35$	$+0''{\cdot}16$	$0''{\cdot}00$	$+0''{\cdot}02$	$+0''{\cdot}07$	$+0''{\cdot}20$	$+0''{\cdot}32$	$+1''{\cdot}10$

These corrections have been applied to the observations made in 1896 whenever the amount of the correction was greater than $0''{\cdot}10$, and to all observations made in 1897.

The application of this correction has reduced the discordance between the nadir and reflexion observations from $-0''{\cdot}44$ to $-0''{\cdot}34$.

A re-determination of the division-errors was made for the 5′ divisions which are used in observations of the nadir and a determination of those used in observations on the collimators (for flexure and for intervals of the telescope-micrometer). The division error corresponding to pointer reading 179° 40′, which is sometimes used in nadir observations, was found to be $0''{\cdot}42$, instead of $0''{\cdot}52$, the value previously used, but the division error corresponding to pointer reading 179° 35′, which is more frequently used, was found to be $0''{\cdot}37$, agreeing exactly with the previous determination.

The discordance between the nadir and reflexion observations is further reduced from $-0''{\cdot}34$ to $-0''{\cdot}26$ if only those observations of the nadir are used which are made at approximately the same time as the reflexion observations. On 84 days in 1896 three or more observations of the nadir were made, and dividing these into three groups according to the time at which they were taken, the following changes of the zenith-point are shown :—

Civil time	9^h—15^h	15^h—21^h	21^h—3^h
	$+0''{\cdot}20$	$0''{\cdot}00$	$+0''{\cdot}16$

while 54 days between 1895 July and 1896 January, give—

$+0''{\cdot}29$	$0''{\cdot}00$	$+0''{\cdot}27$

A more extensive series of observations is required before reliance can be put on the systematic nature of these results.

The correction for R—D, the error of the assumed colatitude, and the position of the ecliptic have been investigated for 1896 ; and the whole of the planetary reductions are complete.

The correction for R—D, $+0''\cdot056+0''\cdot367$ sin Z.D., agrees closely with the correction obtained last year, and is decidedly smaller than the results of previous years. The observations of zenith distance of pairs of stars directly and by reflexion, alternately on alternate nights, have been continued, and 65 pairs have been observed in the year ending 1897 May 10. The following table gives a comparison of the R—D discordance for different Zenith Distances obtained by combining these results with those of the previous year.

Mean Z.D.	R. observations taken immediately before D.	R. and D. observations on different nights.	No. of pairs of observations on different nights.
$-5^{\circ}8$	$-0''\cdot50$	$-0''\cdot25$	32
-51	$-0''\cdot39$	$-0''\cdot40$	23
-29	$-0''\cdot17$	$-0''\cdot16$	29
$+21$	$+0''\cdot38$	$+0''\cdot24$	15
$+37$	$+0''\cdot51$	$+0''\cdot60$	68
$+49\frac{1}{2}$	$+0''\cdot64$	$+0''\cdot34$	32
$+57\frac{1}{2}$	$+0''\cdot70$	$+1''\cdot04$	41

The colatitude of the transit-circle as found from the observations of 1896 is $38^{\circ}\ 31'\ 21''\cdot83$, differing by $-0''\cdot07$ from the adopted value.

The correction to the tabular obliquity of the ecliptic from solar observations in 1896 is $-0''\cdot07$. The discordance between the results from the summer and winter solstices is $-0''\cdot02$, indicating that the mean of the observed distances from the pole to the ecliptic is too large by $0''\cdot01$. The apparent correction from the observations of the Sun to the right ascensions of the clock stars is $+0^{s}\cdot040$. As in past years the readings of the standard meteorological thermometer have been used for reducing observations of the Sun for the year 1896; but since 1897 January 1, a thermometer which was mounted in a screen in the Front Court on July 18 has been used for all observations, including those of the Sun. Comparisons of this thermometer with the exterior thermometer previously in use, were made from July 18 to December 31, both thermometers being read simultaneously at frequent intervals by the transit-circle observer. The front court thermometer generally reads higher than the north wall thermometer in the day and lower in the night.

The mean error of the Moon's tabular place (computed from Hansen's lunar tables with Newcomb's corrections) is $-0^{s}\cdot079$ in R.A. and $+0''\cdot32$ in N.P.D. deduced from 121 observations. These are equivalent to an error of $-0''\cdot98$ in longitude and $+0''\cdot20$ in ecliptic north polar distance.

The preparation of the New Ten-Year Catalogue of Stars 1887–1896 is making good progress. The Mean R.A. and N.P.D. for all the years have been entered on separate sheets for each star, and the precessions and secular variations have been computed in duplicate.

As stated in the last Report the programme of observations with the transit-circle for the next ten years 1897–1906 will include determinations of accurate places of all stars down to the 9th magnitude inclusive within 26° of the Pole, in addition to the observations of Sun, Moon, Planets and Fundamental Stars. A working Catalogue has been prepared giving the Right Ascension and North Polar Distance of these stars for 1900 with sufficient accuracy for the computation of Star-corrections.

Altazimuth.—The total number of observations made in the year ending 1897 May 10 is as follows :—

Azimuths of the Moon and Stars	229
Azimuths of Mark I.	113
Azimuths of Mark II.	110
Zenith distances of the Moon	108
Zenith distances of Mark I.	104
Zenith distances of Mark II.	110

The observations have been completely reduced as far as 1897 March 29.

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.
12^h to 13^h civil time . . .	0	0
13^h to 14^h ,, . . .	0	6
14^h to 15^h ,, . . .	0	7
15^h to 16^h ,, . . .	1	7
16^h to 17^h ,, . . .	2	6
17^h to 18^h ,, . . .	3	4
18^h to 21^h ,, . . .	20	1
21^h to 0^h ,, . . .	25	—
0^h to 3^h ,, . . .	16	—
3^h to 6^h ,, . . .	21	1
6^h to 7^h ,, . . .	7	10
7^h to 8^h ,, . . .	4	4
8^h to 9^h ,, . . .	2	6
9^h to 10^h ,, . . .	0	2
10^h to 11^h ,, . . .	0	1
11^h to 12^h ,, . . .	0	0

The total number of places of the Moon observed with the transit-circle is 101 or 7·6 per lunation, and with the altazimuth 55 or 4·4 per lunation.

The Moon's diameter has been measured with the transit-circle twice in R.A. and 20 times in N.P.D.

The new *Altazimuth* was erected in May 1896, but it was not practicable to make observations with it till the completion of the observing floor in September. It was then found that there were serious discordances in the readings of the circles under the different microscopes, depending on the direction in which the instrument was last turned. Experiments made under Mr. Simms' direction indicated flexure in the axis, which varied with the position of the telescope, and this has now been corrected by stiffening the axis by means of a strong diaphragm of special form fitted in the central part of the axis. The friction-rollers for taking the weight of the instrument have also been modified, the position being changed to bring them close to the pivots, and a system of levers has been substituted for springs. These changes did not altogether remove the discordances, but they reduced them greatly in amount. Quite recently Mr. Simms has discovered in a transit-circle of similar construction, made for the new Perth Observatory, West Australia, an entirely unsuspected cause of error, arising from a tendency in the pivots to act as a screw, a longitudinal force being thus introduced, its direction depending on the direction in which the telescope is turned. This force had the effect of slightly moving the iron standards carrying the bearings and the microscopes, thus changing the position of the microscopes relatively to the graduated circles. This action of the pivots was found to arise from the method adopted in grinding them of giving a helical twist to the grinder, and it was cured by a few circular turns of the same tool. [During the preparation of this Report Mr. Simms has found that there was the same fault in the pivots of the new Altazimuth, which he has now cured, and it is confidently hoped that the difficulties which have delayed regular work with this instrument will now be overcome.]

Clocks and Chronographs.—The Standard Sidereal clock dropped 4 seconds on October 10 and on October 21 was found to be stopping. The contact springs were released but without effect. The pendulum was started again and the clock has since gone satisfactorily.

The electric dials sympathetic with the Mean Solar clock and used in the various rooms of the Observatory are being reconstructed, a single armature being substituted for an oscillating magnet, and one battery being used instead of two. All the dials with the exception of the Gate Clock and the dial in the Ball Lobby are now worked on the new system. Four electric dials have been purchased for use in the new Physical Observatory.

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

Equatorials.—Since the date of the last Report, 14 disappearances and 5 re-appearances of Stars occulted by the Moon have been observed. The occultation of Jupiter and his Satellites by the Moon was observed by six observers on 1896 June 14. 40 phenomena of Jupiter's Satellites have also been observed.

Comet *b* 1896 (Swift) was observed with the Sheepshanks Equatorial on 8 nights and Comet *f* 1896 (Perrine) on 4 nights.

Thompson Equatorial.—This new instrument, presented by Sir Henry Thompson, has been mounted in the Physical Observatory under the Lassell Dome. Its erection there was commenced early in November, but it was not ready for use till April, and there are still certain accessories which have to be supplied. The adjustment of the polar axis and of the 26-inch object-glass were at once taken in hand and the former was soon satisfactorily effected. For the adjustment of the object-glass a number of photographs have been taken inside and outside of the focus, the separation between the lenses being varied with a view to the correction of the small outstanding aberration and coma. Some photographs of the Moon and of double stars have been taken, an enlarging camera with a Dallmeyer concave magnifier being applied to the telescope in some cases to give a magnified image. This Equatorial carries not only the 26-inch photographic telescope with the $12\frac{3}{4}$-inch Merz guiding telescope and the Thompson 9-inch Photoheliograph, but also a Cassegrain reflecting telescope of 30 inches aperture with the 6-inch Hodgson telescope as guider in place of the counterpoise at the other end of the declination axis. It thus provides a very powerful combination of telescopes specially adapted to photographic work of various kinds, and special arrangements in the instrument and observing room have been necessary to meet the varied requirements. The instrument has now been got into good working order and is very satisfactory as regards the mechanical arrangements. The photographic spectroscope mentioned in previous Reports will be used in connection with the Cassegrain Reflector mounted firmly at the back of the cell of the mirror, a diagonal prism being used to reflect the rays into the collimator.

The 28-inch Refractor.—This instrument was in constant use for micrometric measurements from 1896 May 11 to 1897 January 11. On January 12 the crown lens was reversed and the instrument used for photography till April 23, except on the occasion of Prof. Barnard's visit to the observatory (February 17) when the lens was

replaced in the visual position. Since April 23 micrometric observations have been continued. In the year ending May 10, 195 double stars have been measured, each star being measured on the average on 2 nights; the distance between the components of these stars is in 110 cases less than 1″·0 and in 45 less than 0″·5. The distance and position-angle of the satellite of Neptune were measured on 4 nights and the equatorial and polar diameters on 2 nights. The equatorial and polar diameters of Mars were measured on 7 nights. With the crown lens in the reversed position, a number of photographs have been taken in and out of focus for the better adjustment of the separation of the lenses and the tilt; photographs have also been taken of the Moon and of the following double stars :—

	Magnitudes.	Distance.
		″
Castor	2·7 and 3·7	5·8
ξ Ursæ Majoris ...	4·0 „ 4·9	2·0
γ Leonis	2·0 „ 3·5	3·6
Σ 1606	6·3 „ 7·0	1·1
ζ Cancri	5·0, 5·7 and 5·5	1·0 and 5·3
Σ 1877	3·0 and 6·3	3·1

These photographs show that the photographic correction of the object-glass by separation of the lenses and reversal of the crown is quite successful, and further, that certain classes of double stars can with advantage be observed photographically rather than visually.

Astrographic Equatorial.—As the work of the photo-mapping of the heavens approached the Pole, the change of orientation of the plates resulting from the errors of collimation and inclination of the declination axis of the equatorial introduced difficulties which it was desirable to correct mechanically. From measurements of trails of stars near the Pole and Equator and in reversed positions of the telescope it was found that these errors were each $-6'$; they were eventually reduced on December 15 each to $+0'{\cdot}6$—one-tenth of the original amount—by the insertion of thin plates of copper between the cradle of the telescope and the declination axis, and in the cube of the cross-head.

During the year ending 1897 May 10, 348 plates have been taken on 117 nights. Of these 69 have been rejected, viz. :—7 because the images were too faint to show 9th magnitude stars with a 20^s exposure; 18 because the exposure was interfered with by clouds; 15 for mistakes in setting; 5 because the plates were partially fogged; 2 for faults in development; 3 because the reticules were not clearly printed, and 19 for miscellaneous defects.

The following statement shows the progress made with the photo-mapping of the heavens :—

	For the Chart (Exposure 40ᵐ).	For the Catalogue (Exposures 6ᵐ, 3ᵐ and 20ˢ).
Number of Photographs taken	175	139
,, successful plates	135	110
,, fields photographed successfully .	133	98
Total number of successful fields reported 1896 May 10	490	732
Number of photographs, previously considered successful, rejected during year . . .	72	16
Total number of successful fields obtained to 1897 May 10.	551	814
Number still to be taken	598	335

Trails have been taken on 97 of the 139 catalogue plates as a check on the orientation.

A number of miscellaneous photographs (included in the total number of 348 given above) have also been taken :—

	No. of Plates.
For zero of scales	4
Pole and trails of stars at different declinations (for adjustments of equatorial)	24
Typical areas (Chart plates)	1
Typical areas (Catalogue plates)	3
Castor, τ Leonis	2

Each plate has undergone a preliminary examination to see whether it is generally satisfactory, and whether the adopted limits of magnitude were approximately reached, as inferred from the 20ˢ exposure, which should give 9th magnitude stars of Argelander's scale.

Of the fields still required 197 are within 10° of the Pole, and no photographs of this part of the sky have yet been taken, the work being purposely deferred till near the epoch 1900. Of the remainder, considerably the larger number can only be photographed within an hour of the meridian during the winter months, and this year the number of fine nights from September to March has been very small, and the progress made with the chart plates has been slow, although care has been taken to have an observer on duty every night.

During the year positives on glass of 303 chart plates have been made, which, with the 144 mentioned in last year's Report gives 447 as the total number of chart plates which have been copied. In the course of this work 72 chart plates enumerated in the above table were rejected as unsuitable to give good transparencies.

Réseau Gautier No. 71 was replaced by No. 72 on 1896 September 16. The latter now shows many pin-holes which have been stopped out as far as practicable with black varnish. This *réseau* has worn more quickly than previous ones, as it has been placed more nearly in contact with the photographic plates during the printing, so that plates which are not quite plane have probably rubbed it. The *réseaux* lines as now printed on the plates are finer and easier to measure.

It was decided in 1896 June, as a result of the meeting of the Astrographic Committee in Paris, to duplicate the measurement of the catalogue plates—the plates being reversed in the micrometer for the second series of measures. The advantages derived from this are the detection of mistakes, increase of accuracy, and partial elimination of the systematic error of bisection made by the different measurers. The measures have been compared, the measures being repeated in the case of discordances of $1''{\cdot}5$ and upwards, and stars overlooked in one or other measure have been measured a second time.

During the year the co-ordinates of 39,000 pairs of images (6^m and 3^m) have been measured as well as the diameters of the images obtained with 6^m exposure. The number of quarter-plates measured was 768. In addition to these one plate has been measured in two positions by each of five measurers for the determination of personality and probable error. Four plates of the same field as the last were also measured by one measurer in both positions of the plate for determination of probable error. The probable error of the mean of the four measures of a star on a plate (6^m and 3^m images each measured direct and reversed) is thus found to be $\pm 0''{\cdot}13$ and this is reduced to $\pm 0''{\cdot}11$ by applying the correction for personality.

The personality of the measurers has also been determined from the comparison of the direct and reversed measures of the same stars, made in the regular course of measurement. It is generally small but amounts in some cases to about $0''{\cdot}3$.

The division-errors of the central lines of the *réseaux* Gautier 34, 35 and 71 have been determined by comparison of each division with every division of a glass scale. In this way the errors of the scale were also determined ; altogether 16 determinations have been made of the errors of the scale, from which it was deduced that the probable error of a single determination—either of the scale or of the *réseau*—was $\pm 0''{\cdot}02$. The division-errors of the three *réseaux* were found to be very small.

The following table shows the progress made to 1897 May 10 with the measurement of the plates :—

Zone.	Limiting R.A.	—
°		
64	0^h–10^h 48^m	Measured twice and 18^h 36^m–20^h 6^m once
65	0^h–24^h	Measured twice
66	0^h–21^h 18^m	„ „ and 21^h 18^m–24^h 0^m once
67	0^h–24^h	Measured once
68	18^h 50^m–20^h	„ „

Zone 64°, the southern limit of the Greenwich zones, has been measured on one series of plates ; the other zones on two series of plates simultaneously with the duplex micrometer.

During the year plate constants have been determined for 79 plates, which with 119 previously determined gives a total of 198. These are distributed as follows :—

	Centres of Plates.	Number of Plates.
Dec. + 65°	0^h 9^m to 6^h 27^m and 11^h 33^m to 21^h 9^m	55
Dec. + 66°	0^h 0^m to 24^h 0^m	80
Dec. + 67°	0^h 10^m to 9^h 10^m and 9^h 50^m to 20^h 30^m	61
Dec. + 69°	19^h 30^m to 19^h 50^m	2

A form in which it is proposed to print the original measures has been drawn up and the copy for press of parts of Zones 65° and 66° has been prepared.

III.—Spectroscopic and Heliographic Observations :—

Observations with the visual spectroscope have been suspended since the date of the last Report, pending the completion of the photographic spectroscope and its adaptation to the 30-inch reflector of the Thompson Equatorial.

In the year ending 1897 May 10, photographs of the Sun have been taken with the Dallmeyer photoheliograph, mounted on the terrace roof of the South wing of the Physical Observatory, on 222 days, and of these 471 have been selected for preservation, besides 12 photographs with double images of the Sun for determination of zero of position-angle.

For the year 1896 Greenwich photographs have been selected for measurement on 206 days, and photographs from India and Mauritius (filling up the gaps in the series) on 154 days, making a total of 360 days out of 366 on which photographs are available.

The spot activity of the Sun has continued on the whole to decline since the date of the last Report, but has undergone two remarkable cases of temporary revival; the one in September 1896, when the longest connected group ever photographed at Greenwich was observed, and the other at the commencement of the present year. On the other hand, the Sun was seen to be free from spots on 6 days in the year ending 1897 May 10.

The measures are in a forward state, the Greenwich photographs having been measured up to April 2, and the Indian and Mauritius photographs as far as they have been received. The conversion of the measures into heliographic longitude and latitude is well advanced, having been carried forward for the Greenwich photographs as far as 1897 March 10, and for the Indian and Mauritius photographs as far as 1897 January 24, the date of the last negative received. The copy for press of the Daily Results has been prepared as far as 1896 December 23.

IV.—Magnetic Observations :—

The variations of magnetic declination, horizontal force and vertical force, and of earth currents have been registered photographically, and accompanying eye observations of absolute declination, horizontal force and dip have been made as in former years.

The magnetic reductions for 1896 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. The time-scales for the magnetic registers are complete; the base line values, deduced from eye observations, are entered on the sheets, and the hourly ordinates of the photographic curves are read out and reduced. The temperature of the magnet-basement at every hour has been read from the Richard thermograph sheets, and the daily and hourly means have been taken. The time-scales for earth currents are laid down. The dip and deflexion observations are completely reduced.

The principal results for the magnetic elements for 1896 are as follows :—

Mean declination . . .	16° 56′·5 West.
Mean horizontal force . .	3·9834 (in British units). 1·8367 (in Metric units).
Mean dip . . .	67° 8′·5 (by 9-inch needles). 67° 9′·3 (by 6-inch needles). 67° 10′·0 (by 3-inch needles).

These results are to a certain extent affected by the iron in the new Physical Observatory, and in the new Altazimuth Pavilion.

The selection of the site for the new Magnetic Pavilion has required much consideration and observations at a number of stations in Greenwich Park to determine the effect of iron, particularly of the large mass in the Kent Water Works Reservoir to the South of the Observatory. A magnetic survey of the Park in the neighbourhood of this Reservoir was made in October by Mr. Nash, and also afterwards independently by Mr. Watson, of the Royal College of Science, who kindly undertook it at the suggestion of Professor Rücker. As the result of the survey it was decided to abandon a site which had been provisionally selected at a distance of about 250 feet to the east of the Reservoir, and to choose another at a considerably greater distance both from the Reservoir and the Observatory.

The magnetic survey of the Park led to the detection of numerous imperfections in the Elliott portable instrument for determining the declination and horizontal force. It appeared that the mounting of the mirror was unsatisfactory, and that the stand was not free from magnetic material. It has also recently been discovered that the collimation glass of the deflecting magnet was loose.

Possibly these imperfections in the Elliott instrument account for the systematic differences between the values of the horizontal force as determined with it and with the Gibson instrument. The mean value of the horizontal force as determined with the Gibson instrument in 1896 was 1·8367 metric units, as already stated. The Elliott result was 0·0095 larger. This difference has been increasing during recent years; and the determinations of the Elliott instrument increased in a most marked manner after 1896 May, when the collimation glass was re-fixed by Messrs. Troughton and Simms. It is proposed to re-determine the moment of inertia of the deflecting magnet.

The magnetic disturbances in 1896 have been comparatively trifling. There were no days of great magnetic disturbance and 24 days of lesser disturbance. Tracings of the photographic curves for these days, selected in concert with M. Mascart, will be published in the annual volume as usual. The calculation of diurnal inequalities from 5 typical quiet days in each month has been continued.

Information and results of observations have been supplied in reply to inquiries on various occasions during the year.

V.—Meteorological Observations :—

The meteorological instruments are all in good order. The registration of atmospheric pressure, temperature of the air and of evaporation, pressure and velocity of the wind, rainfall, sunshine, and atmospheric electricity has been continuously maintained.

In 1896 May the masses of terra cotta, referred to in last year's Report as seriously curtailing the space at disposal for meteorological instruments, were removed, but the space is still too small, and it is proposed to transfer the standard thermometers to the enclosure that will surround the new magnetic pavilion. Much better conditions of exposure for the standard thermometers will thus be secured.

The sunshine recorder is retained in its altered position on the roof of the Octagon Room, about 50 feet above the ground. On 1896 December 24 it was pointed out by Mr. Marriott that the record obtained was less than that at Bunhill Row in the City. It was suspected that the deficiency was due to the opacity of the glass globe, and on 1897 January 1 a globe of much clearer glass, presented to the Royal Observatory in 1881 by the late Mr. Campbell, was substituted. The discarded ball was mounted on the old Campbell recorder by the side of the Campbell-Stokes instrument for the purposes of comparison.

The following table showing the yearly totals of sunshine registered at Greenwich, Kew, and Bunhill Row, seems to indicate that the Greenwich record began to fall off about six years ago, the deficiency, however, not becoming marked till 1894.

Yearly totals of sunshine registered at—

	Greenwich. hrs.	Kew. hrs.	Bunhill Row. hrs.	Percentage at Greenwich, Kew = 100
1887	1407	1592	1083	88
1888	1068	1157	911	92
1889	1156	1205	965	96
1890	1255	1405	1158	89
1891	1222	1367	1111	89
1892	1277	1519	1265	84
1893	1454	1681	1493	86
1894	1052	1351	1156	78
1895	1227	1592	1300	77
1896	1016	1436	1136	71

The following table exhibits the results of four months' comparison of the old and new balls, and shows clearly that the old ball is defective.

		New Ball.	Old Ball.	Excess with New Ball.
1897	January ...	$19^h{\cdot}8$	$10^h{\cdot}8$	+ $9^h{\cdot}0$
	February ...	$34^h{\cdot}1$	$24^h{\cdot}2$	+ $9^h{\cdot}9$
	March	$123^h{\cdot}4$	$101^h{\cdot}7$	+ $21^h{\cdot}7$
	April	$144^h{\cdot}7$	$124^h{\cdot}8$	+ $19^h{\cdot}9$

The new arrangements in Osler's anemometer for measuring the more rapid fluctuations of the pressure of the wind have continued to work satisfactorily.

The meteorological reductions are in the following state:—The observations of barometers, 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, and the hourly ordinates are read out and completely reduced for the dry and wet bulb thermometers and the electrometer to the end of the year 1896. The table of principal changes in the direction of the wind for 1896 is complete.

The mean temperature of the year 1896 was 50°·1, being 0°·7 above the average for the 50 years 1841–1890.

During the twelve months ending 1897 April 30, the highest daily temperature in the shade recorded on the open stand was 91°·1 on July 14. The highest reading recorded in the Stevenson screen was 87°·6. Under the same conditions of exposure on the open stand there have been 26 instances of temperatures exceeding 90° recorded in the preceding 55 years, the highest having been 97°·1 on 1881 July 15. The temperature rose twice above 90° in 1896 and 17 times above 80°. The monthly mean temperatures for June, July, February and March were respectively above the corresponding averages by 4°·0, 2°·8, 3°·5 and 3°·3; and the means for August, October, November and January were in defect by 2°·5, 3°·5, 2°·7 and 3°·1. The mean temperature for the twelve months 1896 May to 1897 April was 49°·7, being 0°·2 above the 50 years' average.

In the winter months of 1896–1897 there were 42 days on which the temperature of the air fell to the freezing-point, or below; 16 of these days occurring in January and 11 in December. The lowest winter temperature was 23°·8 on 1897 January 18, as compared with 24°·3 in the preceding winter.

The mean daily horizontal movement of the air in the twelve months ending 1897 April 30 was 289 miles, which is 8 miles above the average for the preceding

29 years. The greatest recorded movement was 882 miles on March 3, and the least 69 miles on November 23 and January 2. The greatest recorded pressure of the wind was 26 lbs. on the square foot on March 3, with an extreme hourly velocity of 48 miles.

During the year 1896 Osler's anemometer showed an excess of 37 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 the twelve months ending 1897 April 30 by the Campbell-Stokes instrument (with the old ball up to December 31, and with the new ball after) was 1152 out of the 4454 hours during which the Sun was above the horizon, so that the mean proportion of sunshine for the year was 0·259, constant sunshine being represented by 1. This amount is probably too small for the reasons already explained.

The rainfall for the year ending 1897 April 30 was 26·83 inches, being 2·29 inches above the 50 years' average. The number of rainy days in the twelve months was 178.

Excessive rainfall characterized the month of September, 5·54 inches of rain being recorded, or 3·29 inches in excess of the average amount. The rainfall in March also exceeded the average by 1·89 inches, whilst the falls of May and July were deficient to the extent of 1·73 and 1·41 inches respectively.

VI.—Printing and Distribution of Greenwich Publications :—

The printing is in a more satisfactory state than last year, and arrears are being gradually made up.

The copies of the Greenwich Observations for 1893 were distributed in August.

The copies of the volume for 1894 are being bound and it is hoped that they will be received and distributed very shortly.

As regards the volume for 1895, the heavy sections of Transits and Meridian Zenith Distances are all printed and the Heliographic Results to August 9. Proofs of the Star-Ledger have also been received as far as 15^h. The Altazimuth Section and the Magnetic and Meteorological Results are completely printed with the exception of the Introduction.

As regards the volume for 1896, the manuscript of the Transits, Zenith Distances, and Altazimuth Results, as well as the Chronometer and Deck Watch Rates 1895–96, have been sent to the printers, and portions of each are in type.

In the volume for 1897, the printing of the details of daily observations in the sections of Transits and Meridian Zenith Distances will be confined to the Sun, Moon, planets and fundamental stars (stars for clock-error, azimuth, zenith-point, &c.), for the reasons stated in the last Report, and the copy for press for these sections from 1897 January 1 has been prepared in accordance with this arrangement, which will greatly relieve the printing in this and future years.

VII.—Chronometers, Time Signals, Longitude Operations, &c. :—

The number of Government marine chronometers and deck-watches now being tested at the Observatory is 288 (166 box chronometers, 29 pocket chronometers, and 93 deck-watches). In addition to these, there are on trial for purchase by the Indian Government 42 box chronometers, and 2 box chronometers are being tested after repair. In the year ending 1897 May 10 the average daily number of chronometers and deck-watches being rated was 446 ; the total number received was 1,220, the total number issued 1,124, and the number sent for repair 519. These include 8 box chronometers and 3 pocket chronometers for the Indian Government. The trial of 18 chronometers for the Indian Government, mentioned in the last Report, was finished in 1896 June, and 6 of the chronometers were purchased.

For the annual trial of chronometers, which lasted 29 weeks, with a range of temperature from 42° to 106°, 97 chronometers were sent in, and of these, 54 have been purchased for the Navy. The performance of the chronometers is remarkably good and sustains the improvement shown in recent years.

The deck-watches in the annual trial were this year confined to class A, and were tried in positions "dial up," "pendant up," "pendant right" and "pendant left" ; 154 were entered and of these, 30 were purchased for the Navy. The performance of the watches was above the standard of recent years. The difficulty experienced in securing accurately divided seconds' dials has been met in some cases by centre-seconds dials, which have been found to be as reliable as the others while the divisions are larger and more accurate. There has also been a marked increase of "tourbillon" watches this year. The next competitive trial of chronometers commences on July 3, and the trial of deck-watches on October 23.

The Greenwich time-ball was not raised on five days during the year owing to the violence of the wind. Twice it was dropped accidentally before 13^h, once by a false signal and once because the piston did not rest properly on the clips. It was raised and dropped again at 14^h on these days.

There were no failures in the Greenwich time signal at 13^h, but on Sunday, August 9, it was $1^s{\cdot}0$ late, Sunday, November 8, $0^s{\cdot}8$ late, and on Good Friday, April 16, it was $0^s{\cdot}5$ early.

The automatic drop of the Deal time-ball failed on two days owing to interruptions of the telegraph connections. On 10 days the ball was not raised owing to high wind.

The return signal from the Devonport clock failed on 24 days, and could not be observed on 13 days owing to interruption by telegraph signals. The apparent error of the clock-signal (after daily correction of the clock by aid of a time-signal from Greenwich) did not exceed $0^s{\cdot}2$ on 72 per cent. of the 323 days of observation, did not exceed $0^s{\cdot}5$ on 97 per cent., and never exceeded $1^s{\cdot}0$.

The return signal from the Portsmouth clock (similarly corrected by the help of a signal from Greenwich) failed on 59 days, and could not be observed on 7 days owing to interruption by telegraph signals. The apparent error of the clock-signal did not exceed $0^s{\cdot}2$ on 81 per cent. of the 292 days of observation, did not exceed $0^s{\cdot}5$ on 95 per cent., and never exceeded $1^s{\cdot}0$.

The automatic signals from the Westminster clock have been received throughout the year, except on 31 days, when the signal failed. The apparent error of the clock was not greater than $0^s{\cdot}5$ on 34 per cent. of the days of observation, not greater than $1^s{\cdot}0$ on 55 per cent., not greater than $2^s{\cdot}0$ on 80 per cent., not greater than $3^s{\cdot}0$ on 92 per cent., and once exceeded $4^s{\cdot}0$.

Longitude Operations.—Observations have been continued to determine the difference of longitude between the stations in the Front Court with the same instruments as were used in the Paris–Greenwich longitude determinations. Complete determinations have been secured on six nights, and these observations, as well as those made on eight nights in the winter of 1894–95, have all been reduced. The difference of longitude is found to be $+ 0^s{\cdot}007$ when the level is determined from nadir observations and $+ 0^s{\cdot}107$ when it is obtained from the striding level, the individual results being more accordant when reduced with the level determination obtained from the nadirs. The geodetic difference of longitude is $+ 0^s{\cdot}021$, which agrees sufficiently well with the astronomically determined difference. As the portable transit instruments have now been satisfactorily tested, it is hoped that the determination of the longitude of Killorglin or some other suitable station at the western extremity of the great European arc of longitude (to which reference has been made in previous reports) may be undertaken next year, with a view to eliminating the probable local attraction at Valentia and Waterville, the stations which have been used for longitude determinations.

It may be mentioned here that the Astronomer Royal went to Japan (taking with him the Thompson 9-inch photographic telescope to photograph the corona on a large scale) and Mr. Maunder and Mr. Crommelin to Norway, to observe the total eclipse of the Sun on August 9. No observations during totality were obtained at either station owing to cloud.

VIII.—Personal Establishment :—

The increase in the clerical work of the Observatory, and in the responsibility now thrown upon the Clerk, have been recognized by his appointment as *Clerical Assistant*, at an increased scale of salary. This change took effect from February 1.

Consequent on the re-organisation of the Staff referred to in the last Report, Messrs. Bowyer, Davidson, Edney and Rendell were appointed Established Computers in 1896 June.

The Staff at the present time is thus constituted, the names in each class being arranged in alphabetical order :—

Chief Assistants—Mr. Cowell, Mr. Dyson.

Assistants—Mr. Hollis, Mr. Lewis, Mr. Maunder, Mr. Nash, Mr. Thackeray.

Second-Class Assistants—Mr. Bryant, Mr. Crommelin.

Clerical Assistant—Mr. Outhwaite.

Established Computers—Mr. Bowyer, Mr. Davidson, Mr. Edney, Mr. Rendell and two vacancies.

The two Second-Class Assistants will be replaced by Higher Grade Established Computers as vacancies occur.

There being still two vacancies in the Staff of Established Computers, a limited competitive examination of candidates, nominated from among the Supernumerary Computers as qualified for the duties of Established Computer, took place in February, but none of the candidates were held by the Civil Service Commissioners to have qualified in the theoretical examination. The question of appointment is now under consideration.

Mr. Dyson and Mr. Cowell have the general superintendence of all the work of the Observatory, Mr. Dyson taking special charge of the Astronomical Department, and Mr. Cowell of the Astro-physical Department, in which is included the Magnetic

and Meteorological Branch. Mr. Maunder is charged with the heliographic photography and reductions. Mr. Lewis has charge of the time-signals and chronometers, and of the 28-inch equatorial. Mr. Thackeray superintends the miscellaneous astronomical computations and meridian zenith-distance reductions. Mr. Hollis has charge of the photographic mapping of the heavens, the measurement of the plates, and the computations for the astrographic catalogue. Mr. Crommelin undertakes the altazimuth and Sheepshanks equatorial reductions, and Mr. Bryant the transit-reductions and time-determinations. In the magnetic and meteorological branch, Mr. Nash has the charge of the whole of the work. Mr. Outhwaite acts as responsible accountant officer, has charge of the library, records, manuscripts, and stores, and conducts the official correspondence. The Established Computers, Mr. Bowyer, Mr. Davidson, Mr. Edney and Mr. Rendell, assist Mr. Lewis, Mr. Hollis, Mr. Nash and Mr. Thackeray respectively.

There are at the present time twelve Supernumerary Computers attached to the astronomical branch, four to the astrographic, four to the heliographic, and four to the magnetic and meteorological.

A foreman of works, with two carpenters, and one or two labourers ; a skilled mechanic with an assistant ; a gate-porter, a messenger, a watchman, and a gardener ; and a charwoman, are also attached to the Observatory.

The whole number of persons regularly employed at the Observatory is 51.

IX.—General Remarks :—

The addition of two new instruments to the Observatory equipment has involved much work in supervising their erection and in planning the various accessories required. The Thompson Equatorial with its powerful combination of telescopes adapted to visual, photographic, and spectroscopic work, has been erected and got into good working order. With the new Altazimuth there have been difficulties which it is believed are not confined to this particular instrument, and these have delayed the commencement of regular work with it. There is however good reason to hope that not only will these difficulties be overcome, but that the severe tests which have been applied to this instrument may lead to improvements in the construction of other meridian instruments.

The preparation of the Ten-Year Catalogue of Stars, 1887–1896, has been pushed on vigorously during the past year. This catalogue will give accurate places for nearly 7,000 stars, a large number of these being stars observed by Groombridge, so that good data for proper motions will be available. The observations of fundamental

stars contained in this catalogue are very numerous, the number of observations in the case of Polaris amounting to 1400 in R.A. and 1760 in N.P.D., and there will thus be ample material for discussion of systematic errors.

As regards the Astrographic Chart, the decision to measure the plates for the catalogue twice (in reversed positions) with a view to securing greater accuracy, naturally involves a considerable addition to the work, but the value of the results will be more than proportionately increased. At the present rate of progress the whole work of measurement and re-measurement will be completed within nine years, and by the end of the present year it is expected that all the plates for the zones between 64° and 68° Declination will have been measured twice, and that the measures will be ready for printing together with the constants for the plates. This portion of the catalogue, which it is proposed to publish without delay, will contain the results from 268 plates out of a total of 1,149 plates allotted to Greenwich.

W. H. M. CHRISTIE.

ROYAL OBSERVATORY, GREENWICH.
1897 May 11.