REPORT

OF THE

ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH.

Read at the Annual Visitation of the Royal Observatory, 1936 *June* 6.

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The Report here presented refers to the period from 1935 May 1 to 1936 April 30 and exhibits the state of the Observatory on the last-named day.

I.—New Instruments :—

Reversible Transit Circle.—Reference was made in last year's Report to modifications found to be necessary to the counterpoise system of this instrument. As originally constructed, the weight of the instrument was relieved from the pivots by means of springs and rods acting through self-aligning swivel stirrups, which pressed upwards on to the axis, ball journal races making line contact with a fitting on the axis to reduce friction. The springs were adjusted, calibrated, and fitted with a scale and pointer to indicate the amount of weight relieved. Both supporting rods and springs were carried from the azimuth adjustment plate.

With this form of counterpoise the readings given by the instrument were not consistent. When, for instance, the instrument was set on the nadir and the microscopes were read, then on rotating the instrument through 360° and again setting on the nadir, a different reading was obtained on the microscopes. This indicated that the weight-relieving gear exerted a constraint on the instrument. Some modifications to the gear were made which reduced, but did not entirely eliminate,

the inconsistencies in readings. This method of relieving the weight from the bearings was therefore abandoned. A new counterpoise system was made in which the instrument is supported within anti-friction collars by two chains, attached to the ends of counterpoised lever arms. Each counterpoise consists of a large fixed weight and an adjustable weight, sliding along a calibrated arm ; by the adjustment of this weight, the weight on the corresponding bearing can be varied within a range from zero to 50 lbs. The weight-relieving gear is supported from the piers, below the micrometer blocks, so that there is no tendency for these blocks to be strained. With this self-equilibrating method of relieving the weight from the pivots, the inconsistencies in reading are no longer obtained.

The erection of the instrument was commenced on February 6 and was practically completed by the end of March. The piers have been filled with an anti-freezing mixture, consisting of two parts of ethylene glycol to five parts of water. About 140 gallons of the mixture were required in each pier.

The adjustments for level and azimuth are conveniently and easily made on the base-plates of the instrument. The level is adjusted by means of a wedge, operated by a screw with a pitch of 16 threads to the inch, which raises or lowers one side of the upper base-plate carrying the piers. One revolution of this screw corresponds to a change in level of 5 seconds of arc. The azimuth is adjusted by a screw on the east side of the lower base-plate, which turns this plate, and the instrument with it, about a pivot on the west side. One revolution of the azimuth screw head is equal to five seconds of arc. The level and azimuth errors were reduced to small amounts by preliminary obsevations and adjustments. The collimators were then carefully levelled and aligned, and fixed in position on their respective piers.

A series of observations of collimation have been made (*a*) by observations of both collimators ; (*b*) by observation of either north or south collimator, before and after reversal of the instrument in its bearings ; (*c*) by observation of the nadir, before and after reversal in its bearings. The lines of collimation determined by methods (*a*) and (*b*) were in agreement but differed systematically (by about 0·6 seconds of arc) from that determined by method (*c*). This indicates a slight difference in the diameters of the two pivots.

Preliminary tests of pivot errors have been carried out and have shown that the pivots are slightly elliptical in shape. Further lapping of the pivots will be made to reduce both the difference in the diameters of the pivots and their ellipticity.

The wiring of the transit pavilion was postponed until the instrument had been erected, in order that the most suitable position of the lamps for the general illumination of the micrometer heads could be decided. The wiring has now been completed.

Slit Spectrograph.—Satisfactory progress has been made with the construction, by Messrs. Adam Hilger Ltd., of a slit spectrograph for use with the Yapp 36-inch reflector. In addition to the details mentioned in the last Report, a departure is being made from the standard practice of broadening the spectrum by trailing the star image on the slit. A plane parallel plate of ultra-violet glass will be mounted immediately behind the slit and will be rocked through a small angle by an electric motor and cam.

Free Pendulum Clock.—The construction of this clock, which is being presented to the Observatory by Mr. H. R. Fry, F.R.A.S., is approaching completion. The slave clock is of more refined construction than the standard pattern and is fully jewelled throughout. Experience has shown that the performance of one free pendulum may be consistently better than that of another; thus, the sidereal free pendulum No. 3 performs consistently better than No. 11 and the mean time free pendulum No. 16 performs consistently better than No. 49. Mr. Fry's own free pendulum, No. 40, having given a high standard of performance for 4 years, Mr. Fry has generously allowed it to be used for the new clock. The bob has been repinned to change from mean seconds to sidereal seconds and a steel suspension spring, similar to that in use in Shortt No. 3, has been substituted for the elinvar spring.

Time will be taken directly off the free pendulum by a photo-electric method. The pendulum carries, below the bob, a plate in which there is a narrow rectangular aperture, 1·5 mm. in width. An image of the filament of a low-voltage lamp is thrown on to a narrow slit by means of a condensing lens. An image of this slit is formed in the plane of the plate on the pendulum by a specially constructed lens, achromatised for λ 7000, the light passing through an optically plane parallel window in the case. A second window is fitted diametrically opposite and the photo-electric cell is mounted behind this window. The current from the photo-electric cell is amplified by a thermionic relay and the output from this relay can be used for the distribution of time. The time of rise to maximum of each signal is one milli-second, this time being determined by the width of the slit; the duration of the signal, about 20 milliseconds, is determined by the width of the aperture in the pendulum plate.

As, with this design, the time taken directly from the free pendulum can be distributed throughout the observatory, the proposed special time indicating and distributing clock is no longer required. This portion of the original plan has therefore been dropped.

A specially designed case is being made for the free pendulum by Messrs. Metropolitan Vickers Ltd. All glass to metal joints will be finished to optical limits and the case will be submitted to the tests customary in high-vacuum technique. For convenience in mounting the optical system, the pendulum will swing at right angles to the wall. The case will be supported by two trunnions, which will be carried by two triangular self-aligning brackets, fixed to the wall. A third bracket, fixed to the wall, defines the position of the lower end of the case. This method of mounting the case was designed by Mr. Shortt.

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

A new building for housing the Cookson zenith telescope has been erected in the Christie Enclosure adjacent to the south collimator house of the reversible transit. The central section of the roof is mounted on wheels, running on rails. This section can be opened or closed by turning a handle inside the building, which, through bevel gearing and appropriate shafting, turns sprocket wheels on the north and south sides of the building. These wheels engage in roller chains, whose ends are attached to the movable portion of the roof. The wiring of the building is now in progress.

Paths have been laid in the Christie Enclosure between the several buildings and the gateway.

Consequent upon the alterations to the 26-inch refractor, described on p. 12, the greater portion of the gallery and the false floor surrounding the base of the instrument have been removed. The whole of the electrical circuits in the dome and the adjacent dark rooms have been rewired and internal decorations have been carried out.

A survey of the photoheliograph dome showed that it was in a dangerous condition. The covering of the dome was therefore stripped off, new wooden formers were made and fitted and covered with new zinc panels.

A fluctuation in the general lighting in the observatory which occurred at the times when the compressor, for the refrigerating plant of the chronometer testing

cold chamber, was in operation, proved very troublesome when any of the measuring machines or the photometer were in use. To eliminate this fluctuation, an independent 220-volt transformer was installed to supply the Brook's main. This has proved to be satisfactory.

The greater portion of the boundary fence on the west side of the Observatory has been renewed.

A new sectional boiler has been installed, for heating the chronometer store, wireless room and record room.

The dome housing the 26-inch refractor has been repainted externally with aluminium paint.

The external painting of the following buildings has been completed : South-east building and covered way, New Store, Altazimuth, Porter's Lodge. The water tower at the Magnetic Observatory, Abinger, has been repainted.

The internal redecorations of the following portions of the Observatory have been completed : the Octagon Room, Ball Lobby and Staircase, the Transit Circle Room, Chronograph Room, passage leading to Time Department, Porter's Lodge, Magnetograph Building in Christie Enclosure. At the Magnetic Observatory, Abinger, the garage, store, engine and battery rooms, the magnetic pavilion, old testing hut and portions of the Assistant's and Caretaker's quarters have been redecorated.

A fence has been erected along the north boundary of the Magnetic Observatory Abinger.

The main battery at Abinger has been overhauled and sludge removed. All pendant wiring has been renewed.

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

A 4-inch concave grating 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.

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

The following instrument, borrowed for observation of the Solar Eclipse of 1932 August 31, is stored at the Royal Observatory :—

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

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—

A dip inductor for use at Lerwick Observatory, Shetland Islands.

To the Science Museum—

A number of astronomical instruments of historical interest.

To the Hydrographic Department of the Admiralty—

Harrison's Time Machines Nos. 1, 2, 3 and 4, and the copy of No. 4 by Larcum Kendall. (For exhibition at the Science Museum.)

A declination variometer, with recording mechanism, was loaned for a few months to Professor E. H. Lamb, of Queen Mary College, to make observations in connection with the proposal to extend a tube railway from Liverpool Street into

Essex, passing beneath the college site. Professor Lamb has reported that, as a result of the observations made with the variometer, a clause has been inserted in the Bill promoted by the London Passenger Transport Board, which will ensure satisfactory protection of the physical laboratories of the College from disturbances.

The annual examination of the Library has been made. Thirteen books are reported missing and cannot be accounted for at present. Of these, seven were reported missing last year.

III.—Astronomical Observations :—

Transit Circle.—The Sun, Moon, planets and fundamental stars have been regularly observed. Observations of the programme commenced in 1931—containing all stars down to $7^m \cdot 5$ in the Draper Catalogue between 0° and +24°, as well as the stars in Boss's Preliminary General Catalogue between declination +64° and the pole—have been continued and have made good progress.

During the year, 9,899 transit observations and 9,409 observations of zenith distance were obtained. These include the following :—

127 observations of the Sun
100 ,, ,, Moon

Major Planets.		Minor Planets.	
Mercury ..	10 observations	Pallas ..	3 observations.
Venus	39 ,,	Juno ..	13 ,,
Mars	8 ,,	Vesta ..	19 ,,
Jupiter ..	11 ,,	Hebe ..	7 ,,
Saturn ..	25 ,,		
Uranus ..	14 ,,		
Neptune ..	9 ,,		

The observations of the Sun, Moon and planets are published yearly in the *Greenwich Observations*. A copy of these results for the year 1935 is being prepared for the printer.

The observations of the Sun continue to show an approximately constant

correction to the right ascension given by Newcomb's Tables. The mean corrections to the Tables, indicated by the observations during recent years are as follows:—

Year.	Correction.	Year.	Correction.
1923	+ 0ˢ·106	1930	+ 0ˢ·116
1924	+ ·113	1931	+ ·117
1925	+ ·114	1932	+ ·087
1926	+ ·118	1933	+ ·101
1927	+ ·113	1934	+ ·097
1928	+ ·114	1935	+ ·107
1929	+ ·109		

An amount + 0ˢ·050 of these corrections is accounted for by the correction of − 0ˢ·050 known to be required to the position of the equinox adopted by Newcomb. The remaining portions are attributable to defects in Newcomb's theory, to the effect of variations in the rate of rotation of the Earth and to errors of observation.

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
1934 ..	+ 3·98	+ 3·33	− 0·49	− 0·46	103	64
1935 ..	+ 3·15	+ 3·26	− 0·71	− 0·48	97	61

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

Observations of the Sun, Moon and inner planets can be used for fixing equinox and equator point but in each case the observations are liable to systematic errors

larger than, and different from, those to which star observations are liable. The brighter minor planets have the advantages of star-like appearance and they can be observed at night along with the stars and under the same conditions. Unfortunately the theories of the motions of these planets have not been developed with sufficient accuracy. Vesta has been observed for some years at Greenwich, as a general theory of its motion had been worked out by Leveau. Though this theory was imperfect and not of the accuracy required, there existed the possibility of the revision of the theory. Much attention has recently been given to the possibility of the use of minor planets for fixing equinox and equator point. Theories of the four brightest of the minor planets, and of certain fainter ones, are being developed by Russian astronomers. The regular observations with the transit circle of the brighter minor planets has therefore been resumed at Greenwich. Observations will be extended over as long a period as possible both before and after opposition, subject to the planet being bright enough for observation with the moving wire micrometer. In addition to these observations, photographic observations of selected minor planets will be made with the astrographic telescope.

The general theory of the motion of Vesta, as developed by Leveau, has recently been revised by Voronov and extended to include perturbations of the second order of the mass of Mars and of the third order of the masses of Jupiter and Saturn. The following is the comparison of the positions of Vesta, observed in 1935, with the positions based on the theories of Leveau and Voronov respectively :—

Observed *minus* Tabular.

Theory		R.A.	Dec.	Longitude.	Latitude.
Leveau	..	$-0^{s}\cdot204$	$-0''\cdot25$	$-2''\cdot81$	$+0''\cdot89$
Voronov	..	$+0\cdot026$	$-1\cdot52$	$-0\cdot24$	$-1\cdot54$

The results are based upon 19 observations in right ascension and 20 in declination.

The observed positions agree better with Voronov's theory than with Leveau's theory in right ascension, but show a large discordance in declination. This discordance is most unexpected, as the theory was believed to be exact to the order of $0''\cdot02$, and the comparison between observation and theory, given by Voronov in *Ast. Nach.* No. 6093, showed no mean residual in declination exceeding $0''\cdot34$ at any opposition from 1807 to 1932.

The ledgering of the observations made since 1931 January 1 is complete to 1933 June 2.

Cookson Zenith Telescope.—During the year, 328 plates were taken for latitude variation, and four for the determination of scale.

As soon as the new house for the instrument, in the Christie Enclosure, is completed, the telescope will be dismantled, overhauled and erected again in the new position. Observations, according to the new programme mentioned in the last report, will then be commenced.

The definitive reductions of the observations for the period from 1927·0 to the termination of the present observing programme have been commenced. Terms to represent the systematic effect of the direction of the wind on the observed latitude and a possible dependence of the latitude upon the strength of the wind are being included in the reductions.

28-inch Equatorial.—During the year, 73 observations of 68 double stars were made. These consist of :—

3	double stars,	with	separation	$< 0''\cdot5$.
21	,,	,,	,,	$0''\cdot5$ to $1''\cdot0$.
32	,,	,,	,,	$1''\cdot0$ to $2''\cdot0$.
17	,,	,,	,,	$> 2''\cdot0$.

Thompson 26-inch Refractor.—In previous reports reference has been made to the cramped conditions of the telescope in its dome and their detrimental effect on the work. It was decided to reconstruct the mounting of the instrument and extensive alterations were carried out during the summer months by Messrs. Sir Howard Grubb, Parsons and Co. A section, two feet long, was removed from the upper part of the tube and a corresponding extension added to the breech end. A sliding dewcap was installed which protects the object glass from dew on quiet moist nights, but which can be retracted on windy nights. At the same time the driving clock was replaced by a synchronous electric motor, the driving arc re-ratched and lapped, and the driving worm renewed. Also, a fan for ventilating the telescope tube was fitted.

This reconstruction has necessitated the removal of the false floor in the dome, and this has led to greater floor space and enhanced convenience. The 9-inch photoheliograph has been transferred to the other end of the declination axis and is now mounted on the 30-inch reflector.

Subsequent experience has amply justified the alterations. For the first time there has been no loss of work during the winter months from dewing of the object glass, and there is a distinct improvement in the average definition of the photographs. This is attributed to the more protected condition of the object glass, and to the

ventilation of the telescope tube. The synchronous motor drive has been found most satisfactory. Less work falls on the Grubb controls than was the case with the weight driven clock. As regards the steadiness of the electric supply, the maximum departure of the motor from true rate is about one half of one per cent., and the departure is usually less than one fifth of one per cent.

In consequence of the reconstruction work, the instrument was out of use from June 17 to October 21. During the remainder of the year the work on stellar parallax was continued, and 531 plates suitable for measurement were obtained. 907 plates were measured and the parallaxes of 32 stars determined.

A start has been made on the determination of the proper motions of stars whose parallaxes have already been measured, and for which an interval of not less than 10 years has elapsed since the first plates. It is proposed to expose two further plates on each star, giving proper motions with a probable error of $\pm$ 0″·003 per annum. The repeat plates are exposed through the glass and are coated on patent plate glass. 13 plates, for this purpose, have already been taken.

Yapp 36-inch Reflector.—The colour temperature work on stars of types O to Go has been continued and during the year 217 comparisons of 92 stars with standard stars have been secured. The plates are calibrated in the laboratory by a multiple slit spectrograph, the ratios of the slit-widths being measured by the method of full and half aperture.

An investigation has been made of the applicability of the laboratory calibrations to the photometry of spectra obtained with the telescope. The conditions of exposure are very different. The calibration exposures are continuous and those made at the telescope are intermittent since the spectrum is broadened by trailing the star image. Further, in the laboratory calibrations, a fixed exposure time of 20^s is used whilst a variety of exposure times are employed at the telescope. To investigate the effect of these differences a series of 40 plates was secured. These were exposed on stars at the telescope using the method of full and half apertures and employing a variety of exposure times ranging from 20^s to 540^s. They were calibrated with the multiple slit spectrograph in exactly the same way as the programme plates, and correcting factors were derived applicable to magnitude differences measured with the laboratory calibrations. The correcting factor f was found to be

$$f = 0{\cdot}89 + 0{\cdot}075 \log t$$

where t is the telescope exposure in seconds. The magnitude differences derived

with the aid of the calibrations are to be divided by this factor. Fuller details have been published in *The Observatory* for 1936 January.

Of the series of 42 plates exposed in the previous year on Nova Herculis 1934, nine plates, selected as being taken at typical stages in the development of the Nova have been measured. Measurements were made in the spectral regions near Hα, Hβ, Hγ and Hδ, and the relative distribution of energy in the continuous spectrum at these wave lengths derived. The lines Hα, Hβ and Hδ were contoured and their intensities obtained. Amongst other results it was found that the total absolute output of energy in the Hα line did not follow the variations in the apparent visual magnitude in the Nova. It attained a maximum in 1935 February some two months subsequent to the visual maximum. The results have been published in the *Monthly Notices* for 1936 March.

In December the small cassegrain mirror, and the mirrors in the optical train of the slitless spectrograph, were aluminized by Messrs. Metropolitan Vickers Ltd. There is a marked gain in the intensity in the blue and violet regions of the spectrum.

Observations of Eros.—The measurement and reduction of the plates taken in connection with the 1930-31 opposition is proceeding. The following series have now been measured :—

(*a*) The Greenwich series of 113 plates, taken with the 13-inch astrographic telescope, for the purpose of obtaining positions of secondary comparison stars required for the reduction of photographs of Eros obtained with long-focus instruments.

(*b*) The Cape series of 114 plates, taken with the 13-inch astrographic telescope, for the same purpose.

(*c*) The Greenwich series of 160 plates, exposed on Eros, with the 26-inch refractor.

(*d*) The Greenwich series of 204 plates, exposed on Eros, with the 13-inch astrographic refractor.

(*e*) The Radcliffe series of 52 plates, exposed on Eros, with the 24-inch refractor.

(*f*) The Melbourne series of 41 plates, exposed on Eros, with the 13-inch astrographic refractor.

(*g*) The Cape series of 478 plates, exposed on Eros, with the Victoria 24-inch refractor.

The following are at present being measured :—

(*h*) The Yale series of 60 plates, exposed on Eros, with the 26-inch refractor at the Johannesburg station.

(*j*) The Johannesburg series of 89 plates, exposed on Eros near the meridian, with the Cooke 10-inch refractor of the Union Observatory.

(*k*) The Johannesburg series of 88 plates, exposed on Eros with the Cooke 10-inch, near the meridian and at large hour angles, using orthochromatic plates and a yellow screen.

Of the above, 267 plates of series (*g*), 24 plates of series (*h*) and 49 plates of series (*j*) were measured in the period covered by this report.

The reductions are in hand. As regards series (*a*) and (*b*), the measured positions of the secondary comparison stars south of the equator have been converted into right ascension and declination and a comparison with the places determined at the Bergedorf, Leipzig and Lick Observatories is being made. The conversion to equatorial co-ordinates of the measured positions of the stars north of the equator is proceeding. As soon as the reductions and comparisons are completed it is intended to publish a catalogue giving the adopted places of the secondary comparison stars and corrections to the positions of the primary reference stars, as given in the catalogue prepared by Professor Kopff, which was based on meridian observations made at several observatories.

As regards the remaining series, preliminary standard co-ordinates have been computed for all plates. For series (*d*), (*f*), (*j*) and (*k*) (*i.e.* for the plates taken with short-focus instruments), the star places given in Prof. Kopff's catalogue were used. For series (*c*), (*e*), (*g*) and (*h*), taken with long-focus instruments, the star places used in computing the standard co-ordinates were taken from the Bergedorf catalogue, or from the results of series (*a*) and (*b*). These preliminary standard co-ordinates will be corrected differentially as soon as the definitive places are available.

Astrographic Equatorial.—The following observations were made during the year :—

(*a*) 116 plates were exposed on the minor planet Hebe, on 52 nights between 1935 September 14 and 1936 April 20. In general two plates, with at least two exposures on each plate, were taken on each night that observations were made. These plates were obtained to provide

material for the investigation of the orbit of Hebe, with a view to its use in helping to fix equinox and equator point in meridian observations.

(*b*) 23 plates were exposed on the minor planet Eros, on eleven nights between 1935 October 4 and November 27. These plates were obtained to form a connecting link with the more favourable opposition of 1937, and to serve as a control on the elements of the orbit of Eros deduced from the observations at the well-observed opposition of 1931, in combination with observations at earlier oppositions.

(*c*) Four photographs were obtained of Pluto on the following dates :— 1936 February 22 (exposure 32 min.) ; 1936 March 18 (exposure 60 min.) ; March 21 (exposure 49 min.) ; March 24 (exposure 60 min.).

Photoheliograph.—Photographs of the Sun were obtained on 295 days mainly with the Dallmeyer 4-inch photoheliograph. The number of photographs selected for preservation is 582, including 26 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 347 days in the year 1935 and on 60 days in the first two months of 1936. The Director of the Kodaikanal Observatory has reported that plates were taken there on 324 days in the year 1935 and on 88 days during the first three months of 1936.

Photographs, in duplicate, have been received from the Royal Observatory, Cape of Good Hope, to 1935 September 16, and the single series to 1935 December 16. Eleven photographs have been sent from the Kodaikanal Observatory to complete the series for 1935.

The measurement of the combined series has been made from 1934 October 25 to 1935 September 16 ; the Greenwich plates have been measured to 1936 February 8. The reductions of positions and areas of spot groups and their principal components have been completed from 1934 October 6 to 1935 September 16 and the reductions of the Greenwich plates carried to 1935 December 1.

During the period covered by this report, sunspot activity has continued to increase. There have been recorded no fewer than eighteen groups whose maximum area exceeded 500 millionths of the Sun's hemisphere ; of these, four groups exceeded 1000 millionths in area, the two largest being those which crossed the Sun's central meridian on December 2·1 (latitude 25° S.) and January 19·9 (latitude 32° S.).

Daily sunspot numbers, based on Wolf's method of counting, have been supplied quarterly to Professor Brunner at Zürich 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 1934 October 1 to 1935 September 30, have been supplied to the Director, Solar Physics Observatory, Cambridge. A duplicate set of negatives for the year 1934 has been sent to the Science Museum, South Kensington.

Spectrohelioscope.—The Sun's disk was examined in $H\alpha$ light with the spectrohelioscope on 168 days ; on about 25 days observations were limited to a few minutes owing to cloud. A watch was kept for bright eruptions of $H\alpha$ flocculi on the disk, and 44 eruptions, mainly of minor extent, were observed during the year as compared with four in the preceding twelve months. This increase is another indication of the considerable rise in solar activity. Particulars of the eruptions were reported to M. d'Azambuja at Meudon for inclusion in the Zürich *Bulletin*.

At the request of the Superintendent of the Radio Department of the National Physical Laboratory, a notification is sent immediately by telephone to the Radio Research Station at Slough whenever a bright $H\alpha$ eruption of appreciable magnitude is observed at Greenwich. This arrangement is, in the first instance, for an experimental period of six months from 1936 January 1. The presence of large sunspots on the disk is also reported to Slough.

A note on two allied types of bright chromospheric eruptions was communicated to the Royal Astronomical Society and published in the *Monthly Notices* for 1935 June.

During the year, measures of radial velocities of $H\alpha$ disk markings have been continued ; 410 measures were made on dark markings associated with sunspots. The largest recorded velocities were — 210 km./sec. and + 190 km./sec. on February 14, in association with the large group of sunspots that crossed the central meridian on that date. A description of this active group was communicated to the British Astronomical Association and published in the *B. A. A. Journal* for 1936 March. In addition to these 410 measures, 62 were made on areas of bright flocculi, and 196 on dark flocculi not associated with sunspots.

As reported last year, preliminary photometric measures were made during 1934 of bright flocculi and prominences by means of a wedge photometer fitted with a comparison lamp and attached to the spectrohelioscope. The results of

measures made during 1934 and 1935 have been communicated to the Royal Astronomical Society and published in the *Monthly Notices* for 1935 November. The results comprise (1) a set of visual measures of the contour of the normal Fraunhofer line $H\alpha$ at the centre of the disk, (2) a set of measures of the intensities of bright $H\alpha$ flocculi associated with sunspots, these measures being made at the wave length of maximum brightness, (3) a similar set of measures of the $H\alpha$ intensities of prominences, and (4) $H\beta$ intensities of a few of the prominences, also measured at the wave length of maximum brightness. The intensities were referred to the intensity of the Sun's continuous spectrum 10 A away from the centre of the line; for the flocculus measures an adjacent portion of the disk was used, and for the prominences the reference was to the centre of the disk.

From (4) and (3) the intensity ratio $H\beta/H\alpha$ was derived. The mean value of this ratio for 10 prominences observed during 1934 is 0·25: for 12 prominences in 1935, 0·27, and for 13 prominences in 1936, 0·33. There is some evidence that the Balmer decrement varies substantially from one prominence to another. It is hoped to develop the photometric measures, which are being extended to the observation of the contours of the emission lines given by prominences and bright disk markings and also of the absorption lines given by dark markings. A small prism, in the form of a parallelepiped, has been fitted in a cap to the eyepiece of the spectrohelioscope, so as to bring together in the middle of the field the comparison band, given by the lamp, and the strip of the solar image under observation.

In January, the spectrohelioscope was transferred from its temporary mounting on wooden stands to brick piers keyed to the concrete floor of the south attic of the Main Building. A marked improvement in stability of the instrument, as well as some improvement in the definition of the image, has resulted. Two new optical circular flats of Pyrex glass, $4\frac{1}{2}$ inches and $5\frac{1}{2}$ inches in diameter, respectively, have been purchased for the coelostat. The original flats were re-aluminized in January.

IV.—Magnetic Observations.

Regular magnetic observations have been made at Abinger throughout the year. The variations of declination and of horizontal and vertical intensity have been recorded photographically.

Absolute observations of declination, of horizontal intensity with the Schuster-Smith coil magnetometer, and of vertical intensity with the Dye coil magnetometer are made every week-day. The measurements both of the horizontal and vertical

components of magnetic intensity are dependent upon electrical standards, but observations of horizontal intensity 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.

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 1935 December 31, and with provisional constants to the present time.

The tabulation of results for 1935 is almost complete, and awaits only the receipt of the final list of International " quiet " and " disturbed " days.

The mean values of the magnetic elements at Abinger for the year 1935 are given below. The values for the years 1932, 1933 and 1934 are given for comparison.

	Decl. W.	Hor. Intensity.	Vert. Intensity.	Inclination. *
1932.. ..	12° 2′·6	0·18536	0·42940	66° 39′·1
1933.. ..	11° 51′·7	0·18532	0·42942	66° 39′·4
1934.. ..	11° 41′·1	0·18533	0·42955	66° 39′·7
1935.. ..	11° 30′·3	0·18527	0·42981	66° 40′·9

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.

Mr. R. H. Mansfield, of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, U.S.A., was observing at Abinger from September 16 to 20, at the conclusion of an extended magnetic survey in Africa. He made a series of comparisons between his field instruments and the Abinger standard instruments with a view to indirect comparison, upon his return to Washington, between the latter instrument and the standard instruments of the Carnegie Institution.

The following instruments have been examined during the year for the determination and certification of their constants : —

A Kew-pattern unifilar magnetometer from Alibag Observatory, India.

A collimator-magnet from the Royal Alfred Observatory, Mauritius.

Two portable magnetic variometers for measuring changes of the vertical component of the earth's field.

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

Specifications have been prepared for the instruments to be used for magnetic observations on R.R.S. *Research.*

The quinquennial revision of the Admiralty magnetic charts is in progress.

V.—Meteorological Observations.

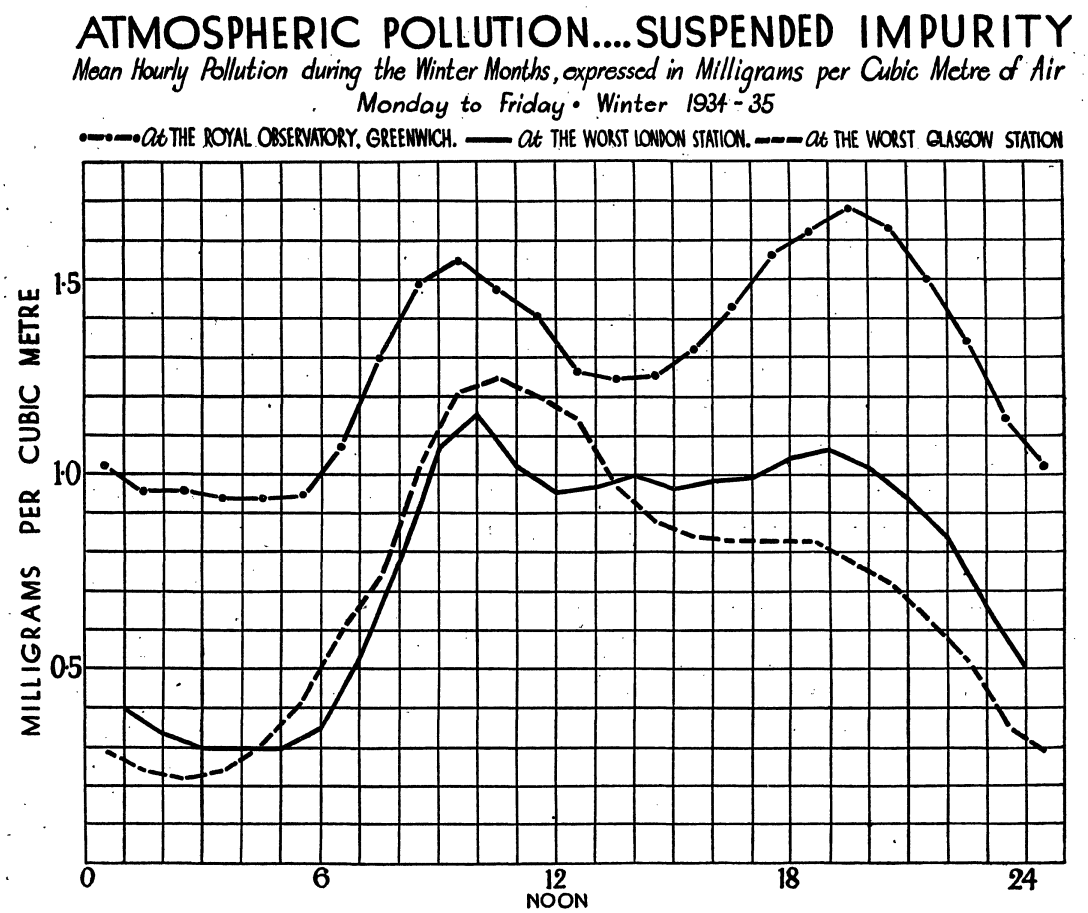
The registration of atmospheric pressure, temperature of the air and of evaporation, the direction, pressure and velocity of the wind, the amount of rainfall, sunshine and cloudiness at night, has been maintained continuously. Estimates of visibility have been made by eye at definite hours.

The measurement, by a continuously recording photographic apparatus, of the air-earth current discharged at a metallic point 30 feet above ground level has been maintained throughout the year. Interesting traces were obtained during the passage of thunderstorms over the neighbourhood, distinct instantaneous movements being shown which were coincident with lightning flashes distant at least five miles.

Regular records for measurement of the amount of solid matter polluting the air have been continued by means of an Owens automatic filter. Tabulation of the results shows that, on the whole, pollution of this kind was substantially less during the winter of 1935-36 than during the previous winter. The diminution can probably be attributed to the much smaller proportion of wind coming from a northerly direction during the winter of 1935-36. Wind from between N.E. and N.W. formed 24·3 per cent. of the whole during the winter of 1934-35, but only 14·3 per cent. of the whole during the winter of 1935-36. A comparison between the pollution experienced at Greenwich during the winter of 1934-35 (for which numerical results were given in the last Report) and that observed at two other bad stations* during the same period is given in graphical form. The data for the comparison stations have been taken from the Annual Report of the Atmospheric Pollution Research Committee, Department of Scientific and Industrial Research, August, 1935.

The gaseous pollution of the atmosphere by sulphur dioxide has been measured daily. The amount appears to vary greatly from day to day. In the worst days of January and February, both in 1935 and 1936, the pollution approached and occasionally exceeded 0·2 parts, by volume, in a million. On the other hand less than a tenth of this amount was present on good days. The days when the pollution is greatest are days of calm air, drifting from a northerly direction, generally accompanied by fog. A strong southerly wind reduces pollution to a minimum.

* Westminster (City Hall) and Glasgow (Central).



The tabulation of meteorological results for 1935 is complete and the copy for press is in the printers' hands.

The following details of the weather refer to the period of twelve months ended 1936 April 30.

The mean temperature was 50°·2 which is 0°·7 higher than the average of the 75 years 1841-1915. The highest temperature in the shade was 90°·9, registered on August 22. Temperatures exceeding 80° were recorded on 27 days. The lowest temperature was 19°·4, on February 12. Temperatures of freezing point or below were recorded on 50 days, one of these being the exceptionally late date May 17. The mean daily horizontal movement of the air was 280 miles, which is 5 miles below the average for 50 years, 1867-1916. The greatest daily movement was

636 miles, recorded on September 15; the least daily movement was 124 miles, on February 15 and also on February 28. The greatest motion in one hour, 34 miles, was recorded on September 17 and again on September 19. The greatest pressure reached was 20·5 lbs. to the square foot, recorded on September 17. The duration of bright sunshine recorded was 1413·8 hours or 31·5 per cent. of the possible total. There were 66 entirely sunless days, 40 being in the three 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 26·11 inches, that is, 1·87 inches more than the average for 75 years 1841-1915, and measurable rain fell on 178 days. The wettest month was November with 3·59 inches. The driest month was July with 0·56 inch.

VI.—Time Service.

Determinations of time have been made by a rota of observers with the reversible transit D until July 24 when transit B was remounted.

Observations were secured on 153 nights, the transits being registered on a syphon recording tape chronograph operated by a thermionic valve relay. The determinations of time have been 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. A personal-equation machine, designed for this purpose, has been constructed in the workshop and will shortly be brought into use. This machine will be housed in a small hut on the roof of the Octagon Room, adjacent to the Ball Turret. The transit instrument will be mounted, for the purpose of observations with the personal-equation machine, in the Tank Room of the Main Building, where a brick pier has been erected to carry the instrument. The observations with the transit instrument and the concurrent signals from the personal-equation machine will be recorded, together with signals from the standard clock, on a two-pen syphon chronograph, placed in the Time Department. Arrangements are being made for this chronograph to be started and stopped by distant control.

The free pendulum clock Shortt No. 3 has been used as sidereal standard throughout the year; and Shortt No. 11 has been compared regularly with it daily.

The mean time free pendulum clock Shortt No. 49 was used to control the mean time clocks used for Post Office and broadcast signals and also the rhythmic signal transmitter until October 29, when Shortt No. 16 was substituted.

The sidereal clock circuits have hitherto employed relays biased for single current working. It has been found possible to employ unbiased relays by the use

of transformers. At each stage the current is fed into the primary of a transformer, and the secondary feeds the unbiased relay. Only one side of the relay output is utilised. The resulting avoidance of relay bias removes a troublesome cause of time-lag. The modified system was brought into operation on April 15.

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 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 Time Ball failed to drop at 13^h British Summer Time on June 23. It was dropped correctly at 14^h B.S.T.

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.	Devonport.	Westminster.
Not greater than $0^s{\cdot}2$	218	234	120
$0^s{\cdot}3$ to $0^s{\cdot}5$	2	2	110
$0^s{\cdot}6$ to $1^s{\cdot}0$	1	1	70
Greater than $1^s{\cdot}0$	0	0	15

The Westminster Clock was found to be 20^s in error on January 17 owing to an accumulation of snow on the hands.

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 and Bordeaux. The Nauen long wave signals have been received since March 5 only. During the remainder of the year they were transmitted on a wave length outside the range of the Marconi Receiver. No long wave signals were sent out from Annapolis, the station being under reconstruction. The signals are registered automatically, and the corrections found for the Nauen and Bordeaux signals, together with the corrections to the Rugby signals, are published monthly in the Admiralty *Notices to Mariners.*

The 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 used for occasional determination of the time lags in recording radio time signals.

The following table gives the monthly means of the differences from Greenwich shown by the various time signals, using the final clock corrections derived from observations made with the small reversible transit instruments at Greenwich, and the corrections for final time determinations published by the Paris and Hamburg Observatories.

1935.	Paris $9\frac{1}{2}^h$ Rhythmic.	Nauen 12^h * Rhythmic.	Bordeaux 20^h Rhythmic.
	s.	s.	s.
January	+ ·003	+ ·018	+ ·006
February	− ·023	− ·017	− ·019
March	− ·009	− ·019	− ·009
April	+ ·002	− ·001	+ ·004
May	− ·045	− ·032	− ·045
June	− ·047	− ·013	− ·048
July	+ ·009	+ ·025	+ ·007
August	+ ·008	+ ·005	+ ·008
September	+ ·001	− ·005	+ ·003
October	− ·001	− ·021	...
November	− ·004	− ·033	− ·003
December	− ·001	− ·025	− ·004
Mean	− ·009	− ·010	− ·009
Number of comparisons ...	309	302	302

* The comparisons with Nauen from March 13 were derived via Paris signals.

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. The reception time of the signals has been corrected for time lag in the recording apparatus. Relative personal equations have been applied to the time observations.

VII.—Chronometers.

The number of chronometers and watches belonging to the Admiralty now at the Observatory is 2,061. Of this total, 216 chronometers, 231 chronometer watches, 252 hack watches and 146 pocket watches are being rated. Five are in regular use

in the Observatory. The remainder, consisting of 305 chronometers, 718 chronometer watches, 105 hack watches and 20 pocket watches, are kept in storage.

In addition to Admiralty chronometers there are 33 chronometers and 30 watches deposited at the Observatory for various reasons.

During the year ended 1936 April 30, a total of 2,088 chronometers and watches has been received and 2,411 issued. The number sent for repair was 1,369, viz., 1,323 for the Admiralty, 24 for the Indian, 4 for the Australian, 6 for the New Zealand, 1 for the Canadian Governments, and 11 for the Royal Air Force.

During the year, 15 chronometers, 46 chronometer watches and 5 pocket watches have been sold out of surplus stock.

VIII.—Printing and distribution of Greenwich Publications.

The printing of the Volume of " Greenwich Observations for 1934 " and its separate parts, is completed, and part of the MSS. of " Greenwich Observations for 1935 " has been forwarded to H. M. Stationery Office for printing.

The distribution of the " Second Greenwich Catalogue of Stars for 1925 " and of Volume II of " Observations of Stellar Parallax " has been completed. " Greenwich Observations " for the years 1933 and 1934 have also been distributed.

IX.—Personal Establishment.

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

Chief Assistants.—W. M. H. Greaves, M.A., R. v. d. R. Woolley, B.A., Ph.D.

Assistants.—W. Bowyer, C. R. Davidson, F.R.S., P. J. Melotte, W. M. Witchell, B.Sc.

Junior Assistants (Higher Grade).—H. W. Acton, R. T. Cullen, H. W. Newton, W. Stevens.

Junior Assistants.—H. H. J. Barton, K. C. Blackwell, E. A. Chamberlain, H. F. Finch, B.Sc., F. Jeffries, E. G. Martin, P. L. Rickerby, G. W. Rickett, L. S. Symms, G. F. Wells.

Writing Assistants.—Miss V. M. Hall, Miss C. M. Lark, Miss G. I. Gennery.

Clerical Assistant.—D. J. R. Edney.

16 Computers, including 6 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.
Transit Circle and Zenith Telescope.	Mr. Cullen, Mr. Acton, Mr. Symms, Mr. Blackwell. Miss Hall, Miss Lark, Miss Gennery	Mr. Slator, Mr. Grimwood, Mr. Stockwell, Mr. F. L. Rudd.
Time Signals and Chronometers	Mr. Bowyer, Mr. Rickett ...	Mr. Harris, Mr. Shortland, Mr. J. L. Rudd.
Thompson and Yapp Equatorials.	Mr. Davidson, Mr. Martin ...	Miss French, Miss Cumberledge.
28-inch Equatorial	Mr. Acton	—
Astrographic Equatorial ...	Mr. Melotte, Mr. Jeffries, Mr. Finch.	Miss Jeffries, Miss Moore.
Photoheliograph and Spectrohelioscope.	Mr. Newton, Mr. Barton ...	Mr. Laurie.
Small Transit	Mr. Finch	Mr. J. L. Rudd.
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.

It was stated in the last Report that proposals had been submitted to the Admiralty for the termination of the system of employing unestablished computers for general computing, measurement of photographs and various miscellaneous duties. The employment in the Observatory of unestablished computers was introduced by Sir George Airy, but changed conditions have made the continuation of such employment undesirable. The proposals have been approved by the Lords Commissioners of H. M. Treasury. Unestablished computers will be replaced by a permanent staff consisting of one Junior Assistant (Higher Grade), five Junior Assistants, twelve Writing Assistants (women) and a typist. The transition to the new permanent complement will be made gradually. Up to the present time, three writing assistants have been appointed.

The staff of workmen now employed consists of a foreman of observatory, 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.

Mr. W. V. Woodman, Foreman of Works, retired on July 27 after 43 years of

valued service, 15 of which were in an established capacity. Mr. A. C. S. Wescott, established joiner, was promoted to succeed Mr. Woodman.

X.—General Remarks.

The meeting of the International Astronomical Union in Paris in July, 1935, brought many foreign astronomers to England, most of whom visited the Observatory. The opportunities which such visits offer of discussing programmes and methods of observation and interchanging ideas are much appreciated.

Mr. R. H. Mansfield, of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, visited Abinger from July 15 to 20, for the intercomparison of instruments.

Lt.-Commander Fryer, R.N., visited Abinger in September for instruction in magnetic observations.

Mr. R. H. Stoy visited the Observatory from September 18 to 28, to study some branches of the work, prior to his appointment as Chief Assistant at the Royal Observatory, Cape of Good Hope.

Mr. H. G. Scott Barrett, formerly an Assistant at the Radcliffe Observatory, Oxford, has been lent to the Observatory by the Radcliffe Trustees, to assist in the reduction of the observations of Eros, made at the opposition of 1931. Mr. Barrett has been working at the Observatory since November 5. His assistance is of great value and is much appreciated.

The members of the Empire Surveyors' Conference visited the Observatory on July 27.

The Astronomer Royal, Mr. Greaves, Mr. Davidson and Mr. Newton attended the meetings of the International Astronomical Union. The Astronomer Royal was elected a Vice-President of the Union. Members of the staff of the Observatory were appointed to Commissions of the Union as follows :—The Astronomer Royal : Astronomical Telegrams (President); Meridian Astronomy, Longitudes; Latitude Variation (President) ; Solar Parallax (President) ; Carte du Ciel ; Stellar Parallaxes ; Stellar Photometry. Mr. Greaves : Stellar Photometry, Spectrophotometry. Dr. Woolley : Solar Radiation and Spectroscopy, Spectrophotometry. Mr. Davidson : Solar Eclipses, Spectrophotometry. Mr. Newton : Sunspots, Chromospheric Phenomena. Mr. Martin : Solar Parallax. The Astronomer Royal also attended the meeting of the Astronomische Gesellschaft in Berne.

The optical grinding machine, which belonged to the late Mr. H. G. Tomkins, has been presented to the Observatory by Mrs. Tomkins. The machine is being erected in the Instrument Store.

The alterations to the 26-inch refractor have proved even more successful than had been anticipated. Not only has the loss of observations through dewing of the object glass been eliminated, but also a marked improvement in definition has resulted from the ventilation of the tube and from the increase in the distance of the objective from the aperture in the dome. The results emphasise the importance of the attention to such details in the design and housing of telescopes that are to be used for work of great refinement. The synchronous motor drive has proved much superior to the former clockwork drive. There is no doubt that, wherever there is an electric supply sufficiently well regulated for frequency, a synchronous motor drive provides the simplest and most efficient method of driving a telescope.

Attention should be drawn to the successful application of the spectrohelioscope to the measurement of intensities and of line contours. The results show that with this small instrument such measures can be made with a high degree of accuracy. Observations with the spectrohelioscope, and in particular the study of sudden bright eruptions, promise to prove of importance in connection with the investigation of the conditions in the ionosphere.

The aluminizing of the mirrors of the spectrohelioscope and of the auxiliary mirrors of the 36-inch reflector has proved most beneficial, because the aluminium films do not tarnish. The 36-inch mirror has not yet been aluminized as it is difficult to spare the mirror for the time that would be required to send it away for this purpose. It is hoped that it will eventually be possible to have a large mirror coated with aluminium and returned within two or three days. But in this, as in other matters, the convenience of astronomers is dependent upon the successful development of commercial applications.

H. SPENCER JONES.

Royal Observatory, Greenwich.
1936 May 8.

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