

R E P O R T

OF THE

ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH.

Read at the Annual Visitation of the Royal Observatory, 1921 June 4.

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REPORT OF THE ASTRONOMER ROYAL
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The Report here presented refers to the year from 1920 May 11 to 1921 May 10, and exhibits the state of the Observatory on the last-named day.

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

The external painting of the Astrographic, Sheepshanks, Altazimuth, and Thompson domes, the Transit Pavilion, the New Observatory, and the covered way of the Front Court, was completed on May 25.

A number of minor repairs to the buildings have been made during the year, including a chimney stack on the Octagon Room, which was considered unsafe and was rebuilt, and a cornice on the roof of the Record Room.

A slow combustion stove has been substituted for the open stove in the Central Store, and the ventilation altered so as to ensure a greater circulation of the hot air.

The substitution of electric for gas heating in the chronometer ovens was completed in June. The temperature control works quite satisfactorily and within a close range. It is a great advantage to have got rid of the gas fumes which frequently found their way into the Chronometer Room.

For the purpose of testing chronometers and watches at low temperatures at any period of the year, a refrigerating plant was installed by Messrs. Hall & Co., of Dartford, in January. The plant consists of a suitably lagged chamber, $7\frac{1}{2}$ ft. \times $6\frac{1}{2}$ ft. \times $6\frac{1}{2}$ ft., with shelves for 45 chronometers, cooled by a brine tank reduced to a low temperature by the expansion of liquid carbon dioxide in a coil immersed in the brine. The compressor is worked by a 3 horse-power single phase motor.

A $6\frac{1}{2}$ -inch self-contained motor-driven lathe, with a $1\frac{1}{4}$ horse-power motor and accessories, has been supplied to the workshop. The lathe was installed and brought into use in March and has already been of considerable service.

A milling machine has been received from the Disposals Board, but has not yet been installed.

The internal wiring of the Observatory has been taken over by the Admiralty from the General Post Office as from April 1.

The principal movable instruments are thus distributed:—

At Greenwich—

Transits B, C, D, and E.—Transit B has been fitted with an Impersonal Micrometer by Messrs. T. Cooke & Sons.

Altazimuths D and E.

Equatorials (6-inch).—Cooke No. 2, Simms No. 1, Lee.

Photoheliographs Nos. 2 and 3 complete and the mechanical parts of Nos. 1 and 5.

Detached Telescopes (on tripod stands).—Three 4-inch (Simms Nos. 1 and 2 and R.O. No. 2).

Cooke 6-inch Triplet photographic objective.

Two Hilger Chronographs.

A single-prism Spectroscope.

On loan—

Transit A, at the Cape Observatory.

Transit, with axis view, at the Science Museum, South Kensington.

Altazimuths.—A, at the Imperial College of Science and Technology, South Kensington; B, at the Cape Observatory.

Equatorials.—Simms No. 2 (6-inch), at the Imperial College of Science and Technology.

Two Heliotropes at the Science Museum, South Kensington.

Photoheliographs :—

No. 1. At the Cape Observatory with the exception of the parts mentioned above.

No. 5. Object-glass on loan to Professor Newall, Cambridge.

Clocks.—Dent No. 1916 and Dent No. 2013, at the Cape Observatory; Dent No. 2011, at the Kew Observatory; Arnold 2, at the University Observatory, Oxford; Graham 2, for use in connection with the Time Ball at Rosyth.

Anemometer.—Whewell's Anemometer at the Victoria and Albert Museum, South Kensington.

On loan to the Royal Observatory—

The Cookson Floating Zenith Telescope from the Cambridge Observatory, for a further period of seven years from July 1918.

One 16-inch cœlostat from the Joint Permanent Eclipse Committee.

One 8-inch cœlostat from the Royal Irish Academy. (Mounting only.)

Two 16-inch cœlostats and a 12-inch cœlostat from the Eclipse Committee for use at the total eclipse of the Sun, 1914 August. (Left in Russia, at Pulkovo Observatory.)

A Quartz spectroscope from Prof. H. F. Newall, Cambridge, for the same eclipse. (Left in Russia, at Pulkovo Observatory.)

A 7-inch Prism of 40° angle from the Joint Permanent Eclipse Committee.

A Position Micrometer for measuring solar photographs, from the Solar Physics Observatory, Cambridge.

A Bendorff Electrometer, two Kelvin-White Multicellular Voltmeters, and a Flame Collector from Dr. G. A. Carse, University of Edinburgh. One seven-valve amplifier and one C.W. syntoniser from the Royal Air Force.

One seven-valve amplifier and two condensers from the Wireless Station at the Admiralty.

A box of Pearwood Curves from the Hydrographic Office.

The annual examination of the Library has been made as usual, the books on the shelves being compared with the catalogue. Sixteen books are reported missing from the shelves and cannot be accounted for at present, including twelve books reported missing last year. Six of the books reported missing last year have been returned. Seven books which have been reported missing for several years will be written off the catalogue. They are works of little value.

The Observatory is indebted to Lieut.-Commander R. T. Gould, R.N., of the Hydrographic Department, for the restoration of Harrison's first Time machine. In connection with work on the history of the chronometer, permission was given him to examine records and horological instruments of historical interest at the Observatory. He kindly volunteered to take to pieces, clean and reassemble the instrument in a condition to prevent future deterioration. This historic instrument is now placed in the Octagon Room.

II.—Astronomical Observations :—

Transit Circle.—The Sun, Moon, planets, and fundamental stars have been observed regularly on the meridian as in previous years. The remaining stars in the Working Catalogue are taken from the list prepared by Dr. Backlund and Mr. Hough. It is anticipated that by the end of the year all stars will have been observed at least six times, and preparations are being made for the formation of a catalogue.

A Working Catalogue is being constructed of all the stars between the limits of 32° and 64° N. dec., of magnitude $8^m \cdot 0$ or brighter. As the parts of the sky from 24° to 32° N. dec. and from 64° N. dec. to the Pole have been observed at Greenwich recently and the results given in the catalogues for 1910 and 1900, this will complete the part of the sky most suitable for the latitude of Greenwich for all stars down to $8^m \cdot 0$. This programme will be commenced on January 1.

TO THE BOARD OF VISITORS, 1921 JUNE 4.

7

The total number of observations made during the year is as follows:—

Transits	-	-	-	-	7,499	Circle observations	-	-	7,011
Collimation	-	-	-	284		Nadir point	-	-	558
Level	-	-	-	585		Reflection observations	-		244

The Sun was observed on 151 days and the Moon on 101 days.

The observations of transits are completely reduced to April 22, and of zenith distances to April 13.

The ledgers for 1920 are completed.

The two catalogues for 1910, one of fundamental stars and the other of stars from N. dec. 24° to N. dec. 32° , have been printed and distributed. In the latter the proper motions of 12,000 stars obtained by comparison with earlier observations are included.

Altazimuth.—This instrument has been used to supplement the observations of the Moon with the transit circle and extra-meridian observations have been made on 26 nights.

In the year ended 1920 Dec. 31 the Moon was observed with one or other of the instruments on 114 nights. The mean correction in right ascension required by the *Nautical Almanac* is $+0^s\cdot87$, and by the *Connaissance des Temps* is $+0^s\cdot25$, agreeing with $+0^s\cdot28$ given by the mean of the four preceding years. The following table gives the mean tabular error of the Moon's longitude of Hansen's tables, with Newcomb's corrections for each year since 1883, when these corrections were introduced into the *Nautical Almanac*:—

1883	-	-	$0''\cdot03$	1893	-	-	$0''\cdot06$	1903	-	-	$3''\cdot08$	1913	-	-	$11''\cdot93$
84	-	-	$0\cdot16$	94	-	-	$1\cdot20$	4	-	-	$3\cdot16$	14	-	-	$12\cdot86$
85	-	-	$0\cdot09$	95	-	-	$1\cdot47$	5	-	-	$5\cdot29$	15	-	-	$12\cdot58$
86	-	-	$0\cdot11$	96	-	-	$1\cdot68$	6	-	-	$5\cdot91$	16	-	-	$14\cdot05$
87	-	+	$0\cdot21$	97	-	-	$2\cdot77$	7	-	-	$5\cdot96$	17	-	-	$14\cdot03$
88	-	+	$0\cdot76$	98	-	-	$3\cdot03$	8	-	-	$5\cdot97$	18	-	-	$14\cdot05$
89	-	-	$0\cdot38$	99	-	-	$2\cdot18$	9	-	-	$6\cdot41$	19	-	-	$12\cdot26$
90	-	-	$0\cdot27$	1900	-	-	$2\cdot69$	10	-	-	$7\cdot85$	20	-	-	$13\cdot11$
91	-	+	$0\cdot72$	01	-	-	$2\cdot77$	11	-	-	$8\cdot34$				
92	-	+	$0\cdot79$	02	-	-	$3\cdot15$	12	-	-	$9\cdot79$				

B 3

The Cookson Floating Zenith-Telescope.—During the year 170 photographs have been taken for variation of latitude. The measurements are completed to the end of 1920, and the results for the variation of latitude at Greenwich were published in the *Monthly Notices of the Royal Astronomical Society* for March, 1921.

A discussion of seven years' observations with the instrument has been published and is ready for distribution.

Equatorial Observations.—During the year eight occultations of stars by the Moon have been observed by one or more observers.

Both contacts of the Partial Solar Eclipse of April 8 were observed with several instruments, the exact times of contact being determined from measures of the distance between the cusps. These were supplemented by photographs taken near the beginning, end and mid-eclipse. The results are in good accordance and furnish accurate values of the time of conjunction of the Sun and Moon and the difference of their declinations.

Comet *a* 1921 (Reid) and Comet *b* 1921 (Pons-Winnecke) were each observed on four nights with the Sheepshanks equatorial. Photographs of Reid's Comet were also taken on one night with the 30-inch reflector and of Comet Pons-Winnecke on three nights.

The 28-inch Refractor.—The repair and re-erection of the equatorial mounting was completed by Messrs. T. Cooke & Sons in October. Hoffmann ball bearings have been introduced to the top and bottom pivots, and a ball-bearing end thrust to take the weight. During the alterations the telescope was lifted out of the declination axis and the pivots examined. They were found to be in good condition. The instrument moves with great ease both in right ascension and declination.

Observations were recommenced on October 25. While the instrument was out of use a new Working Catalogue of double stars was prepared. The stars included in it are taken from Burnham's General Catalogue between declinations -10° and $+65^{\circ}$. Care was taken to exclude all stars which have been reobserved during the last 20 years and show only small relative motion. Also the stars

discovered by Aitken and Hussey and now being reobserved at Mt. Hamilton and Yerkes have been omitted. The Catalogue includes stars in rapid motion and stars for which present observations are insufficient to determine the relative motion, and contains 953 stars. It is proposed to observe each star three times, and rapidly moving stars more frequently. During the year, 279 observations of 191 double stars have been obtained.

The use of the instrument was granted to Commander Ainslie, Major Hepburn and Dr. Steavenson for the study of the rings of Saturn near the times of their disappearance. An account of these observations is given in the *Monthly Notices* for December 1920 and in several numbers of the *Journal of the British Astronomical Association*.

The Catalogue of double stars referred to in the last report is in the printers' hands, except the Introduction. It consists of: (1) Unpublished separate observations from 1910-1919, (2) Catalogue of collected observations from 1893-1919, (3) Notes on stars showing any relative motion, (4) Orbits of 25 binary stars.

The first three parts have been already printed off. In the course of this work the relative motions of all the stars in the Catalogue have been examined and the parallaxes of 556 double stars determined on the assumption that the mass of each system is twice that of the Sun. These are discussed by Mr. Jackson and Mr. Furner in the *Monthly Notices* for November, 1920.

Thompson Equatorial.—With the 26-inch refractor 719 plates have been taken for parallax, fairly evenly divided between evening and morning observations. Since the date of the last report 829 plates have been measured and the parallaxes of 49 stars deduced. The total number of stars whose parallaxes have been completely determined is 103. The probable error of the stars determined during the last year is just under $\pm .009$; it would be even smaller but for those stars where the short summer nights make a large parallax factor impossible.

The method of exposing the same plate twice at an interval of approximately six months has been discontinued. With uncertain weather its full advantage is difficult of realisation. This discontinuance has necessitated a change in the

method of measurement. A small ruling machine has been constructed with which short lines are ruled with a diamond on a piece of plate glass in positions which the star and selected comparison stars would occupy. This plate, when placed face to face with a photograph, provides fiducial marks, from which the positions of the stars can be measured. The same fiducial plate is used with all the photographs of each star. The method has been found to work very satisfactorily.

The 30-inch *Reflector* has been principally used for the determination of effective wave-lengths of stars. Following Prof. Hertzsprung's suggestion, a wire grating was constructed in the workshop, made of steel wire 1.42 mm. in diameter and separated by an equal amount. The distance between the two first order spectra is 1.05 mm. for $\lambda = 4300$. From a single plate the effective wave-length is obtained with a probable error of $\pm 15 \text{ \AA}$.

A trial of the method has been made on the part of the sky within 3° of the North Pole. Twenty-eight plates have been taken with the same centres as the plates of the *Astrographic Catalogue*. Effective wave-lengths have been determined for 550 stars with a probable error somewhat less than $\pm 10 \text{ \AA}$.

It is proposed to continue this for the whole of the Greenwich *Astrographic Zone*. With exposures of 7 minutes satisfactory photographs are obtained for stars down to $10^m \cdot 5$ (photog.)

With the 26-inch refractor 14 plates were also taken for stellar magnitude, and with the reflector 6 photographs of Comet Pons-Winnecke and two of Comet Reid.

In addition, Mr. Luyten took a number of photographs of Variable Stars and Clusters and of Nova Cygni with the refractor, as well as a number of special stars for effective wave-length with the reflector.

Astrographic Equatorial.—The repairs to the clockwork were completed by Sir Howard Grubb & Sons, Ltd., early in June and the telescope was brought into use on 1920 June 19. The periodic error in the driving worm was found to have been satisfactorily corrected.

Since that date the instrument has been used mainly for photometry. The programme of work is the determination of the photographic magnitudes of the stars of the Harvard North Polar Sequence, down to about the 13th magnitude, using a diffraction grating placed in front of the object-glass. The magnitudes of

the sequence stars between the 10th and 15th magnitudes, as determined at Harvard, Mount Wilson and Greenwich, are in substantial agreement; but for the brighter stars there is a systematic disagreement between Harvard and Mount Wilson increasing to nearly half a magnitude for the brightest star. The present investigation, undertaken at the request of Prof. Seares, is to make a third independent determination of these magnitudes.

The grating used has a calculated magnitude interval of 2.83 magnitudes. The first diffracted images are round and well-separated from the principal image.

The number of plates obtained is 161 and the series is now complete. Eleven of these plates (taken on eight nights) have exposures on the pole only, ranging from 15 to 30 minutes. Assuming the magnitudes of the sequence stars between the limits 10^m to 13^m, these plates serve to determine the magnitudes of the sequence stars Nos. 10, 11, 12 and also to check the calculated grating interval. The interval so determined is 2.80 magnitudes, in close agreement with the calculated value. Alternatively, assuming the calculated interval, the plates confirm the value of the light ratio of the Harvard Sequence in this interval and make the whole series of determinations an absolute one.

The remaining 150 plates were exposed on the 19 brightest stars of the sequence. In general, two exposures on the sequence star and two equal exposures on the pole were given. The measures of the pole field on these plates have also been utilised to provide additional determinations of the magnitudes of the sequence stars fainter than 9^m.0. The magnitudes of the brighter stars, including Polaris and δ Ursæ Minoris, were obtained by comparing these stars directly with stars of the sequence three magnitudes fainter, by setting the telescope so that the stars to be compared came at equal distances from the centre of the plate. For these stars, the aperture of the telescope was reduced in order to enable a longer exposure to be given.

The magnitudes of all the stars brighter than 10^m can in this way be determined by a three-step process, which involves using the grating interval three times. Nearly half the plates have been measured and provisionally reduced. The provisional magnitudes so obtained are in substantial agreement with those determined at Mount Wilson.

In August 1920, 12 photographs were taken of Nova Cygni III, using the grating for determination of its magnitude near maximum. The results are given in the *Monthly Notices* for November 1920.

Twelve plates have been taken of the field of stars which will be in the neighbourhood of the Sun at the time of its total eclipse on 1922 September 21. Varying apertures and times of exposure were given. Besides serving to determine the positions of the stars, these plates give useful information as to the number of stars which may be expected to be shown on the eclipse plates.

During the year Vol. IV. of the Astrographic Catalogue has been printed, with the exception of a brief introduction, which has just been sent to the printer. This volume includes the result of two researches which have arisen in connection with the Astrographic Catalogue—the determination of proper motions and of magnitudes. The stars whose proper motions have been determined are, roughly speaking, the brightest stars in this part of the sky, with a few fainter stars of large proper motion.

The magnitudes are those of 17,000 stars from $9^m \cdot 0$ to $13^m \cdot 0$, distributed over the area comprised in the Greenwich Section of the Astrographic Catalogue, the magnitudes of the brighter stars having been already given in Vol. III.

Heliographic Observations.—In the year ended 1921 May 10 photographs of the Sun were obtained on 243 days. Of these, 468 have been selected for preservation, including 15 with double images of the Sun for the determination of the zero of position angle. This has also been determined regularly by visual observations of the transit of the Sun's limb over the cross-wires of the Photoheliograph.

H.M. Astronomer at the Cape has reported that the Sun was photographed there on 333 days in the year 1920, and on 86 days in the first three months of 1921. The Director of the Kodaikanal Observatory has reported that plates were taken there on 323 days in the year 1920, and on 84 days during the first three months of 1921.

Photographs have been received from the Royal Observatory, Cape of Good Hope, to 1921 February. Photographs have been received, through the Solar Physics Committee of the University of Cambridge, from Dehra Dûn, India, and from the Kodaikanal Observatory to complete the series for 1917 to 1919.

The measurement of the combined series has been made to 1919 October 4, and thus the heaviest part of the arrears of measurement, due to the maximum years of sunspots, has now been cleared off.

The reductions of positions of spot groups and their principal components have been made to 1918 April 2; the positions of faculae for 1917 June-December have also been computed. The copy for press for 1917 is being prepared.

The printing of the Photoheliographic Results for 1915 has been completed during the year and also the complete Results for 1916.

During the period covered by this report the spot-activity has declined appreciably; at times, however, during the last four months of 1920 the activity was considerable, and quite recently a large equatorial spot has appeared.

Franklin-Adams Chart.—In co-operation with the Royal Astronomical Society a second series of 35 sets is being prepared. The work was commenced in the autumn and on May 10 prints had been made of 82 plates out of 206. Zones -15° , 0° , and $+15^{\circ}$ (72 plates) have the headings printed and are ready for distribution.

Total Eclipse of the Sun of 1922 [Sept. 21.—In conjunction with the Joint Permanent Eclipse Committee it has been arranged that Mr. Jones and Mr. Melotte shall make observations at Christmas Island of the Deflection of Light by the Sun's Gravitational Field. The Admiralty has given permission for the Astrographic Telescope to be taken. It will be fitted on a new stand, designed for the latitude of Christmas Island. This is being made by Sir Howard Grubb and Sons, who have already obtained the necessary castings. The instrument will shortly be dismantled and parts sent to the firm for alterations and fitting. Permission has been granted by the Admiralty for the observers to stay in Christmas Island for a period of six months, in order that they may make comparison of the photographic scales of magnitude in the Northern and Southern Hemispheres. The Directors of the Christmas Island Phosphate Company have given the observers all available information and have kindly promised to give the expedition all the assistance in their power. The observers will leave England early in the year 1922.

III.—Magnetic Observations:—

The variations of magnetic declination, north force and vertical force have been registered photographically. Absolute observations of declination are made five or six times a week, of horizontal force twice a week, and of dip three times a week. The absolute observations and the photographic records are made in the two buildings in the Magnetic Enclosure.

The control temperature of the liquid thermostat in the Magnetograph Room has fallen during the year to about 15° C. This is below the temperature to which the room rises in the summer. The liquid thermostats have proved unsatisfactory in that their control temperature slowly falls, due to the gradual formation of bubbles in the beechwood creosote contained in the bulb. They are, therefore, being replaced by an adjustable bi-metallic thermostat similar to that in use in the Clock room. The makers are able to supply a pattern having a difference of only $0^{\circ}\cdot 25$ F. between the switch-in and switch-out temperatures.

A new vertical force Magnetograph of the Watson quartz fibre pattern has been obtained from Messrs. Adam Hilger. It has just been brought into use and the one kindly lent by the Meteorological Office is being returned.

The mean hourly ordinates of the declination, north force and vertical force registers are read off to the end of April, 1921, and partly reduced.

The absolute observations are all reduced. The mean values of the magnetic elements for 1920 and the three previous years are as follows:—

	Dec. W.	Hor. Force.	Vert. Force.	Dip.
1917 - -	14 37'0	0·18477	0·43250	66 52'0
1918 - -	27·7	0·18462	0·43224	52·3
1919 - -	18·2	0·18455	0·43239	53·2
1920 - -	8·7	0·18455	0·43225*	53·0*

From March 22–25, 1920, there was a very great magnetic disturbance, particularly in the vertical force, associated with a large group of sunspots.

IV.—Meteorological Observations:—

The registration of atmospheric pressure, temperature of the air and of evaporation, pressure and velocity of the wind, rainfall and sunshine has been continuously maintained.

* Provisional values.

The Polar night sky camera mentioned in the last report was replaced at the end of 1920 by another, giving a larger scale. Reports are sent daily, weekly, and monthly to the Meteorological Office and published by them.

The insulation of the radium collector has proved satisfactory, even in lengthy spells of damp weather, and good records of variations of atmospheric potential have been obtained. The present method of using the electrometer, in which a constant charge is placed on the needle, one pair of quadrants connected to the variable potential and the other to earth, is not satisfactory, in that the maximum deflection is obtained with a potential of about 1,700 volts, whereas potentials exceeding this value frequently occur. It is proposed, therefore, to modify the method by connecting the variable potential to the needle, one pair of quadrants to a constant potential of about 100 volts and the other pair of quadrants to earth. To obtain sufficient sensitiveness, the present bifilar suspension will be replaced by a single suspension of phosphor-bronze. For maintaining the constant potential of 100 volts, a battery of Leclanché cells is being loaned by the Director of Scientific Research of the Admiralty.

The observations of barometers, thermometers, anemometers, rain-gauges and sunshine recorder are entered and reduced to date. On the photographic sheets the hourly ordinates are read off and reduced to the end of April 1921.

The following details of the weather refer to the year ended 1921 April 30. The mean temperature was $50^{\circ}\cdot 5$, or $1^{\circ}\cdot 0$ above the average of the 75 years 1841-1915. The highest temperature in the shade was $86^{\circ}\cdot 5$ on May 25, the only day on which the temperature exceeded 80° . The lowest temperature was $15^{\circ}\cdot 7$ on December 13, and on 33 days fell as low as $32^{\circ}\cdot 0$.

The mean temperature for January was the highest recorded during the last 80 years, as that also was for the four months January to April inclusive. July and August were decidedly cool, $3^{\circ}\cdot 0$ and $3^{\circ}\cdot 7$ respectively below the 75 years' average (1842-1916), while January and March were above the average by $7^{\circ}\cdot 5$ and $4^{\circ}\cdot 2$ respectively.

The mean daily horizontal movement of the air was 266 miles, which is 18 miles below the average of the 50 years, 1867-1916. The greatest daily movement, 895 miles, was recorded on January 18, and the least, 24 miles,

on October 22. The greatest pressure on the square foot was 25·7 lbs. on May 18; the greatest velocity in one hour, 45 miles, was registered on January 18 for two consecutive hours.

The duration of bright sunshine registered by the Campbell-Stokes instrument was 1,536 hours, out of a possible 4,456 hours, or 34·5 per cent.

The rainfall was 18·77 inches, or 5·47 inches below the average for the period 1841–1915. The number of rainy days (0·005 inch or over) was 153. The driest month was February with 0·12 inch and the wettest month September with 3·44 inches. July with 3·23 inches was the only other month not showing a deficiency compared with the normal.

V.—Printing and Distribution of Greenwich Publications :—

The volume for 1915 and the separate results have been distributed. The Star Catalogue for 1910 has also been distributed. The results of Seven Years' Observations (1911–1918) with the Cookson Floating Telescope are printed and ready for distribution.

The Volume for 1916 is in type, except the Introduction, which is in the printer's hands. The fourth volume of the Astrographic Catalogue is in the same state of progress.

The printing of the Catalogue of Double Stars has made good progress. About three sheets, the manuscript of which has been sent to the printers, and the Introduction are required to complete the Volume.

VI.—Chronometers :—

The number of chronometers and watches belonging to the Admiralty now at the Observatory is 3,054. Of this total, 236 chronometers, 160 chronometer watches, 247 hack watches, and 64 pocket watches are being rated. The remainder, consisting of 243 chronometers, 1,221 chronometer watches, 392 hack watches and 491 pocket watches, are being kept in storage.

In addition to Admiralty chronometers, 17 chronometers are being tested for the Indian Government. There are also 52 chronometers and watches deposited at the Observatory, for various reasons.

During the year 8 new chronometers have been tested and purchased for the Indian Government.

In connection with the purchase of chronometers by the United States Shipping Board, 119 new chronometers and 3 second-hand chronometers have passed the requisite tests satisfactorily and have been dispatched.

During the year ended 1921 May 10 a total of 2,600 chronometers and watches have been received and 2,921 issued. The number sent for repair was 1,361, namely 1,291 for the Admiralty and 70 for the Indian Government.

The usual annual trials of chronometers and watches were discontinued during the war, but, in order to maintain the highest efficiency in the manufacture of chronometers, the annual trial will be reinstated during the current year.

The substitution of electric heating in the chronometer ovens has been completed during the year, and a small refrigerating plant for testing chronometers at low temperature has been erected. The ovens are working very satisfactorily, but the cold chamber has not yet been brought into regular use.

VII.—Time Service :—

The new Standard Clock, mentioned in the last report, was delivered at the Observatory by Mr. Cottingham on February 26 and is now under test. A clock made by Riefler, of Munich, purchased from the University of Manchester, was set up on July 30.

Daily time signals have been sent to the General Post Office without failure.

On one occasion—December 4—the time-ball was not raised on account of the violence of the wind. On six occasions—May 13, 15, June 19, 20, September 12 and December 12—the ball was not dropped correctly at 13^h owing to various causes. From September 13—September 16 the time-ball was out of use.

The 13^h signal from Greenwich failed to release the Deal time-ball on one occasion. On four days—June 14, November 14, January 19 and May 10—the Greenwich signal failed to reach Deal. On these dates the ball was released by hand.

The performance of the time-balls at the Admiralty Signal Stations and of the Westminster Clock is shown by the following table of the errors of the return signals:—

Error of Return Signal.	Portsmouth.	Portland.	Devonport.	Rosyth.	Westminster.
Not greater than $0^{\cdot}2$ - - - -	277	236	276	88	54
Between $0^{\cdot}2$ and $0^{\cdot}5$ - - -	3	9	12	8	62
„ $0^{\cdot}5$ „ $1^{\cdot}0$ - - -	1	2	2	5	82
Greater than $1^{\cdot}0$ - - - -	0	0	0	1	73

Of the 274 days of observation, the error of the Westminster Clock at midday never exceeded $3^{\text{s}}.0$. The clocks at Portsmouth, Portland, Devonport and Rosyth are corrected daily by the 10^h Signal; the Westminster Clock is not corrected daily.

The connection between Greenwich and Rosyth for return signal was brought into operation during the latter part of October.

Wireless time signals have been received regularly from the Eiffel Tower, Nauen, and Annapolis throughout the year, and observations have been made of signals from Lyons and Darien as often as possible.

Special series of rhythmic signals from Lyons, for longitude determination, were observed during the periods June 21–July 4, November 16–23, December 5–20 and April 20–May 10. During the last period special signals from Annapolis and Bordeaux were also observed.

A very low frequency amplifier, designed for operating a syphon recorder for registering time signals, was brought into use during November. The apparatus is suitable for the reception of wireless signals if transmitted by spark, or continuous wave from high frequency alternator. The Paris and Nauen signals are usually registered and the last three special series of rhythmic signals sent from Lyons for longitude determination in Australia were recorded.

VIII.—Personal Establishment :—

The permanent staff at the present time is constituted as follows :—

Chief Assistants.—Mr. Jackson, Mr. Jones.

Assistants.—Mr. Bowyer, Mr. Bryant, Dr. Crommelin, Mr. Davidson.

Clerical Assistant.—Mr. Edney.

Junior Assistants (Higher Grade).—Mr. Furner, Mr. Melotte, Mr. Witchell (acting Assistant).

Junior Assistants.—Mr. Acton, Mr. Barton, Mr. Chamberlain, Mr. Cullen, Mr. Jeffries, Mr. Martin, Mr. Newton, Mr. Stevens, and two vacancies.

Mr. Bowyer was promoted Assistant on June 11 with effect from January 10. Mr. Melotte was promoted to the Higher Grade of Junior Assistants on May 25 with effect from February 20. Mr. Barton was appointed Junior Assistant on July 2.

14 Computers, including 4 ladies, are employed at the Observatory.

The present arrangement of the staff under the general superintendence of the Chief Assistants is as follows :—

Branch.	Established Staff.	Unestablished Staff.
<i>Transit Circle and Altazimuth</i> -	Dr. Crommelin, Mr. Witchell, Mr. Cullen, Mr. Acton.	Mr. Kinnear, Mr. Longley, Mr. Fellows.
<i>Time Signals and Chronometers</i> -	Mr. Bowyer, Mr. Stevens - -	Mr. Rickett, Mr. Scott.
<i>Thompson Equatorial</i> - - -	Mr. Davidson, Mr. Martin - -	Miss Faulkner, Miss Jeffries.
<i>28-inch Equatorial</i> - - -	Mr. Furner - - - -	
<i>Astrographic Equatorial</i> - -	Mr. Melotte, Mr. Jeffries - -	Mr. Smith.
<i>Photoheliograph</i> - - - -	Mr. Newton, Mr. Bartou - -	Miss Crommelin, Mr. Woolford.
<i>Magnetic and Meteorological</i> -	Mr. Bryant - - - -	Miss Clack, Mr. Wells, Mr. Tibbitts.
<i>Secretariat and Library</i> - -	Mr. Edney, Mr. Chamberlain -	Mr. Cox.

The staff of workmen now employed consists of a foreman of works, two joiners a mechanic, a boy assistant mechanic, a gate-porter, two messengers, a night-watchman, a gardener, three labourers, and a charwoman.

IX.—General Remarks :—

The Observatory was honoured by a visit from His Imperial Highness the Crown Prince of Japan on the afternoon of Whit Monday, May 16, 1921. He was accompanied by Prince Kan-in and a number of distinguished Japanese Officers.

Mr. Luyten, of the Leiden Observatory, again worked at the Observatory during the summer. He was here from July 1 to October 18, engaged on the observation and the measurement of Clusters and Variable Stars.

Magnetic charts for the year 1922 are in course of preparation. Charts of declination were compiled in 1917, but not of horizontal force and dip. As no British charts for these elements have been issued since 1907, it has been decided to prepare charts for all three elements.

During the year much time has been occupied with the repair of instruments and the installation of new ones. For the workshop, a new lathe and milling machine have been provided. In connection with chronometers, there is the electrification of the ovens and provision of a cold chamber. Two new clocks, one by Mr. Cottingham and the Riefler clock bought from the Manchester University, have been set up in the Clock Room. The new Vertical Force Magnetograph replaces the one borrowed, and completes the equipment of the new Magnetograph House.

The ruling machine, which (with the exception of the screw) was made in the workshop, has solved the problem of making a sufficiently accurate micrometer for the parallax plates. A grating, for the determination of effective wave-lengths with the reflector, was made entirely in the workshop. The micrometer for measuring photometry plates has also been completely remodelled. These instrumental changes have in some cases originated with members of the Staff and in all cases have required care and attention. In particular, the installation of new clocks, ovens and cold chamber for chronometers, and various modifications of the reception of the wireless time signals, have involved much additional work during the year on the part of Mr. Bowyer. Reference may be made to the success he has attained in the mechanical record of wireless signals. The various instrumental changes have made a great call on the zeal and skill of the workmen and Mr. Woodman and his staff have responded admirably to the demands made upon them.

TO THE BOARD OF VISITORS, 1921 JUNE 4.

21

Another feature in this year's report which may be emphasised is the progress made in the printing. The Meridian Catalogue for 1910, Vol. IV. of the Astrographic Catalogue, the Discussion of seven years' observations with the Cookson Telescope, and the Double Star Catalogue summarise many years' work with the Transit Circle, Astrographic Equatorial, Cookson Telescope and 28-inch Equatorial. In addition the attempt has been made to give an adequate discussion of the observations.

Two new pieces of work have been embarked on during the year. The verification of the photographic magnitude scale for stars brighter than $10^m \cdot 0$, on account of its importance, has required much care. The measurements of effective wave-length were commenced with the view of determining the spectral type of faint stars. It is also of interest to determine the extent to which effective wave-length agrees with classification of stars according to spectra.

1921 *May* 23.

F. W. DYSON.