REPORT

OF THE

ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH.

Read at the Annual Visitation of the Royal Observatory, 1934 *June* 2.

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The Report here presented refers to the year from 1933 May 11 to 1934 May 10, and exhibits the state of the Observatory on the last-named day.

I.—New Instruments :—

The 36-inch Reflecting Telescope presented, with its accessories, by Mr. W. Johnston Yapp, has been completed and erected. The telescope and dome were constructed by Messrs. Sir Howard Grubb, Parsons and Co., and the building was erected by the Civil Engineer's Department of the Admiralty.

The mounting of the telescope is of the modified English form, that is the long polar axis is supported by piers at the north and south ends, the crosshead carrying the telescope being attached to the middle of the axis. The polar axis is long enough to permit of reversal under the axis. The telescope consists of a central heavy casting to which is attached, on the one side, the mirror cell, and on the other, the open work tube. The instrument can be turned by electric motors in either co-ordinate, quick and slow setting motions, in addition to guiding motions, being provided. The driving mechanism is of the Grubb pattern and incorporates important recent improvements by the makers.

The telescope is designed for use in Cassegrain form. The 36-inch mirror is made of glass and is of 15 feet focal length. Two alternative secondary convex mirrors, made of fused quartz, are provided. The larger of these is of 11 inches diameter and 75$\frac{3}{4}$ inches focal length. It is set 50$\frac{1}{2}$ inches inside the principal focus, giving an equivalent focal length of 45 feet. In this form it will be used with a slit spectrograph. The smaller convex mirror, of 7 inches aperture and 30 inches focal length, is set 30 inches inside the principal focus of the 36-inch mirror. It thus returns a parallel beam 6 inches in diameter which is fed into a slitless spectrograph.

The slitless spectrograph has been constructed by Messrs. Adam Hilger, Limited. Its construction is similar in principle to that which was made in the Observatory workshop some years ago and mounted on the 30-inch reflector. As a result of the experience gained the present spectrograph has been improved in detail. The 6-inch parallel beam from the telescope passes through a prism of 45° angle. The dispersed beam then falls on a 9-inch concave mirror of 36 inches focus and after reflection from a diagonal flat, the spectrum focusses on the photographic plate which is situated at the side of the spectrograph. The spectrum is broadened by an automatic device, the plate holder being moved by an electric motor and cam. Three cams are provided giving broadenings of $\frac{1}{3}$ mm., $\frac{1}{2}$ mm. and 1 mm.

The working tests of the new telescope have shown a highly satisfactory performance. In conjunction with the slitless spectrograph, work has been commenced on a programme of observations of the colour temperatures of stars, in continuation of the work which has been carried on under difficulties with the 30-inch reflector mounted on the Thompson Equatorial. The light grasp of the combination of telescope and spectrograph is very satisfactory. For a star of magnitude 3·0, a well-exposed spectrum is obtained with an exposure time of three minutes.

Plans for the construction of a slit spectrograph have been prepared. The spectrograph will have two prism systems, viz., one prism and three prisms. All the optical parts will be constructed of ultra-violet glass.

Satisfactory progress has been made with the construction of the new transit circle by Messrs. Cooke, Troughton and Simms, Ltd. The mechanical work is approaching completion and the important stage of dividing the circles, which are of glass and of 28 inches diameter, has been reached. The housing for the instrument, constructed by the Cleveland Bridge Company, has been erected. The housing is semi-cylindrical in shape, the axis of the cylinder coinciding with that of the transit circle. The interior diameter of the cylinder is 30 feet. Two shutters

can be opened to give an aperture of 8 feet width along the meridian. The housing is covered externally with copper sheeting and adequate thermal insulation is secured by a lining of compressed cork slabs, 3 inches thick. The motor and gear for opening and closing the shutters have been installed.

A linear thermo-couple, by Messrs. Kipp and Zonen, and a Paschen galvanometer, by the Cambridge Scientific Instrument Company, have been purchased. They will be used for the measurement of total line intensities in the solar spectrum; the south gallery of the Altazimuth building is being used as an observing room.

A cathode ray oscillograph and mains unit has been purchased from Messrs. A. C. Cossor, Ltd. In conjunction with a motor-driven film camera giving continuous motion and a time marking oscillator, it will be employed for the accurate registration of radio time signals and for the determination of the time lag in the receiving apparatus. The oscillator was designed and constructed by the Radio Department of the National Physical Laboratory.

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

A small building has been erected in the Enclosure containing the new transit circle building and the Yapp equatorial reflector. It forms an annexe to the Recording Room (formerly known as the Magnetograph House), and contains provision for the installation of the chronograph for recording the transit observations. Part of it will serve as an observers' rest room. The wooden structure in the enclosure, formerly known as the Magnetic Pavilion, has been demolished.

Various structural alterations were made to the interior of Flamsteed House consequent upon the change of occupancy; the house was also rewired and redecorated.

The cellar below Flamsteed House, adjacent to the existing clock cellar, has been prepared as a second clock cellar. The walls and ceiling have been rendered with cement, a new concrete floor and steps have been provided and a thick lagged door, to reduce leakage of heat, has been made.

The exteriors of several of the buildings, including the Octagonal Building and Flamsteed House, have been repainted. Internal re-decoration of the Transit Pavilion, Time Department Office, and Photoheliograph dome, has been carried out. The wooden staircase leading to the roof of the Octagonal Building has been repaired.

The Thompson Equatorial dome has been painted with aluminium paint. It is anticipated that this will prove more satisfactory than lead paint for the

papier-mâché covered domes and that a longer interval will elapse before repainting becomes necessary.

The dome of the Transit Pavilion had become very difficult to open owing to the rusting of the iron work in places where it was impossible to keep it painted; this caused the angle iron to twist and resulted in considerable friction on the running rails. The two halves of the dome were therefore jacked up, the bad portions of ironwork were cut away and new angle iron pieces were bolted on.

Owing to a crack appearing in the stone on which the small reversible transit, used for time observations, is mounted, a new stone has been substituted. At the same time, the top portion of the brick work of the pier was rebuilt.

Lightning conductors, conforming to existing Admiralty regulations, have been fitted to the exteriors of all domes and buildings.

A new electric main cable has been laid between the basement housing the transformer and the courtyard. This cable is supplementary to the old cable and its installation was necessitated by the increase in the amount of electric current used for heating and power in the older portion of the Observatory. Electric heating has been installed in the Transit Pavilion and will be used in damp weather for keeping the small reversible transit and its accessories dry.

A new engraved "staybrite" plate has been fixed outside the main entrance to the Observatory. It adjoins a flush bracket placed by the Ordnance Survey Department over an old bench mark cut on the wall, and gives the corresponding height above mean sea level at Newlyn (154·70 feet).

The pressure of the water supply having become unsatisfactory owing to deposits in the 6-inch main, the main was opened at several points and the deposit cleared. A satisfactory pressure is now obtained.

At Abinger the engines and main storage battery have been overhauled and minor internal decorations carried out to the dwelling house of the Assistant-in-Charge. The path from the entrance to the house has been made up and asphalted.

The following instruments which are in regular use have been lent to the Royal Observatory:—

The Cookson Floating Zenith Telescope, from the Cambridge Observatory, for a fourth period of seven years from July, 1932.

A 13-foot spectrohelioscope, complete with coelostat, but without grating, from the Mount Wilson 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 Schuster-Smith coil magnetometer for measurement of horizontal intensity, from the National Physical Laboratory.

A coil magnetometer, designed by the late Dr. W. D. Dye, F.R.S., for measurement of vertical intensity, from the National Physical Laboratory.

Three potentiometers with standard cells and resistances for measuring current supplied to the coil magnetometers, from the National Physical Laboratory.

The following instruments, borrowed for observation of the Solar Eclipse of 1932 August 31, are stored at the Royal Observatory.

16-inch coelostat and two spectroscope slits from the Royal Astronomical Society.

Two 16-inch coelostats, one 12-inch coelostat, a 15-inch concave mirror and a 4-inch concave grating from the Joint Permanent Eclipse Committee.

A 6-inch lens of 45-feet focus, from J. H. Worthington, Esq.

Several other smaller instruments are also on loan to the Royal Observatory.

The following instruments have been lent by the Royal Observatory :—

To the Royal Observatory, Cape of Good Hope—

Transit A : Altazimuth B : Object glass of photoheliograph No. 1 : Clocks, Dent 1916 and Dent 2013.

To the University Observatory, Oxford—

Clock Arnold No. 2.

To the Solar Physics Observatory, Cambridge—

Photoheliograph object glass No. 5.

To the Imperial College of Science and Technology—

6-inch equatorial, Simms No. 2 : Altazimuth A.

To the Meteorological Office—

Three variometers, one recording apparatus, a dip inductor, and an ammeter, for use at Fort Rae, N.W. Canada, during the International Polar Year 1932–33.

To the Science Museum—

Harrison's Time Machines Nos. 2 and 3, and a number of other instruments of historical interest.

The annual examination of the Library has been made. Thirteen books are reported missing and cannot be accounted for at present. Of these, nine were reported missing last year and three books, which have been missing for a number of years, are now assumed lost and have been written off. Four books which were missing last year have since been returned.

III.—Astronomical Observations :—

Transit Circle.—The Sun, Moon, planets and fundamental stars have been regularly observed. Progress has been made with the programme commenced in 1931.

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

Transits	10,973	Zenith Distances	10,434
Collimation	297	Nadir point	680
Level	704		

The Sun was observed on 148 days and the Moon on 100 days.

Transits are reduced as far as apparent place to April 29 and zenith distances to April 25.

The observations of the Moon continue to show a decrease in the correction to the longitude given by Brown's Tables which were introduced into the Nautical Almanac in 1923.

Year.	Longitude.		Latitude.		No. of observations.	
	Limb.	Mösting A.	Limb.	Mösting A.	Limb.	Mösting A.
	″	″	″	″		
1923 ..	+ 6·99	+ 7·47	− 0·36	− 0·43	101	60
1924 ..	+ 7·21	+ 7·14	− 0·62	− 0·39	87	54
1925 ..	+ 6·61	+ 6·71	− 0·67	− 0·55	90	52
1926 ..	+ 6·40	+ 6·55	− 0·48	− 0·72	93	66
1927 ..	+ 6·20	+ 6·24	− 0·50	− 0·71	80	43
1928 ..	+ 5·51	+ 5·88	− 0·73	− 0·46	97	60
1929 ..	+ 5·20	+ 5·89	− 0·58	− 0·60	108	67
1930 ..	+ 5·08	+ 5·40	− 0·73	− 0·63	82	47
1931 ..	+ 4·76	+ 4·87	− 0·82	− 0·71	69	46
1932 ..	+ 4·61	+ 4·56	− 0·81	− 0·77	85	57
1933 ..	+ 4·21	+ 4·10	− 0·56	− 0·60	96	61

The above values are referred to Newcomb's Equinox and adopted colatitude of 38° 31′ 21″·70.

The printing of the Second Greenwich Catalogue of Stars for 1925, from observations made over the period 1922–30 is in progress. The proof-sheets up to 19 hours of right ascension have been passed for press.

Cookson Zenith Telescope.—During the year, 218 plates were taken for latitude variation, and 5 for determination of scale. The results for 1933 were published in the *Monthly Notices* for 1934, March.

28-inch Equatorial.—During the year, 358 observations of 227 double stars were made. These consist of :—

75	double stars,	with	separation	$< 0''\cdot5$.
73	,,	,,	,,	$0''\cdot5$ to $1''\cdot0$.
58	,,	,,	,,	$1''\cdot0$ to $2''\cdot0$
21	,,	,,	,,	$> 2''\cdot0$

Thompson 26-inch Refractor.—The work on stellar parallax has been continued. 1,318 plates suitable for measurement were obtained. During the year, 968 plates were measured and the parallaxes of 32 stars determined. As in previous years, the output has suffered from the circumstance that the proximity of the object glass to the dome does not permit of the installation of a suitable dew-cap. In consequence, the frequent dewing of the objective during the winter months further restricts the observing programme at a time when the weather already imposes a handicap. The question of re-mounting the telescope in such a way that a dew-cap can be fitted is under consideration.

The proof sheets of " Observations of Stellar Parallax," Vol. 2, containing the parallaxes of 250 stars, have been passed for press.

30-inch Reflector.—With the 30-inch reflector attached to the Thompson mounting the work on colour temperatures has been continued. Attention has been concentrated on the re-determination of the zero point of the Greenwich standard system. In place of the acetylene burner formerly employed, the comparison source used was an " Osram " unifilar tungsten filament vacuum lamp which was calibrated at the National Physical Laboratory at the beginning and at the end of the programme. The spectrum of this was photographed with a laboratory spectrograph on plates which had been previously exposed on stars with the telescope. This procedure involved a frequent determination of the difference in the transmissions of the two optical trains. The comparison was effected with the aid of the acetylene burner whose spectrum was successively photographed with the telescope (the burner being then mounted on the roof of the Octagonal Building) and with the laboratory instrument. These observations revealed the progressive deterioration of the telescope mirrors throughout the period covered.

Apart from this, the programme followed in general outline the methods employed previously. Eighteen plates were exposed on stars on 12 selected nights,

and 29 plates were taken on 12 other nights for the comparison of optical trains. Thirty-three plates were taken for the determination of filter absorptions and other auxiliary quantities.

The measures and reductions have been completed and the results communicated in a paper to the *Monthly Notices* of the Royal Astronomical Society. They confirm the high temperature of the zero point previously obtained. The combined results of the two determinations give a colour temperature of 18,000° K. for A0 stars.

In addition, 21 comparisons of 10 stars with standard stars were obtained prior to the transfer of the colour temperature programme to the new Yapp reflector.

Yapp 36-inch Reflector.—The necessary adjustments to the telescope and the slitless spectrograph have been made and the instrument was brought into use on April 20. It will be devoted in the near future to the colour temperature work hitherto carried on with the 30-inch reflector. The superior optical performance and light grasp of the new instrument, its convenience in use, and the fact that it is not coupled on the same mounting with another instrument will greatly facilitate the work. Attention will be concentrated on stars of types O to A0 down to the fifth magnitude.

Up to the date of this report, 19 comparisons of 12 stars with standard stars have been secured on four nights.

Observations of Eros.—The measurements of the photographs taken in connection with the 1930–31 opposition is proceeding. In the last report it was stated that the measurement had been completed of the Greenwich series of plates taken for the purpose of obtaining positions of secondary comparison stars; these positions are required for the reduction of photographs of Eros obtained with long focus instruments. The measurement of the corresponding series of Cape plates, which had been forwarded to Greenwich is now in hand. There are 115 of these fields of which 82, involving some 5,400 secondary reference stars, have been measured. In general, two separate exposures of each star have been measured and each plate has been measured in the direct and reverse positions.

With regard to the plates exposed on Eros, the measurement of the Greenwich series of plates taken with the 26-inch refractor, consisting of 160 plates is complete. The Radcliffe series of 52 plates which had been sent to Greenwich has also been measured. The complete reductions of these measures must necessarily be postponed until definitive positions of the comparison stars are available. The measurement of the 200 Eros plates secured with the Astrographic equatorial at

Greenwich is now proceeding and 123 have been measured. It is found that there are appreciable errors in the positions of some of the primary reference stars as given in the catalogue prepared by Professor Kopff, based upon meridian observations at a number of observatories. From the measures of these stars on the series of path plates, obtained primarily for the derivation of the positions of the secondary comparison stars, it will be possible to obtain improved positions. The improved positions will be used for the final reduction of the astrographic plates.

Series of 42 plates of Eros, obtained at the Melbourne Observatory with the astrographic refractor and of 87 plates, taken at the Boyden Station (South Africa) of the Harvard College Observatory with the 24-inch Bruce refractor, have been received. The measurement of these plates has not yet been commenced.

The Eros plates are being measured with the long-screw micrometer constructed by Messrs. Adam Hilger. The comparison field plates are being measured against a réseau and the errors of the réseau have been determined with the long-screw machine.

Photoheliograph.—Photographs of the Sun were obtained on 271 days with either the Dallmeyer 4-inch photoheliograph or the Thompson 9-inch. The number of photographs selected for preservation is 545, including 42 with double images of the Sun for the determination of the zeros of position angle. The zeros of position angle have also been determined regularly by visual observations.

H.M. Astronomer at the Cape has reported that the Sun was photographed there on 339 days in the year 1933, and on 90 days in the first three months of 1934. The Director of the Kodaikanal Observatory has reported that plates were taken there on 332 days in the year 1933 and on 83 days during the first three months of 1934.

Photographs, in duplicate, have been received from the Royal Observatory, Cape of Good Hope, to 1933 November 11, and the single series to 1934 January 15. Six photographs have been sent from the Kodaikanal Observatory to complete the series for 1933.

The measurement of the combined series has been made from 1933 January 1 to 1933 November 11; the Greenwich plates have been measured to 1934 May 1. The reductions of positions and areas of spot groups and their principal components have been completed from 1933 January 1 to November 11 and the reductions of the Greenwich plates carried to 1934 April 19.

For the greater part of the epoch covered by this report sunspot activity has been slight, a large number of spotless days having been recorded during the six months commencing in mid-July. Recently, however, a large group of spots in latitude 29° south was visible from April 15 to 28. The occurrence of this group

and a small general increase in solar phenomena suggest that the sunspot minimum (if not already past, as appears probable) will be of brief duration. According to the Mt. Wilson determination of magnetic polarities, two small high-latitude groups seen on October 10 and October 29 to 31, respectively, belong to the new cycle, and during the last three months about a dozen small groups have appeared in high latitude (20° to 35°) in addition to the recent large group, whose area exceeded 1,000 millionths of the Sun's hemisphere.

Daily spot-numbers, both for the whole disc and for a central zone of the Sun, based on Wolf's method of counting, have been supplied quarterly to Zurich for incorporation in the *Bulletin for Character Figures of Solar Phenomena*, published under the auspices of the International Astronomical Union.

Photographic prints of solar negatives from 1933 January 1 to September 30 have been supplied to the Director, Solar Physics Observatory, Cambridge. A duplicate set of negatives for the year 1932 has been sent to the Science Museum, South Kensington.

A commencement has been made of a photographic reproduction, on bromide paper, of the series of solar negatives obtained at Greenwich from 1874, when photographs of the Sun were first regularly obtained, to 1903. Many of these early photographs are deteriorating, and there is also considerable difficulty in providing storage for the increasing bulk of glass negatives. These prints, which will occupy comparatively little storage space, are intended to replace the original negatives. Suitable cases, each holding about 150 prints, have been supplied by H.M. Stationery Office, and two steel presses, each one to contain 45 cases, have been supplied by H.M. Office of Works to ensure safe storage of the series. The number of prints made to date is 2,492, covering the period 1874 January to 1892 August.

Spectrohelioscope.—The Sun's disc was examined in Hα light with the spectrohelioscope on 190 days ; on about 25 days, observations were limited to a few minutes owing to cloud. A special watch was kept for bright eruptions of Hα on the disc, but only two of minor extent were recorded near sunspots on February 9 and April 20 respectively. Priority is also given to the observation of dark flocculi associated with sunspots, and 69 measures of radial velocity, out of a total of 450 measures made during the year, relate to these flocculi. The largest velocities measured were $-$ 80 km./sec. and $+$ 65 km./sec. It is of interest that the frequency curve given by the Greenwich observations of the radial velocities of dark flocculi associated with sunspot areas is in general accordance with that given by a recent theory of the solar chromosphere, developed by Dr. S. Chandrasekhar of Cambridge.

Sixty-nine measures of the light intensity of bright Hα flocculi relative to the adjacent background were made by means of an optical wedge placed between the viewing eyepiece and the rotating prisms of the spectrohelioscope.

Some exploratory observations have been made for the purpose of a comparison of solar phenomena in the light of Hα and Hβ respectively.

The four mirrors of the optical train of the spectrohelioscope have been coated with an aluminium film by Messrs. Adam Hilger, Ltd. The two mirrors of the coelostat are subjected to considerable exposure, and in the past it has been necessary to re-silver them every two months. The aluminium coating is not tarnished by the sulphur dioxide in the atmosphere and has a high reflecting power with very little scattering of the light incident upon it.

IV.—Magnetic Observations.

Regular magnetic observations have been made at Abinger throughout the year. The variations of declination, horizontal and vertical force have been recorded photographically. In connection with the "Second International Polar Year" the variations have been recorded on a time-scale twelve times as great as the normal scale (that is to say on a scale of 180 mm. to the hour) on four specified days in each month up to and including August 1933.

Absolute observations of declination, of horizontal force with the Schuster-Smith coil magnetometer, and of vertical force with the Dye coil magnetometer are made every week-day. The measurements both of the horizontal and vertical components of magnetic force are now dependent upon electrical standards, but observations of horizontal force with a unifilar magnetometer and of inclination with an inductor have been taken frequently, for purposes of comparison.

The Observatory is indebted to the National Physical Laboratory for periodical re-measurement of the electrical constants of the potentiometers which are essential accessories to the coil magnetometers. In connection with this re-measurement a duplicate potentiometer for use with the Schuster-Smith instrument has been kindly supplied by the Laboratory in order that no interruption to routine observation shall occur during the absence of the original.

As regards the reduction of observations, the mean hourly ordinates of all the traces have been read off to date. The reduction of absolute observations is complete to 1933 December 31, and with provisional constants to the present time.

The tabulation of results for 1933 is complete, and the copy for press is in the printer's hands.

The mean values of the magnetic elements at Abinger for the year 1933 are given below. The values for the years 1930, 1931 and 1932 are given for comparison.

	Decl. W.	Hor. Force.	Vert. Force.	Inclination.†
1930.. ..	12° 24′·6	0·18542	0·42924	66° 38′·2
1931.. ..	12° 13′·7	0·18544	0·42923	66° 38′·1
1932.. ..	12° 2′·6	0·18536	0·42940	66° 39′·1
1933.. ..	11° 51′.7	0.18532	0.42942	66° 39′·4

The weekly report of mean hourly values of declination has been sent regularly to several offices for publication or information—a service maintained in conjunction with Eskdalemuir Observatory.

A Kew pattern unifilar magnetometer has been tested after renovation for the Hydrographic Department of the Admiralty and the constants, including the moment of inertia of the inertia cylinder referred to the Greenwich standard cylinder, re-determined.

Five portable magnetic variometers for measuring changes of the vertical component of the earth's field have been examined for the determination and certification of their constants.

A re-determination has been made of the coil constant of the Smith portable coil magnetometer belonging to the Ordnance Survey Department. A certain number of observations were made with this instrument to test the equivalence as regards horizontal force of the central piers in the new hut and in the pavilion for absolute observations. An apparent difference of $+3\gamma$ for pavilion minus hut was found, but, owing to the fact that the magnetic conditions were unfavourable, further investigation is desirable.

V.—Meteorological Observations :—

The registration of atmospheric pressure, temperature of the air and of evaporation, the direction, pressure and velocity of the wind, the amount of rainfall, sunshine and cloudiness at night, has been maintained continuously. Estimates of visibility have been made by eye at definite hours.

Registration of the electric potential gradient of the atmosphere was discontinued at the end of June, 1933. Preparations are being made for the measurement, by a continuously recording photographic apparatus, of the earth-air current discharged

† These values are deduced from observations with the coil magnetometers, and are not derived from actual observation of the angle of inclination.

by a metallic point. The point will be mounted in the Enclosure on a pole 30 feet from ground level and will be earthed through a galvanometer. The apparatus is under construction in the workshop.

Regular observations for the measurement of atmospheric pollution by an automatic recording filter, as designed for the Committee for the Investigation of Atmospheric Pollution, and for the determination of the sulphur dioxide content of the atmosphere will shortly be commenced. The instrumental equipment necessary for these observations has been ordered.

As stated last year it has been necessary to remove the thermograph and the standard thermometer screen to temporary sites on account of new buildings. Permanent sites will be chosen when the new conditions can be studied as a whole from the point of view of meteorological suitability.

The tabulation of results for 1933 is complete and the copy for press is in the printer's hands.

The following details of the weather refer to the period of twelve months ended 1934 April 30 :—

The mean temperature was 50°·5 which is 1°·0 above the average of the 75 years 1841–1915. The highest temperature in the shade was 95°·8 registered on August 6. Temperatures exceeding 90° were recorded on four days, two in July and two in August. The lowest temperature was 22°·5 on February 3. Temperatures of freezing point or below were recorded on 55 days. The mean daily horizontal movement of the air was 265 miles, which is 20 miles below the average for 50 years 1867–1916. The greatest daily movement was 582 miles recorded on December 13 ; the least daily movement was 125 miles on January 1. The greatest motion in one hour, 36 miles, was recorded on January 14. The greatest pressure reached was 21·5 lbs. to the square foot, on January 14. The duration of bright sunshine recorded was 1,458 hours, or 32·6 per cent. of the possible total. There were 72 entirely sunless days, of which 44 occurred in the winter months, November to January. There were 41 entirely cloudless nights, that is, nights on which an unbroken trace of Polaris was obtained by the Night Sky Camera. The total rainfall was 16·96 inches, that is, 7·28 inches less than the average for 75 years 1841–1915, but measurable rain fell on 144 days. The wettest month was September with 2·81 inches. The driest month was February with 0·20 inch.

VI.—Time Service :—

Determinations of time have been made by a rota of three observers with the reversible transit instrument D fitted with an impersonal micrometer. Observations

were secured on 142 nights, including 45 nights during the period covered by the special longitude observations described below. The transits are now recorded on a syphon recording tape chronograph with a scale of 2·5 cm. per sec. The chronograph can be started or stopped by the observer at the instrument by means of a switch, so that the chronograph is not in operation during the interval between the observation of two stars. The mechanical relay previously in use for converting the breaks in the micrometer circuit into makes has been replaced by a thermionic valve circuit, to eliminate the time-lag of the mechanical relay.

A special programme of observations was carried out during the period 1933 September 15 to December 15, in connection with the International Longitude Programme planned by the International Astronomical Union and the International Union for Geodesy and Geophysics. During this period, observations for time were secured on 45 nights, stars in the list prepared by the Joint Longitude Commission of the two Unions being observed. The results were corrected for the relative personal equations of the three observers, but no determination has been made of the absolute personal equation of the mean observer. The probable error of the time determination on a single night as judged both by internal evidence and by intercomparison of different nights was $0^s{\cdot}010$. The results of the time-determinations in connection with this programme and the observed times of reception of various time-signals have been communicated to the Bureau International de l'Heure, Paris, where the results obtained by the various co-operating observatories will be co-ordinated and discussed.

The free pendulum clock Shortt No. 3 was overhauled by the Synchronome Company in February and coils of higher insulation were fitted in all its circuits. The upper face of the clock casing being far from plane and never having been ground to the glass bell-jar, difficulty had always been experienced in securing an air-tight joint after the clock case had been opened. The opportunity provided by the overhaul of the clock was used to have the bearing face properly surfaced and the bell-jar ground to the face. This was done by the workshop staff and an air-tight joint is now easily obtained.

Creed relays were installed in November for operating all standard sidereal clock circuits. These relays have a very small time-lag and they have all been adjusted to give as nearly as possible equal time-lag.

The service of rhythmic time signals at 10^h and 18^h transmitted through the Post Office wireless station at Rugby, and also the daily time signals to the General Post Office and the British Broadcasting Corporation, have been transmitted

regularly. The free pendulum clock, Shortt No. 16, controls the mean time clocks used for the Post Office and Broadcast signals, in addition to the rhythmic signal transmitter.

The corrections to the transmitted times of the rhythmic signals for adjustment to the final time determinations are published and distributed periodically by the Hydrographer of the Navy in "*Notices to Mariners*".

The performance of the time balls at the Admiralty Signal stations and also the Westminster Clock is shown by the following table of the errors of the return signals.

Error of Return Signal.	Portsmouth.	Portland.	Devonport.	Westminster.
Not greater than $0^s \cdot 2$	223	51	232	105
$0^s \cdot 3$ to $0^s \cdot 5$	0	0	2	86
$0^s \cdot 6$ to $1^s \cdot 0$	0	1	1	74
Greater than $1^s \cdot 0$	2	1	0	27

The return signal from Portland was discontinued after August 31 when the Time Ball was dismantled.

The clocks at the Admiralty stations are corrected daily by the 10^h signal, but the Westminster Clock is not so corrected.

Radio time signals are received regularly from the Eiffel Tower, Nauen, Bordeaux and, when possible, from Annapolis. These are registered automatically, and the corrections found for the Nauen, Bordeaux and Annapolis signals are published monthly for distribution in "*Notices to Mariners*", together with the corrections to the Rugby signals.

A cathode ray oscillograph apparatus embodying mains unit for operation of tube, square wave oscillator for time scale, and recording camera of cinema type has been obtained and is now in process of assembling for the purpose of eliminating time-lags in the recording of radio time signals.

Preliminary work in this connection carried out in November with a Duddell oscillograph lent by the Professor of Physics of the Royal Naval College, Greenwich, showed that with the present syphon recorder a time-lag of $0^s \cdot 01$ existed in recording a radio time signal relative to the recording of the standard clock beat.

The following table gives the monthly means of the differences from Greenwich shown by the various time signals, using the final clock errors derived from

observations made with the small reversible transit instrument D at Greenwich, and the corrections for final time determinations published by Paris, Hamburg and Washington Observatories.

The Annapolis signals have been corrected for lag of land line to Washington and by $0^s \cdot 02$ for time of travel. A correction of $0^s \cdot 01$ has been applied to all signals for lag in reception. Relative personal equations have been applied to the time observations from September 15.

1933.	Paris $9\frac{1}{2}^h$ Rhythmic.	Nauen 12^h Rhythmic.	Annapolis 17^h.	Bordeaux 20^h Rhythmic.
	s.	s.	s.	s.
January	− ·033	+ ·005	+ ·034	− ·017
February	− ·010	+ ·001	+ ·029	+ ·004
March	− ·020	− ·005	− ·005	− ·005
April	− ·027	− ·011	− ·007	− ·012
May	− ·030	− ·015	− ·018	− ·014
June	− ·041	+ ·012	− ·024	− ·032
July	+ ·012	+ ·011	− ·007	+ ·017
August	− ·028	+ ·003	− ·010	− ·016
September	− ·044	− ·001	− ·018	− ·036
October	− ·031	·000	− ·043	− ·020
November	− ·000	+ ·017	− ·031	+ ·006
December	− ·041	− ·018	− ·012	− ·031
Mean	− ·024	·000	− ·007	− ·013
Number of comparisons	302	292	231	355

The sign + means late on Greenwich. The reference point for all comparisons is the commencement of the signals. The Nauen times have been referred to the Eichelberger system of star places.

VII.—Chronometers :—

The number of chronometers and watches belonging to the Admiralty now at the Observatory is 2,514. Of this total, 193 chronometers, 216 chronometer watches, 273 hack watches and 50 pocket watches are being rated. Five are in regular use in the Observatory. The remainder, consisting of 424 chronometers, 952 chronometer watches, 247 hack watches and 154 pocket watches, are kept in storage.

In addition to Admiralty chronometers there are 33 chronometers and 31 watches deposited at the Observatory for various reasons.

During the year ended 1934 April 30, a total of 1,997 chronometers and watches has been received and 2,458 issued. The number sent for repair was 1,336, viz.,

1,297 for the Admiralty, 36 for the Indian Government, 2 for the New Zealand Government, and 1 for the Royal Air Force.

During the year, 2 chronometers, 21 chronometer watches, 4 hack watches, and 411 pocket watches have been sold out of surplus stock.

VIII.—Printing and distribution of Greenwich Publications.

The distribution of the Volume of Greenwich Observations for 1931 and its separate parts, together with Volume VI of the Greenwich Astrographic Catalogue has been completed. The volume for 1932 and its separate parts have also been distributed.

The proofs of Volume II of Observations of Stellar Parallax have been passed for press and the Second Greenwich Catalogue of Stars for 1925 is nearly all in type. Both these volumes are being produced by photo-lithographic process.

Considerable delay in the publication of these volumes has resulted from the use of this process and the amount of proof correcting required has proved to be much heavier than with ordinary printing. Now that the contractors have gained experience, it is not anticipated that future publications produced by this process will involve such difficulties as have been encountered in the production of these two volumes.

Part of the MSS of Greenwich Observations 1933 has been forwarded to H.M. Stationery Office for printing.

IX.—Personal Establishment :—

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

Chief Assistants.—Mr. Greaves, Dr. Woolley.

Assistants.—Mr. Bowyer, Mr. Davidson, Mr. Furner, Mr. Witchell.

Junior Assistants (Higher Grade).—Mr. Acton, Mr. Cullen, Mr. Melotte, Mr. Stevens.

Junior Assistants.—Mr. Barton, Mr. Chamberlain, Mr. Finch, Mr. Jeffries, Mr. Martin, Mr. Newton, Mr. Rickerby, Mr. Rickett, Mr. Symms and Mr. Wells.

Clerical Assistant.—Mr. Edney.

20 Computers, including 7 ladies, are employed at the Observatory.

Dr. R. v. d. R. Woolley was appointed to succeed Dr. J. Jackson as Chief Assistant on June 1.

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

Branch.	Established Staff.	Unestablished Staff.
Transit Circle and Zenith Telescope.	Mr. Furner, Mr. Cullen, Mr. Acton, Mr. Symms.	Mr. Slator, Mr. Blackwell, Mr. Malyon, Mr. Diston, Mr. Larkin, Mr. Grimwood, Mr. Stockwell.
Time Signals and Chronometers	Mr. Bowyer, Mr. Rickett ...	Mr. Harris, Mr. Shortland, Mr. Rudd.
Thompson and Yapp Equatorials.	Mr. Davidson, Mr. Martin ...	Miss Jeffries, Miss French.
28-*inch Equatorial*	Mr. Furner	—
Astrographic Equatorial ...	Mr. Melotte, Mr. Jeffries, Mr. Finch.	Miss Cumberledge, Miss Moore.
Photoheliograph and Spectrohelioscope.	Mr. Newton, Mr. Barton ...	Mr. Howes, Miss Fine.
Small Transit	Mr. Finch	
Magnetic and Meteorological ...	Mr. Witchell, Mr. Stevens, Mr. Wells, Mr. Rickerby.	Miss Clack, Mr. Dennis, Mr. Deeks.
Secretariat and Library ...	Mr. Edney, Mr. Chamberlain ...	Miss Brickman.

The staff of workmen now employed consists of a foreman of works, two joiners, a mechanic, a gate porter, three messengers, two of whom perform in turn the duty of night watchman, a gardener, four labourers and a charwoman. There is also a mechanic at Abinger who has charge of the engines and acts as caretaker.

X.—General Remarks :—

The Astronomer Royal attended the meeting of the International Union for Geodesy and Geophysics held in Lisbon in September.

Mr. Jolly, of the Ordnance Survey Department, and Dr. Bullard, of the Department of Geodesy and Geophysics, Cambridge, made some further gravity observations at the Observatory in May.

Dr. de Graaff Hunter, formerly Director of the Geodetic Branch of the Survey Department of India ; Dr. E. Stenquist of the Upsala Observatory and Dr. P. S. Lall of the Punjab University Observatory studied some of the work of the Observatory during the year.

Lieut.-Comdr. W. I. Farquharson, R.N., visited Abinger for a course of instruction from June 26 to June 30.

The copies of the Standard Yard and Pound, kept at the Royal Observatory, were returned on April 17 by the Standards Department of the Board of Trade after comparison.

Special attention has been given during the year to the improvement of the time determinations. Relays of uniform pattern and of extremely small time-lag have replaced a miscellaneous series of relays whose time-lags were not negligible and were probably variable. The mechanical relay used for converting the break circuit from the transit micrometer into a make circuit for chronographic registration has been replaced by a valve relay. A syphon recording tape chronograph has been substituted for the barrel chronograph, the moving parts of which possessed considerable inertia. Preliminary determinations of the time-lag in the reception of the radio time signals have been made. Observations for time determination have been made more frequently and shared by three observers with a view to detecting the irregular variations of small amplitude in the errors of the standard clocks.

A cathode ray oscillograph and a moving film camera will in future be the standard method of recording the radio time signals and comparing with the clock signals. Valuable assistance has been received from the Superintendent of the Radio Department of the National Physical Laboratory in the choice of the best method of eliminating the lag in reception of the radio time signals ; the time marker for impressing suitable time marks at intervals of $0^s{\cdot}01$ on the moving film was designed and constructed in the Radio Department. It is intended to construct in the workshop a personal equation machine for the determination at frequent intervals of the personal equation of the mean observer.

The re-determination of the zero point of the Greenwich colour temperature scale was an important investigation which was undertaken and completed during the year. Absolute work of this nature is carried out in the face of great difficulties at Greenwich ; the different atmospheric conditions north and south of the Observatory and the rapid yellowing of the silvered mirror due to the high sulphur dioxide content of the atmosphere are complicating factors which would be avoided to a large extent in a more favourable situation. The various sources of error which might influence the results were carefully considered and were controlled where they could not be eliminated. The results confirm the earlier determination in indicating that the colour temperatures of the stars are considerably higher than the values

which have been generally accepted hitherto. The observations of colour temperatures, referred to the zero point derived from the two determinations, will be continued with the Yapp 36-inch reflector. The few observations which have been obtained with this instrument since the preliminary adjustments were completed have already shown the instrument to be convenient in use and of excellent optical quality.

H. SPENCER JONES.

Royal Observatory, Greenwich.
1934 May 15.

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