REPORT

OF THE

ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH

Read at the Annual Visitation of the Royal Observatory, 1938 *June* 4.

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The Report here presented refers to the period from 1937 May 1 to 1938 April 30 and exhibits the state of the Observatory on the last-named day.

I.—New Instruments :—

Reversible Transit Circle.—At the date of last year's report the eye-end had been returned to York for examination. Tests at Greenwich had revealed anomalies that could be explained on the assumption that the moving wire lagged behind the micrometer screw by about 12 microns.

The frame carrying the moving wire is constrained to move along a guiding rod by two sets of bearing surfaces, and motion in a direction perpendicular to the plane of the frame is prevented by a tailpiece, which bears in a slotted slide.

Messrs. Cooke, Troughton and Simms found that the guiding slide of the tailpiece required easing and that the guide rod was slightly convex to the eyepiece. These defects were rectified by the removal of very small amounts of metal, and at the same time similar defects in the zenith-distance micrometer were removed in the same way. The eye-end was returned to Greenwich on May 26, where it was repainted ; the instrument was brought into use again by the middle of June. Observations, both instrumental and of transits of fundamental stars, indicated that the lag was now negligible.

Before the dispatch of the micrometer to York another defect had been detected. On setting the moving R.A. wire on one of the fixed wires of the micrometer it was found that the micrometer readings for the position of coincidence varied with the position of the instrument, the range of the readings amounting to about half a second of arc. This meant that the reading corresponding to the line of collimation would vary with the declination. The defect had been only slightly improved when the micrometer came back from York, and after much time had been spent in investigation, it was found possible to cure it by a simultaneous adjustment of the screws clamping the guide rod to the main casting of the instrument, and those holding the bearing surfaces of the wire frame against the guide rod.

Tests made at intervals of a few months confirm that the adjustments made to the frame remain constant and satisfactory. The lag has also remained negligible.

Similar tests have been made with the Z.D. micrometer on a speck of dust on a fixed wire. These show a total range of approximately $0''\cdot2$, with maximum and minimum values roughly at the N. and S. horizon positions of the telescope. A discordance of this nature may have a direct bearing on flexure determinations of meridian instruments.

The induction motor operating the movable R.A. wire has been replaced by a synchronous motor running at two-thirds of the speed. This eliminates one reduction-gear, which was responsible for a great deal of noise, and the drive is also much more uniform. The metal friction plates of the universal gear have been replaced by raw hide, and a number of minor changes have been made which have further reduced the noise.

A programme has been prepared for laying the foundations of a system of right ascensions.

Stars for clock and azimuth error were selected from those contained in the FK3 fundamental catalogue and supplement; the right ascensions given there were adopted for the initial stage of the work. For the stars in the supplement, definitive right ascensions were kindly sent in advance of publication by Prof. Kopff. Right ascensions of clock stars will be retained when the observations are spread over a minimum period of 4 hours.

The azimuth determination will depend primarily on the consecutive above-and-below transits of bright circumpolar stars near the zenith; in addition there will be a

secondary list of stars between 70° and 90° declination whose transits will be used above or below pole at night only. Comparison of the two methods will afford some check on possible diurnal variations of azimuth and on possible horizontal refraction.

Transit observations on this plan were begun during the winter months by one observer.

Portable screens, to shield the piers from direct sunlight by day and to reduce the effects of any rapid changes of temperature, were constructed on an aluminium framework and fitted with " masonite "—a wood pulp compressed on to a canvas backing. Each screen is made in two sections, easily fixed together by means of clips. These screens protect not only the piers, but also the microscopes, both circles and the pivots. They were brought into use on February 3.

The two tape chronographs have been enclosed in a case of polished wood with glass panels. The front has two sliding glass doors. The sides and top have detachable glass panels, giving ready access to any part requiring attention. An electric strip bulb, fixed inside the case, besides giving illumination keeps the interior at a satisfactory temperature during the winter ; to prevent damp and insulation troubles two desiccators are also kept inside. In order readily to determine the parallax of the chronograph pens a switch that can connect all three pens to the clock at once has been introduced.

The determination of the division errors of the circle has been continued. The method of dividing the circle employed by the makers gives in effect two independent series of divisions, each spaced at an interval of 10′, the divisions of one series bisecting the intervals between the divisions of the other series. In the preliminary tests of the instrument it was found that this bisection was not accurate, alternate 5′ intervals being unequal. The inconvenience of having to apply large corrections for runs was avoided by setting three alternate microscopes on one series of graduations and the other three microscopes on the second series, so that the intervals between the microscopes are alternately 60° 5′ and 59° 55′. The effect of doing this is that division errors must be determined over an arc of 120°, instead of over an arc of 60°, because it is only after turning the instrument through 120° that the same six divisions come under the six microscopes. The errors of the one-degree divisions have been determined and the observations to determine the quarter-degree divisions have been com-

pleted. The determinations have shown that accidental (as opposed to periodic) errors in dividing play an important part, and this will necessitate the determination of the error of each five-minute division on the circle.

The observations of level are presenting some peculiar features. Under conditions of rapid change of temperature there is a drift in the level error determined by nadir observations. This drift can be represented by a smooth curve. The usual procedure is to interpolate from this curve the level error for each star observation. The observations of transits with the new instrument are so accurate that it is clear that the observed variations are not wholly real, because they result in a spurious drift in clock error in the course of a night's observations. It appears that all parts of the instrument do not respond at the same rate to rapid changes of temperature and that the variable time lags are responsible for an apparent drift in level, which is superimposed on any real drift that there may be under such conditions. In the absence of permanent meridian marks there is no direct control, unfortunately, on the changes of azimuth.

It is hoped to obtain further light on the variations by frequent observations of collimation combined with observations of zenithal stars and of as many azimuth stars as possible, in both positions of the instrument.

Slit Spectrograph.—The Hilger slit spectrograph was mounted on the 36-inch reflector for testing, from June 17 to August 4. It has been balanced so that it can be rotated about the collimator axis without affecting the balance of the telescope. Under rather poor atmospheric conditions adequately-exposed spectra of α Lyræ were secured with exposures of 300 seconds and 50 seconds with the three-prism and one-prism trains respectively. The slit width used was 0·04 mm. and the spectra were broadened to $\frac{1}{3}$ mm. and $\frac{1}{2}$ mm. respectively. A number of tests with the spectroscope on its stand have also been made. Focussing curves taken with the broadening plate in various positions showed that the effect of its tilt on the focus was negligible. Focussing curves were also taken with the plate removed. There appears to be a little coma in either case, but the central definition is good. The apparent motion of the image, produced when the plate is rocked by its cam and motor, is extremely uniform in both directions. The complete double traverse of the spectrum width takes 40 seconds, and the times of traverse from extreme to extreme are fairly nearly the same in both directions. The focussing scale and vernier of the camera lens were not of the necessary quality and new ones were fitted by Messrs.

Hilger; focussing curves with the new scale are being taken at present. Tests for spherical aberration, and for the effect of change of temperature, are projected; in hot weather the temperature cannot be controlled below about 75°, but in cold weather it would be preferable to hold it considerably lower.

The source of light has been an iron arc fed from the 110-volt rectifiers through a temporary choke and condenser arrangement to smooth it; a 1½ kilowatt 220 volt D.C. motor generator, which was authorised in 1935 for this and other purposes, has now been installed in the annexe to the Yapp basement. It has an adjustable voltage, and fine and coarse output resistances. It will be possible to start and stop it from either the dome or the basement. A krypton discharge tube has also been obtained from the Clarendon Laboratory, Oxford.

The spectrograph has been fitted with a silica-gel desiccator which can remain inside it at all times.

Magnetograph.—A magnetograph of the type designed by Dr. D. La Cour, director of the Danish Meteorological Institute, was obtained for the Abinger station in August. It was at first installed in a temporary position, where changes of temperature are slow, to facilitate adjustment and calibration. Dr. La Cour generously arranged for the attendance of his assistant, Dr. V. Laursen, during the assembly and adjustment of the instrument, and the help thus given was much appreciated. In January the instrument was transferred to the smaller of the two testing huts, where considerable changes of temperature were available, and the temperature compensation of the intensity variometers was accurately adjusted. On February 15 the old instruments in the magnetograph house for recording variations of declination and of horizontal intensity were dismounted, and after some constructional work, much of which had been done in advance, the new apparatus was installed on March 2. The magnetic instruments themselves are on a large slate slab cemented on to one of the old piers, and the recording drum, driving clock and rank of prisms are on a massive wooden table a few feet away, whose legs pass through holes in the floor to the cement base of the building. The slate will eventually carry also an additional set of instruments for quick-run recording, which it is proposed to install shortly. The Watson quartz-fibre variometer for vertical intensity is being retained. The value of the new instrument has been notably illustrated already. The exceptionally violent storm of April 16th was completely registered on the normal scale. The ranges involved

were much beyond any that had previously been recorded at Greenwich or Abinger. The very great storm that accompanied the brilliant display of the aurora on January 25 was also completely registered.

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

The four conduit rails for the 28-inch dome motor have been removed, together with the contact arms, and a flexible lead has been run from the main girder at the apex of the dome to the top of the north pier and so to the controls. This arrangement is possible since the telescope cannot in any case cross the meridian except well south of the zenith. By this means the maximum travel of the dome has been increased from 180° to about 310°. External painting of the dome will in future require only one scaffold and it is hoped in consequence to reduce appreciably the cost of the biennial painting. The mechanism for operating the dome shutters, which had worn out, has been replaced by an endless steel cable and winch operated at the side of the dome ; the work was designed and carried out by the workshop staff, and the gain in convenience is appreciable.

The water-clock formerly used for driving the 28-inch refractor has been removed and presented to the Science Museum, together with Airy's Water Telescope and Reflex Zenith Tube.

The shutters of the Airy Transit Circle have been covered with copper sheeting.

The old battery basement has been converted into a thermostatically-controlled room for the new crystal clock. A large capacity battery has been obtained from surplus stock at the National Physical Laboratory and work is in progress on a new battery room for it. The battery will be able to drive a small 220 volt A.C. motor generator in case of mains failure, so as to keep the crystal clock in operation and also hold the temperature of its cabinet constant for a limited period.

The adaptation of the old battery basement necessitated the transference of part of the apparatus for lifting the time ball to the ball lobby ; at the same time, a new braking system was arranged, as well as an indicator to show the position of the ball. The coils of the electro-magnets in the release apparatus have been rewired.

The old watch room has been converted into a computing room for the use of the time department. The new watch room is now complete ; cupboards for storing watch boxes have been fitted, and extra heating and lighting have been provided.

The charging panel for small batteries has been removed from the wireless room and installed in a small cupboard near the time battery room. A new 7-pair cable has been laid from the lower computing room to the wireless room.

The lead flats on the roof of the Octagon room have been overhauled and repaired where necessary and the flagstaff moved from the west to the east side of the building, so that it is no longer possible for the flag to foul the anemometer cups.

The Chart room has been converted into a rest room for the female staff. Heating for this room, and also for the Thompson dark room, has been arranged by diverting part of the hot air duct.

An Ascot water heater has been installed in the lavatory on the principal floor of the Main Building.

A small dark cupboard has been erected in the Thompson dome for loading and changing plates.

A set of bookshelves has been constructed and fitted in the Astronomer Royal's office.

The tables removed from the old watch room have been erected in the east attic and adapted for mounting an optical bench.

The floor of the old magnetograph house in the Christie Enclosure has been re-rendered with cement.

Louvred frames, painted white, have been fitted on the roof and the south and west sides of the Cookson building. It was found that on warm sunny days the roof and the south and west walls became heated, causing temperature gradients in the hut from north to south and from east to west, which would have produced apparent displacements of the zenith. The louvred frames have successfully eliminated these temperature gradients.

The floor of the solar dark room has been re-covered with sheet lead, the woodwork under the sink has been repaired and the room has been redecorated.

The floors of the Cookson building, photoheliograph dome, chronograph room and new watch room have been covered with corticene.

New gates have been fitted at the main entrance to the Observatory.

The necessary equipment for the 3-inch fire hydrant in the Christie enclosure, mentioned in the report last year, has now been supplied.

All fuse boxes with fuses of obsolete pattern have been replaced by boxes with standard type fuses.

The external painting of the following buildings and domes has been completed :—

Octagon room, north and east sides of Flamsteed House, north side of Old Observatory, covered way, Central Store and 26-inch dome.

The interior painting of the Yapp dome (walls only), silvering room, watch rating room and paper store has been completed.

At the Abinger Magnetic Station the mains supply of electricity has been extended to all buildings. Heating elements similar to those in use in the magnetograph chamber have been provided in the pavilion for absolute observations and in the two testing huts. An automatic electric fire-alarm system has been installed in each of the buildings in the magnetic enclosure.

The interior of the magnetograph house, including the recording chamber, has been re-painted.

The following instruments in regular use are on loan from other institutions :—

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 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 D. W. 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.

A Smith portable coil magnetometer, with potentiometer, for measurement of horizontal intensity, from the Ordnance Survey Department.

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 Solar Physics Observatory, Cambridge—

Photoheliograph object glass No. 5.

9-inch speculum concave mirror with stand and guiding microscope.

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 National Maritime Museum—

Harrison's Time Machines Nos. 1, 2, 3 and 4, and the copy of No. 4 by Larcum Kendall. Harrison No. 4 and the Larcum Kendall copy are being exhibited at the Empire Exhibition, Glasgow.

The annual examination of the Observatory Library has been made. Sixteen books are missing and cannot be traced at present. Of these eleven were reported missing last year, and two which have been missing for a number of years have now been written off. Two books which were missing last year have since been returned, and one book which had been written off has also been returned and re-entered in the catalogue.

III.—Astronomical Observations :—

Transit Circle.—The Sun, Moon and planets 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 the Preliminary General Catalogue of Boss between declination + 64° and the pole—have been completed. Efforts to attain a minimum of five observations for every star have been successful, and out of about 7,000 stars more than 6,000 have been observed six or more times.

During the year 8,094 transit observations and 7,991 observations of zenith distance were obtained. These include the following :—

122 observations of the Sun.
98 ,, ,, Moon.

Major Planets		Minor Planets	
Mercury ..	7 observations.	Pallas ..	5 observations.
Venus ..	32 ,,		
Mars ..	11 ,,		
Jupiter ..	17 ,,		
Saturn ..	2 ,,		
Uranus ..	4 ,,		
Neptune ..	17 ,,		

The observations of the Sun, Moon and planets are published yearly in the *Greenwich Observations*. The results for the year 1936 are now ready for the printer.

The observations of the Sun show a small decrease in the 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	+ $0^s \cdot 106$	1931	+ $0^s \cdot 117$
1924	+ ·113	1932	+ ·087
1925	+ ·114	1933	+ ·101
1926	+ ·118	1934	+ ·097
1927	+ ·113	1935	+ ·107
1928	+ ·114	1936	+ ·102
1929	+ ·109	1937	+ ·094
1930	+ ·116		

An amount $+0^s\cdot050$ of these corrections is accounted for by the correction of $-0^s\cdot050$ 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
1936 ..	+ 3·14	+ 3·09	− 0·94	− 0·61	78	46
1937 ..	+ 2·4	+ 2·3	—	—	84	54

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

No corrections later than 1936·5 for the variation of latitude from the Cookson zenith telescope observations are yet available in consequence of the introduction of a new observing programme. To prevent further delay the results of the International latitude service for 1936 printed in the *Astr. Nach.*, Band 263, No. 6290 (Table 7, X co-ordinate) have been adopted in the declination reductions. The values given for 1937 are approximate, as the latitude variation results have not yet been published.

The departure of the position of the Moon from the position given by pure dynamical theory continues to increase and there is no indication of any sudden change in the rate of rotation of the earth.

Cookson Zenith Telescope.—During the year 271 plates were taken for latitude variation, and 7 for the determination of scale.

The definitive discussion of the observations made from 1911 to 1936, in accordance with the original programme, has been practically completed and the discussion is being written up for publication. A determination of the constant of nutation from all the material available in these observations gave the value $9''\cdot217 \pm 0''\cdot004$. This value, in conjunction with Oort's value of the constant of precession, which takes galactic rotation into account, gives a value of 1/81·59 for the ratio of the mass of the Moon to the mass of the Earth. The discussion of the observations of Eros, made at the opposition of 1931, should lead to a very precise determination of the mass of the Moon and should provide a valuable check on the constant of nutation.

28-*inch Refractor.*—The comparison image micrometer, mentioned in last year's report, designed for measuring binary stars by comparison of the images of the real pair with those of an artificial star, was brought into use in September. A description of this micrometer, with a comparison between some results of measures made with it and recent filar micrometer measures of the same stars, has been published in the *Monthly Notices of the Royal Astronomical Society*. The gain in reliability when the separation is less than 1″ is evidently very great. At present the telescope is only used at full aperture, since it is unsafe to have the apertures for the natural and artificial star different; the micrometer will be altered in this respect if necessary.

A small motor-driven fan has been mounted at the lower end of the telescope and eight holes, $1\frac{1}{8}$ inches in diameter, have been cut in the tube at its upper end, adjacent to the object glass cell, for the ventilation of the tube. All the circuits have been rewired and a switchboard has been made and mounted on the telescope with controls for the double image micrometer, the filar micrometer, the illumination of the setting circles, and the ventilating fan.

An interferometer similar to that first used by Anderson on the 100-inch reflector at Mount Wilson has been constructed in the workshop and mounted on the telescope. It is hoped to use it for certain bright binaries that are too close for the comparison-image micrometer.

The new programme commenced in May 1936 is progressing satisfactorily. During the year 252 observations of 98 pairs were secured. They were distributed as follows :—

27	observations	of	13	pairs	having a separation	$> 2''\cdot0$
74	,,		29	,,	,,	$2''\cdot0 - 1''\cdot0$
101	,,		40	,,	,,	$1''\cdot0 - 0''\cdot5$
50	,,		16	,,	,,	$< 0''\cdot5$

Elements of an orbit for OΣ 79 and a discussion of the system of α Ursæ Majoris have been communicated to the Royal Astronomical Society.

Thompson 26-inch Refractor.—The number of plates suitable for the determination of stellar parallaxes was 1,151. 942 plates were measured and 29 parallaxes completed. The parallaxes of 28 stars were published in the *Monthly Notices* for November. In addition 105 photographs for the determination of proper motion have been secured and 240 measured.

Yapp 36-inch Reflector.—Colour temperature work with the slitless spectrograph was resumed in August, after an interruption for testing the slit spectrograph.

215 comparisons of 79 stars with standard stars have been secured. In order to correct the spectrophotometric observations for time effects, which are introduced by the plate being calibrated with a different time of exposure from the times of exposures on the stars, it has been found necessary to determine for each batch of plates ordered the two quantities, designated by ϕ'_0 and ε (see *Monthly Notices*, 96, 828), which are involved in the corrections. 25 plates at the telescope have been taken to determine ϕ'_0 and 16 plates in the laboratory to determine ε.

The measurement of these plates has been kept up to date and the measurement of the comparisons of star with standard star is well in hand.

A paper on the " Colour Temperature Variations of γ Cassiopeiæ " was published in the April number of the *Monthly Notices*. Further observations of the variations of this star are being obtained.

Observations of Eros.—The corrections to the positions of the Primary Reference Stars in Dr. Kopff's Catalogue, together with the final places of the Secondary Reference Stars, have been published in the *Memoirs of the Royal Astronomical*

Society, Vol. 65, part 4. The positions of the secondary reference stars and the corrections to the positions of the primary reference stars were derived by a combination of the results from plates taken and measured at the Bergedorf, Leipzig and Lick Observatories, with those from plates taken at the Greenwich and Cape Observatories, both of which series were measured at Greenwich. It was found possible to include both lists of secondary reference stars (north and south of the equator), in the one volume. The two lists contain the places of 5,624 stars arranged in zones of declination. It was printed by the replika process, the typewritten copy for press being prepared at Greenwich.

The number of positions of the planet Eros to be computed from measures made at Greenwich on plates taken at various observatories is as follows :—

Greenwich	—Astrographic	205
	—26-inch Refractor	101
Oxford	—24-inch Refractor	49
Cape	—24-inch Refractor	558
Yale	—26-inch Refractor	63
Johannesburg	—10-inch lens	237
Melbourne	—Astrographic	106

The measures on plates taken at Greenwich, Oxford, Cape (24-inch refractor) and Yale (Johannesburg) have been completely reduced and the observed positions of the planet compared with the tabular places interpolated from Dr. Witt's ephemeris. The reduction of the plates taken at Johannesburg (10-inch lens) and Melbourne is in hand.

Astrographic Equatorial.—4 plates of the total solar eclipse field of 1940 October 1, and of two near-by comparison fields were taken with a view to deciding as to their suitability for observing the Einstein displacement at this eclipse.

For the purpose of further correcting the elements of the orbit of the planet Eros, 56 plates were taken on 19 nights around opposition between 1937 November 25 and 1938 March 1.

Photoheliograph.—Photographs of the Sun were obtained on 284 days. The number of photographs selected for preservation is 570, including 33 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 343 days in the year 1937 and on 86 days in the first three months of 1938. The Director of the Kodaikanal Observatory has reported that plates were taken there on 330 days in the year 1937 and on 84 days during the first three months of 1938.

Photographs in duplicate have been received from the Royal Observatory, Cape of Good Hope, to February 19, and the single series to March 18. Nine photographs have been sent from the Kodaikanal Observatory to complete the series for 1937. One day, November 3, is as yet unrepresented.

The measurement of the combined series has been made from 1936 November 25 to 1937 April 27. The reductions of positions and areas of spot groups and their principal components have been completed from 1936 August 28 to 1937 January 23. In addition, plates for the period 1937 May 21 to June 9 have been measured and reduced in order to supply Dr. J. A. Miller with a manuscript copy of sunspot ledgers for comparison with solar eclipse data.

The sun's activity is now passing through its maximum, and the sunspot frequency during the last twelve months has not been exceeded since the maximum of 1870. There have been during the year about 35 groups whose maximum area exceeded 500 millionths of the sun's hemisphere ; of these, fourteen groups attained or exceeded 1,000 millionths in area, and three groups, with respective central meridian passages on July 28·5, October 4·5 and January 18·4, reached an area of 3,000 millionths. Of these fourteen groups, seven were associated within four days of their respective times of central meridian passage with magnetic storms recorded at Abinger. The great magnetic storm of April 16 was associated with a spot group of area exceeding 1,500 millionths, but the great storm and aurora of January 25 were not associated with the central meridian passage of any large sunspot.

The computed times of central meridian passage of groups with an area of 500 millionths or greater have been supplied to the Superintendent, Radio Research Station, Slough, as soon as possible after the first appearance of each group. At the request of the Engineer-in-Chief, General Post Office, advance notification is also being given to the General Post Office of the occurrence of spots having an area of 1,000 millionths or greater (or of smaller spots showing unusual activity spectroscopically). Such spots appear to give the best statistical index at present available of the probable occurrence of terrestrial magnetic storms.

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.

Spectrohelioscope.—Observations were made with the spectrohelioscope on 202 days ; on 25 days, observations were limited to a few minutes owing to cloud. The observations comprise (*a*) a search for bright $H\alpha$ eruptions, (*b*) radial velocity measures of dark $H\alpha$ flocculi, special attention being given to those associated with sunspots, (*c*) photometric measures of prominences, bright flocculi and dark flocculi seen in $H\alpha$, and measures, as far as observing conditions would allow, of prominences in $H\beta$.

(*a*) The number of bright eruptions observed during the year was 109 as compared with 72 in the preceding twelve months. The occurrence of major eruptions has been reported immediately by telephone to the Radio Research Station at Slough. Quarterly lists of all eruptions observed are sent to Slough and also to M. d'Azambuja, at Meudon, for inclusion in the Zürich *Bulletin*. Following on the statement, given in last year's report, concerning the relationship found to exist between the larger and brighter chromospheric eruptions and sudden disturbances in the ionosphere (giving rise to sudden fadings in short-wave wireless transmission), a preliminary statistical discussion, based on data for the years 1935–36, was published in *Monthly Notices*, **97**, 594, 1937.

(*b*) 429 measures of radial velocity were made, of which 379 measures relate to dark markings associated with sunspots. The largest component of radial velocity recorded during the year was — 325 km./sec. on September 7, belonging to an absorption marking associated with a bright eruption. On ten other occasions, radial velocities between 100 and 160 km./sec. were recorded.

(*c*) 103 photometric measures were made of prominences and disk markings by means of an accessory lamp photometer, and 107 measures with a direct wedge photometer. Except in three cases, when the contour was determined, the measures relate to the mean maximum intensity (*not* total intensity) of the prominence or disk marking. Photometric measures of seven prominences were made with the lamp photometer both in $H\alpha$ and in $H\beta$, the mean ratio $H\beta/H\alpha$ being 0·38. The corresponding mean ratio derived from 57 prominences observed during 1934–37 is 0·32.

A paper on the visual observations, made at Greenwich during 1936, of the intensity of dark $H\alpha$ markings on the sun and of prominences was published in *Monthly Notices*, **97**, 531, 1937.

The two original mirrors of the cœlostat of the spectrohelioscope were re-aluminized in January, and the duplicate mirrors were re-aluminized in March-April. The small electric motor which drives the rotating prisms of the spectrohelioscope was replaced by a new one in August.

Total Eclipse of the Sun, 1940 *October* 1.—The Admiralty has authorised the sending of an expedition to South Africa to make observations at the total eclipse in 1940. It is proposed to study the change from line absorption to emission near the sun's limb by means of a slit spectrograph guided on the moon's limb. This will be a 3-prism spectrograph with an automatic exposing and plate-shifting mechanism, and will be fed by a cœlostat. It is also planned to study the Einstein displacement with an equatorial camera designed to shift very rapidly from the eclipse field to a check field and back several times during totality. The same two fields will also be photographed at night beforehand. The Joint Permanent Eclipse Committee of the Royal Society and of the Royal Astronomical Society is providing funds for the principal mechanical parts of the apparatus, whilst the spectrograph prisms and lenses are being provided by an Admiralty vote and will remain part of the equipment of the Observatory for other purposes.

IV.—Time Service :—

The pivots of the Small Transit (B) used for time determinations had become worn by the striding level. As they were made of gunmetal, it was decided to trim them down and fit stainless steel sleeves on to them. This was done by Messrs. Cooke, Troughton and Simms, Transit C taking the place of Transit B meanwhile. Subsequently Transit C was similarly fitted. In both cases the new pivots are somewhat conical and a little elliptical, as shown by tests with the mikrotast gauge ; it is planned to lap them into shape shortly. The present performance is, however, at least as good as that of the old pivots.

Determinations of time have been made throughout the year by a rota of observers with the Transit Instrument B, except during the period September 9 to December 5 when steel sleeves were being fitted to the pivots ; during this interval Transit C was substituted.

Observations were secured on 109 nights, the transits being registered on a syphon recording tape chronograph operated by a thermionic valve relay. Except during a repair period two pens were used for clock and transit respectively.

In previous years it has been the practice to employ as sidereal standard simply the free pendulum clock against which the transits were being directly recorded. During periods when observations were not obtainable the only method of detecting a change in rate was by comparisons with the reserve standards ; such tests are often inconclusive. All pendulum clocks appear to be liable to sudden small changes of rate which, during cloudy weather, may give rise to considerable discrepancies between the true clock error and that predicted. With the object of minimising such effects, a change in procedure was adopted in 1937.

The mean of all available free pendulum clocks is now computed and fitted to an ephemeris. Astronomical observations give the error of one clock ; by adding the difference between this clock and the mean clock the error of the mean clock is obtained ; these observed errors are plotted against the ephemeris, and a smooth curve, drawn as nearly as possible through the points representing the observations, can then be extrapolated to give a forecast of the errors of the mean clock. The effect of a change of rate of any one clock will thus be reduced in a ratio corresponding to the number of clocks incorporated in the mean. In so far as the smooth curve provisionally adopted for the mean clock does represent its real error, it is also thus possible to determine the real variations of any one of the constituents.

Thus the error of any one clock can be predicted with greater certainty, so that the time of transmission of signals is more nearly correct ; and the final corrections, published after all the observations have been obtained, are also better determined.

For some years, by courtesy of the Director of the National Physical Laboratory, the daily errors of the free pendulum clock at Teddington, relative to the 10^h Rugby rhythmic signal, have been forwarded to Greenwich. Since the error of the signal is determined at Greenwich, a comparison between the National Physical Laboratory clock and the Greenwich clocks is thus possible. From 1937 June 1 this clock has been incorporated in the mean clock, because it is of advantage to incorporate a clock that is not affected by influences local to Greenwich, which might possibly perturb all the Observatory clocks at the same time.

The sidereal clocks Shortt Nos. 3, 11 and 40 and the mean time clocks Shortt Nos. 16 and 49, together with the National Physical Laboratory Shortt clock, or those of them that are in use, are combined to give the mean clock.

The chronograph and sidereal circuits of the Observatory have been operated throughout the year by clock Shortt No. 3, and Shortt No. 16 has been used as standard mean time clock. For the purposes of incorporation in the mean clock, the rate of No. 16, which is corrected daily in order to be used as mean time standard, has been deduced from the amounts of correction required each day to keep it to time; on this basis, it has proved to be as accurate as any of the other clocks in use. The photoelectric cell apparatus on Shortt No. 40 has been in operation throughout the year and regular comparisons have been obtained.

During the summer it was noticed that the pallet wheels of both No. 3 and No. 11 showed signs of serious wear on the pivots. No. 11 was opened, and a new wheel, presented by the Synchronome Company, was mounted. It comes to rest exceptionally smoothly, after impulsing, but the performance of the clock was unreliable after the change; it proved difficult to seal the case up satisfactorily, and, during the manipulation involved, the rate several times changed suddenly by such large amounts that the case had to be opened again for re-rating. Finally a brass rod was passed down inside the case, until it rested on the top of the bob, and it was then struck smartly down on to the bob several times. This was done to ensure that the bob, which happens to be a very tight fit on the stem, really was properly bedded down on the retaining pin. Since then, the case has several times been tapped with a light mallet without producing any changes of rate greater than the normal and spontaneous ones. The pressure is still rising very slowly, but the clock will be taken into use again shortly.

As in previous years, the mean time standard clock Shortt No. 16 has controlled the clocks which provide the Post Office and the British Broadcasting Corporation time signals and the Rugby rhythmic time signals. All these clocks are magnetically corrected four times a day, as a result of inter-comparisons between No. 16 and the other free pendulums.

The Rugby time signal transmitter has undergone further modification to improve the regularity of the dots of the rhythmic series. A relay has been fitted to cut out the synchronizing coil, by which No. 16 controls it, during transmission of the

series, so as to prevent a discontinuity during the emission of the signal due to the synchronizing action. Formerly, the signal was passed on to London by means of a biassed relay sending a single current signal. This relay has been replaced by a more modern type, and the circuit arrangements re-designed to allow this to be used unbiassed, and driven by the induced transients in the secondary of a transformer whose primary is in the clock circuit. The relay is used with a double current output, which means that the Post Office relay in London can also be used unbiassed.

The renovation of the clock Dent 2 has been completed and it has been installed in the Octagon Room. The Graham regulator has also been cleaned and repaired and placed in the visitors' room. The clocks Earnshaw, Arnold 2 and Riefler 50 have been sold.

The service of rhythmic radio time signals at 10^h and 18^h transmitted through the Post Office Radio Station at Rugby and also the hourly time signals to the General Post Office and the six dots signals to the British Broadcasting Corporation, sent every quarter hour, have been transmitted regularly. The hourly signals to the Post Office have been utilised for the automatic correction of the Talking Clock, which has proved a remarkable success.

The radio time signals from Paris (FLE), Bordeaux (FYL) and Nauen (DFY) have been regularly received in addition to the Rugby signals sent out from Greenwich.

The corrections to the transmitted times of the rhythmic signals for adjustment to the final time determinations are published and distributed monthly by the Hydrographer of the Navy in *Notices to Mariners*, together with the corrections obtained for the time signals from Nauen and Bordeaux.

The cathode-ray oscillograph has been employed for the determination of recorder lag. The six dots time signals radiated by the British Broadcasting Corporation have also been recorded in order to check the time of emission from Greenwich.

The following table gives the monthly means of the differences from Greenwich shown by the principal foreign time signals, and is computed by differencing the corrections to the signals as determined at Greenwich and at the observatory of origin.

1937	Paris 9½ hr. Rhythmic.	Nauen 12 hr. Rhythmic.	Bordeaux 20 hr. Rhythmic.
	s.	s.	s.
January	+0·014	−0·014	+0·006
February	− ·026	− ·032	− ·026
March	+ ·012	+ ·004	+ ·008
April	+ ·013	− ·015	+ ·008
May	+ ·050	+ ·026	+ ·046
June	+ ·041	+ ·010	+ ·039
July	+ ·036	+ ·018	+ ·031
August	+ ·003	− ·024	·000
September	+ ·033	+ ·002	+ ·031
October	− ·001	− ·024	− ·006
November	+ ·005	− ·020	+ ·002
December	− ·021	·000	− ·021
Mean	+ ·014	− ·006	+ ·009
Number of comparisons ...	313	296	344

The sign + means late on Greenwich. The reference point for all comparisons is the commencement of the signals. The times of the Nauen signals 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 at Greenwich, but it is not known what corrections are applied at the foreign stations.

The radio time signal receiver constructed by Messrs. Haynes Radio to the design of the Radio Department at the National Physical Laboratory is not yet in regular use, as a number of small modifications and adjustments which have been found to be necessary have been held up by pressure of other work. The Marconi set, which has been in use for many years, has therefore been employed during the past year, but arrangements for a change over are approaching completion.

Considerable inconvenience has been occasioned by unbiassed relays acquiring a bias in use. It has been found necessary to keep a constant check on all relays employed on circuits of major importance. Investigations are being made with relays employing compliant tongues and stops with a view to their adoption on the time circuits, and it is also planned to reorganize the circuits so that there shall be no point at which a lag in any relay could produce an error in signal transmission that cancelled out on signal reception ; at present it is possible in principle for undetectable errors of this nature to occur, but the actual lags are all small.

A short-wave wireless receiver has been ordered, but has not yet been delivered. It is hoped to receive the American short-wave time signals and thus to continue direct comparisons between Greenwich and Washington which have been in abeyance since June 1934, when Annapolis ceased to transmit on the long wave-length.

The performance of the Westminster clock during the year is shown by the following table giving the errors of the clock signals :—

Error of Signal.	Number of Days.
Not greater than $0^s \cdot 2$	131
$0^s \cdot 2$ to $0^s \cdot 5$ ..	92
$0^s \cdot 5$ to 1^s	52
Greater than 1^s	18

The clock is not corrected by any signals from the Observatory.

During the year trouble was experienced with the time ball apparatus and it was accordingly dismantled and overhauled and a number of parts were replaced.

The time ball was out of action on July 14, from August 17–26 and from September 28–October 8.

The ball failed to drop on September 5 due to an earth on the electrical release circuit. It was dropped in accordance with custom at 11^h on November 11th.

V.—Chronometers :—

The number of chronometers and watches belonging to the Admiralty now at the Observatory is 1,875. Of this total 227 chronometers, 527 chronometer watches, 214 deck watches and 113 pocket watches are being rated. Seven chronometers are in regular use in the Observatory. The remainder, consisting of 306 chronometers, 186 chronometer watches, 242 deck watches and 53 pocket watches, are kept in storage.

In addition to Admiralty instruments, there are 61 chronometers and watches deposited at the Observatory for various reasons.

During the year ending 1938 April 30, a total of 2,178 chronometer watches have been received and 2,269 issued. The number sent for repair was 1,409, viz., 1,349 for the Admiralty, 35 for the Indian Government, 1 for the Australian Government, 2 for the Colonial Office and 22 for the Royal Air Force.

Various changes have been made by the Admiralty during the year, some of which have resulted in a considerable increase in the amount of testing to be done at the Observatory. The withdrawal of all deck watches (previously known as hack watches) with separate seconds dial has reduced the stock of available deck watches by about 30 per cent, and 100 new centre-seconds watches have been ordered. An increase in the number of chronometer watches was also decided on and after a considerable amount of correspondence and study of samples a type was selected; it is expected that 200 will be delivered during the current financial year for testing and purchase. The amount of work involved in a " test for purchase " is greater than in the case of a watch tested after repair only, and the load on the Observatory will evidently increase further. It is also planned to replace all deck watches by a new pattern in which the seconds graduations are on a ring that can be rotated so as to set the seconds error to zero at any time. This principle is also being applied to wrist watches.

The position regarding the repair by the trade of the high grade instruments necessary for navigational use is still unsatisfactory. The public demand for high grade watches is now very small and this has led to the almost entire elimination of the highly skilled craftsmen, not only in adjusting but in other branches of the repairing trade. The present position is such that the illness of one key craftsman can seriously hamper all the firms undertaking Admiralty repairs.

As foreshadowed in the last report, the Observatory now has its own adjusting and repair shop with a small staff and, although it has been in action for a comparatively short time (since 1937 November 30), it has already proved to be of great assistance. The convenience of having skilled adjusters at the Observatory has greatly facilitated and accelerated the repair of the watches.

The equipment of the repair shop consists of a lathe, watch cleaning machine, demagnetiser, case polishing equipment, a small thermostatically controlled oven and a watch rate recorder. This last has a crystal-controlled constant-frequency drive against which the ticks of the watch are automatically recorded. The watch may be tested in all positions, and in a few seconds its rate can be read off with ample precision for all preliminary work. Any irregularity in its beat is also immediately apparent.

VI.—Nautical Almanac Office :—

During the year under review the work of the Office has been mainly devoted to the routine calculation and proof reading involved in the preparation of the *Nautical Almanacs* for 1939 and later years, and of the *Air Almanac* for 1937 and 1938; considerable preliminary work and calculation have also been done on other publications to be issued shortly. Frequent changes in and additions to the established staff, together with the unsettled condition of the publications undertaken on behalf of the Air Ministry, have made a formal organization of the Office impossible up to the present time. The nature of the work, involving specialized theoretical and practical knowledge and extraordinarily careful supervision, does not easily allow the separation of the staff into groups responsible for one aspect of the work or for one publication ; modern methods of calculation, using commercial adding and printing machines, necessitate the centralization of a considerable portion of the work, while proof reading, upon which depends the essential accuracy of the publications of the Office, must be done by the members of the staff best qualified by experience. With the stabilization of the establishment and of the routine commitments of the Office, it has recently been possible to introduce a rearrangement of staff and duties, which it is hoped will form a basis for a subsequent formal organization.

The Nautical Almanac.—The *Nautical Almanac* for 1938 was published on May 20, and that for 1939 on April 20. It had been anticipated that the arrears in publication would be overtaken more rapidly, but the additional work and especially proof-reading involved in the *Air Almanac* have necessitated delay in the reduction of arrears. The last sheet of the *Nautical Almanac* for 1939 was, however, passed for printing on February 8, as compared with the corresponding date April 20 of the previous year, and the acceleration, as far as the Office is concerned, was thus $2\frac{1}{2}$ months as compared with the 3 months hoped for in the last report.

As mentioned in last year's report, the main feature of the 1938 edition was the complete revision of the data provided for the reduction of occultations. The data now given consist of Occultation Reduction Elements which are computed for each star that can be occulted in favourable circumstances from some place on the Earth. By their means, an observation of an occultation can be reduced in from 10 to 15 minutes ; reports suggest that the centralization of such a large proportion of the work of reduction is much appreciated. Other alterations to the standard features of the *Almanac* include the revision of the pages giving the data for the Sun referred

to the equinox of 1950·0, and the rearrangement of the list of observatories to allow the inclusion of quantities for the easier computation of parallax factors and corrections.

Additions to the contents of the *Nautical Almanac* for 1939 are the inclusion of predictions of occultations for Calgary and Vancouver, and the provision of tables giving Moonrise and Moonset for southern latitudes. These latter tables obviate the necessity for the complicated rules which have previously been necessary for the determination of these times from those of the corresponding phenomena in northern latitudes.

The first part of the *Nautical Almanac*, including the ephemerides of the Sun, Moon and planets, is set in type in advance of the remainder. The first part of the *Almanac* for 1942 is now in type, and revised or stereo proofs have already been circulated to the other almanac offices in accordance with the arrangements for the interchange of computations to avoid duplication.

Occultations.—The major part of the work on occultations during the year has been concerned with the programme for 1940, though considerable work was done towards the completion of the predictions for 1939. It has this year been possible to complete the predictions for 1940, although copy for all the stations has not yet been made; it is unlikely that further improvement can be effected in future years. Predictions for the remaining 46 stations for 1939 and for 10 stations for 1940 have been forwarded to the observatories and periodicals concerned.

For 1940, elements of occultations for 1,550 stars not fainter than magnitude 6·5 were received from the Office of the American Ephemeris, and elements for 757 stars between magnitude 6·6 and 7·5 were computed in the Nautical Almanac Office from material supplied by Washington. These 2,307 stars were examined by the occultation machine and preliminary times recorded for 1,131 stars, which were retained for subsequent computation of predictions; during the latter process a further 82 were rejected for various reasons. Prediction and reduction elements for 1,038 stars will therefore be published in the *Almanac* for 1940, together with the prediction elements for 11 planets, for which reduction elements are not given. The total number of predictions made for the 58 stations has been 3856 involving 7084 separate computations; these figures compare with 4,364 predictions and 7,897 computations for 1939.

The occultation supplement " The Prediction and Reduction of Occultations " was published on August 20. The scope of this publication was described in last year's report; it includes a complete description of the occultation machine, the new method of reduction of occultations, and generally of the work of the Office in this direction.

Navigational Tables.—The *Abridged Nautical Almanac* for 1938 was published on June 8 and followed the lines of previous issues. The edition for 1939 was passed for printing on January 28 and published on April 28; it contains for the first time the extended tables of Moonrise and Moonset, reprinted from the standard edition.

A reprint from the *Abridged Nautical Almanac* for 1938, containing the tables of Sunrise and Sunset, Moonrise and Moonset, and other associated data, was made available for general sale towards the end of 1937. This information had been reprinted in previous years for the use of the Air Ministry, and it was considered desirable that it should also be accessible to other users of the *Air Almanac*. A corresponding reprint for 1939 will be issued shortly.

The *Air Almanac*, whose origin and purpose were described in detail in last year's report, has now become established. In order to provide an experimental period for the use of the *Almanac* by the Air Ministry, the permanent portion was issued on September 28, together with ephemeral sheets for the last three months of 1937. Subsequently, the publication of the ephemeral sheets has been continued, those for the first two quarters of 1938 being published on December 13 and February 24 respectively. Efforts have been made to publish these further in advance each quarter, with the object of issuing them eventually in half-yearly batches and later annually. The ephemeral sheets for the second half of 1938 are now all in print and will be published together early in June.

It has been found by experience that although the *Air Almanac* has been very well received in several quarters, and has been favourably compared with previous publications of a similar nature, it is not sufficiently simple in use for the purpose for which it was designed. Consequently it has been decided to make use of the results of experience and to remodel the tabulated data. From 1939 January 1 onwards, the *Air Almanac* will therefore appear in a completely new form, in which the essential data required by the airman can be obtained with considerably greater ease. This has been achieved by doubling the size of the *Almanac*, and giving the data at much

smaller intervals of time. The increase in size will mean that it will not be possible to continue to issue the *Almanac* half-yearly, and a return will be made to quarterly issue, starting with the first quarter of 1939.

The altitude-azimuth tables, to which reference was made last year, are now well in hand. These tables, which will be known in future as *Astronomical Navigation Tables*, will be published in twelve octavo volumes, instead of the six volumes previously envisaged ; copy for the first volume is now awaiting the completion of printing arrangements, and it is anticipated that publication will take place during the summer. Systematic work on these tables did not start until the beginning of October, when the additional staff was appointed and the new National machine delivered.

Other Publications.—The preparation of the second volume of Planetary Coordinates for the equinox of 1950·0 to cover the years 1940–1960 has been continued, and the ephemerides of all the planets are now completely ready for the printer. It is planned to illustrate the computation of the perturbations of a comet, and at the same time to compare the various methods in use, by calculating the perturbations of Comet 1933*f* (Whipple) by three independent methods—Cowell's, Numerov's extrapolation method devised for minor planets, and the variation of elements. An arrangement has been made with Dr. F. L. Whipple, of Harvard University, by which he will use the method of variation of elements for comparison with the two methods to be examined by this Office. The completed volume should appear early in 1939.

Arrangements for the production of a separate volume containing the apparent places of the 1,535 stars in the FK3 and its supplement have been continued, and complete agreement has been reached with the directors of the other four almanac offices, relative to the computation of the apparent places and the general form of the publication. The first issue will be for the year 1941 and will appear about the middle of 1940.

Copy for the tables of trigonometrical functions for every second of time has been sent to the printer, and although publication may have to be delayed owing to pressure of other proof-reading, issue is expected towards the end of the year.

The 7- and 8-figure tables of the trigonometrical functions for every second of arc, which have been prepared in collaboration with Professor Peters, still await

completion ; it is anticipated that the copy for the 8-figure table will be completed in a short time. No arrangements for printing have, as yet, been made.

Machines.—The present equipment of the Office consists of Brunsviga, Marchant, Mercedes, Monroe and Muldivo calculating machines and of Burroughs and National adding and accounting machines, which have been applied to scientific computing, while the Hollerith tabulating, sorting and multiplying equipment is used as occasion demands. During the year three new calculating machines have been added to the equipment :—a Brunsviga, model 20 ; a Marchant, model M ; and a Muldivo, model 1 B.T.R.

The new 12-bank decimal National machine was delivered in October, since when it has been in constant use on the preparation of the *Astronomical Navigation Tables.* The sexagesimal National machine continues to be indispensable for the checking of computations and the preparation of copy ; most of the copy for the *Air Almanac* is prepared on this machine, and it has consequently been used to its full capacity.

VII.—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 1937 December 31, and with provisional constants to the present time.

The tabulation of results for 1937 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 1937 are given below. The values for the years 1934, 1935 and 1936 are given for comparison.

	Decl. W.	Horizontal. Intensity.	Vertical. Intensity.	Inclination.
1934.. ..	11° 41′·1	0·18533	0·42955	66° 39′·7
1935.. ..	11° 30′·3	0·18527	0·42981	66° 40′·9
1936.. ..	11° 20′·0	0·18524	0·43007	66° 41′·8
1937.. ..	11° 10′·4	0·18522	0·43031	66° 42′·7

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.

During the past twelve months there have been 22 magnetic disturbances reaching the dimensions of a " storm," and, in addition, three disturbances classified as " great storm." (A range of 30′ in declination or 150 γ in horizontal intensity is considered the lower limit for a " storm " ; 60′ or 300 γ for a " great storm.")

The first of the great storms occurred on 1938 January 16–17, the range in H being 370 γ. The second great storm (January 25-26), was of exceptional severity and coincided with one of the most extensive and brilliant displays of aurora which have been seen here within living memory. The ranges were 125′ in declination, 1,040 γ in horizontal intensity and 568 γ in vertical intensity. The third great storm occurred on April 16. The ranges were 307′ in declination, 1,380 γ in horizontal intensity and 494 γ in vertical intensity. It was probably one of the greatest storms of the past hundred years.

A hexagonal cement platform with three bronze footholds has been laid down, for use when instruments on a tripod mounting are employed in the open air. The platform marks the site for which geographical co-ordinates were determined—in 1928 by zenith telescope and in 1931 by prismatic astrolabe—and it corresponds roughly to the centre of the group of buildings in the magnetic enclosure.

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 (re-examined after the supply of new magnets and distance-bar).

A Kew-pattern unifilar magnetometer and a Dip Circle (constructed by Messrs. C. F. Casella and Co.) for use in Peru.

Disturbance of the traces by artificial magnetic fields due to electric traction is still increasing, and, as a result of electrification of the main line through Dorking to the coast, will, it is feared, be very serious in future.

VIII.—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, of sunshine and of cloudiness at night has been maintained continuously. Estimates of visibility have been made by eye at definite hours. Regular records for measurement of the amount of solid matter polluting the air have been continued, using an Owens automatic filter. The gaseous pollution of the air by sulphur dioxide has also been measured daily.

On 1938 January 1 the continuous photographic registration of temperature was superseded by a method more convenient in several ways. A distant-recording wet and dry bulb thermograph by Negretti and Zambra was set up, recording by pen in the basement of the Yapp telescope house at a distance of some fifty feet from the controlling thermometers. The traces are constantly visible through a window of the building.

Coincidently with this change the whole set of standard thermometers was transferred from the open screen hitherto employed (sometimes referred to as the " Glaisher screen ") to a screen of the Stevenson type set up in close proximity and sufficiently large to shelter, in addition, the bulbs of the thermograph thermometers.

It is expected that the readings of temperature made under these conditions will be less liable to effects brought about by the change in the character of the surroundings, for which the advent of large telescope houses in the Christie enclosure has been responsible.

The tabulation of meteorological results for 1937 is complete and the copy for press is well advanced.

The following details of the weather refer to the period of twelve months ending 1938 April 30.

The mean temperature was 51°·0 which is 1°·5 higher than the average of 75 years 1841–1915. The highest temperature in the shade was 91°·9, registered on August 6, the only day on which the reading of the thermometer reached 90°. Temperatures exceeding 80° were recorded on 22 days. The lowest temperature was 23°·9, on November 21. Temperatures of freezing point or below were recorded on 31 days of which 2 were in April, but only 1 in January. The month of March was remarkable for a mean temperature 7°·1 above the 75 years' average, thus easily achieving the distinction of being the warmest March ever recorded at Greenwich.

The mean daily horizontal movement of the air was 260 miles, which is 25 miles below the average for 50 years 1867–1916. The greatest daily movement was 656 miles, recorded on January 15; the least daily movement was 81 miles, on December 25. The greatest motion in one hour, 37 miles, was recorded on January 15 and the greatest pressure reached, 22·0 lbs. to the square foot, was recorded on January 29.

The duration of *bright* sunshine recorded was 1,268·4 hours, or 28·4 per cent. of the possible total. One day in October was without registration owing to the accidental displacement of the glass ball forming the solar image.

There were 74 entirely sunless days, 47 being in the three months November to January. No day in June was entirely sunless. There were 32 entirely cloudless nights in the period, that is, nights on which a complete unbroken trace was obtained by the night-sky camera. The number of nights on which no trace of δ Ursæ Minoris appeared on the plates was 74, while on a further 40 nights the record was not more than ten per cent. of the whole time of exposure.

The total rainfall during the period was 19·50 inches, that is 4·74 inches less than the average for 75 years 1841–1915 and 10·37 inches less than in the corresponding period twelve months earlier.

The wettest month was December with 3·51 inches; the driest month, April with 0·104 inch.

In the last report reference was made to the sequence of abnormally wet months in the previous winter and spring. The circumstances this year have been abnormal in the opposite direction.

The total measured rainfall in the four months since January 1 amounts to 3·49 inches of which 2·44 inches fell in January. Since March 1 the whole amount has been only 0·437 inch—0·333 inch in March and 0·104 inch in April. There have been instances of a lower total in March and one instance of a lower total in April (1912), but the dryness of these two months in succession is without previous example in Greenwich records. The low total for the three months February to April is also without previous example, though in 1893 there was a similar deficiency in the period March to May.

With regard to pollution of the air by solids in suspension, exceptionally bad days were November 25 to 28. At one time during this period the amount reached 4·4 milligrams per cubic metre, that is, approximately seven pounds in the volume of air contained in a cube with one hundred yards edge.

The mean amount of solid matter in suspension during the period covered by " Summer Time " increased from 0·42 milligrams per cubic metre in 1936 to 0·48 milligrams in 1937. The corresponding figures for the periods of normal time were 0·62 milligrams in 1936–37 and 0·88 milligrams in 1937–38. It appears that conditions have substantially deteriorated during the last twelve months.

With regard to gaseous pollution the average amount over the whole period May 1937 to April 1938 was found to be 0·056 parts of sulphur dioxide per million parts of air, which is the same as the average for the previous period of twelve months. On the two worst days, November 27 and December 26, the amounts, respectively, were 0·311 and 0·298 parts per million.

IX.—Printing and Distribution of Greenwich Publications:—

The Volume of *Greenwich Observations* and its separate parts for 1935 were issued during the current year.

The Volume for 1936 is being prepared and manuscript is being sent to the printers as it becomes available.

X. Personal Establishment:—

The staff of the Royal Observatory at the present time is constituted as follows:—

(*a*) Observatory Staff.

Chief Assistants.—R. d'E. Atkinson, Ph.D. One vacancy.

Assistants.—A. Hunter, Ph.D., P. J. Melotte, H. M. Smith, B.Sc., W. M. Witchell, B.Sc.

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

Junior Assistants.—H. H. J. Barton, K. C. Blackwell, E. A. Chamberlain, H. F. Finch, B.Sc., C. C. Harris, H. C. Howes, B. R. Leaton, E. G. Martin, P. L. Rickerby, G. W. Rickett, A. Shortland, L. S. T. Symms, J. E. Terry, G. F. Wells.

Temporary Junior Assistant.—P. S. Laurie.

Clerical Assistants.—Miss J. Auckland, Miss M. L. Bullock, Miss M. G. Cumberledge, Miss R. A. Foster, Miss M. E. French, Miss G. I. Gennery, Miss E. B. Gray, Miss V. M. Hall, Miss F. E. A. Jeffries, Miss O. M. Judd, Miss E. M. Moore, Miss D. A. Nunn, Miss D. P. Young.

Principal Watch Adjuster.—R. Kunzler.

Assistant Watch Adjuster.—H. Warden.

Secretary and Cashier.—H. G. Barker.

Established Typist.—Miss M. Brickman.

(*b*) Nautical Almanac Office Staff.

Chief Assistant as Superintendent.—D. H. Sadler, M.A.

Assistants.—Miss F. M. McBain, M.A., H. W. P. Richards, B.Sc.

Temporary Assistant.—W. E. Candler, B.A.

Junior Assistants (Higher Grade).—A. J. Daniels, S. G. Daniels, W. A. Scott, B.Sc.

Junior Assistants.—A. E. Carter, W. G. Grimwood, G. A. Harding, Miss M. R. Rodgers, Miss M. C. Scadeng, E. Smith, Miss W. D. White.

Clerical Assistants.—Miss E. N. Histed, Miss V. H. Hitches, Miss D. J. Ifield, Miss G. E. Jackson, Miss J. E. Pullen, Miss R. E. West.

Clerical Officer.—W. R. J. Brockwell.

Shorthand Typist.—Miss V. M. Hooper.

A number of piece-workers are also employed.

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

Transit Circle, Right Ascensions	..	Mr. Acton, Miss Hall, Miss Judd.
Transit Circle, Declinations	..	Mr. Symms, Miss Gennery, Miss Young.

Transit Circle, Ledgering and Miscellaneous Reductions	Mr. Cullen, Mr. Blackwell, Mr. Terry, Miss Bullock, Miss Nunn.
Cookson Zenith Telescope ..	Mr. Acton, Mr. Symms.
Time Department	Mr. Smith, Mr. Rickett, Mr. Finch, Mr. Harris, Mr. Shortland, Miss Gray.
Thompson and Yapp Equatorials ..	Dr. Hunter, Mr. Martin, Miss Auckland, Miss French, Miss Cumberledge.
28-inch Equatorial	Mr. Symms.
Astrographic Department	Mr. Melotte, Mr. Jeffries, Mr. Howes, Miss Jeffries.
Photoheliograph and Spectrohelioscope	Mr. Newton, Mr. Barton, Mr. Laurie.
Magnetic and Meteorological ..	Mr. Witchell, Mr. Stevens, Mr. Wells, Mr. Rickerby, Mr. Leaton, Miss Moore, Miss Foster.
Watch and Chronometer Repairs ..	Mr. Kunzler, Mr. Warden.
Secretariat and Library	Mr. Barker, Mr. Chamberlain, Miss Brickman.

Dr. R. v. d. R. Woolley resigned the position of Chief Assistant on June 1, to take up the appointments of Chief Assistant at the University Observatory, Cambridge and John Couch Adams Astronomer in the University of Cambridge. Though Dr. Woolley had occupied the post of Chief Assistant for a comparatively short time, since June 1933, he had thrown himself energetically into the work of the Observatory, taking an especial interest in the double star observations and in the observations with the spectrohelioscope. He was succeeded on June 28 by Dr. R. d'E. Atkinson, Professor of Physics at Rutgers University, New Jersey and formerly Fellow of Hertford College, Oxford.

Mr. W. M. H. Greaves resigned the position of Chief Assistant on March 31, to take up the appointments of Astronomer Royal for Scotland and Professor of Astronomy in the University of Edinburgh. He came to the Observatory on 1924 January 1 and has contributed greatly to the progress of the Observatory, more particularly by his work on the colour temperatures of the stars, his discussions of the relationships

between sunspots and magnetic storms and his interest in the magnetic work undertaken at Abinger.

Mr. C. R. Davidson, F.R.S., Assistant, retired on August 31, after more than 41 years' established service at the Observatory. It is not possible to state how much the Observatory has owed to Mr. Davidson, who for many years was in charge of the various programmes of observation with the 26-inch refractor and the 30-inch reflector. With a flair for the design of apparatus, he was consulted in many matters of design outside his own department. He had an unusual degree of skill in the adjustment and testing of optical apparatus and would always obtain the best possible results out of any given equipment. The design and supervision of construction of apparatus for use by several eclipse expeditions from the Royal Observatory was entrusted to Mr. Davidson. He has been succeeded by Dr. A. Hunter, of the Imperial College of Science and Technology.

Miss F. M. McBain was appointed Assistant and Mr. W. E. Candler Temporary Assistant at the Nautical Almanac Office on September 20.

At the Observatory the replacement of unestablished computers by permanent staff has now been completed.

The staff of workmen employed at the Observatory consists of a foreman of observatory, two joiners, a mechanic, an improver in the watch-repairing department, a gate porter, four messengers, three of whom perform in turn the duty of night watchman, a gardener, four labourers and a charwoman. There is also a caretaker-mechanic at Abinger and a messenger at the Nautical Almanac Office.

XI.—General Remarks :—

Visitors to the Observatory during the year included H. R. H. Prince Seif-al-Islam Hussein of Yemen, Señor E. Levin of La Plata Observatory, Mr. Zunderman of the Leiden Observatory, Sir Charles and Lady Collett, Dr. Luis Tamayo, Minister Plenipotentiary of Colombia, and Dr. Rudolf Ramek, formerly Chancellor of Austria.

Senhor J. A. Madeira of Coimbra University Observatory, Portugal, studied the work of the Royal Observatory from July 17 to August 9.

Mr. A. H. Samaha, Chief Assistant at the Helwan Observatory, Egypt, spent from November 15 to December 9 at the Observatory. He was engaged in a study of the work in general, with particular reference to microphotometry.

Mr. B. C. Browne, of the Department of Geodesy and Geophysics in the University of Cambridge, spent two days at the Observatory in August, standardising some fuzed quartz pendulums for the Cape Town University.

Eight students of the advanced class at the Military College of Science under the superintendence of Professor C. E. Wright visited the Nautical Almanac Office on March 15, to inspect the machines and methods of calculation.

Captain Radler de Aquino visited the Nautical Almanac Office in July, to discuss navigational problems.

Colonel A. H. D. Phillips, O.B.E., and Dr. J. W. Maccoll of the Ordnance Committee visited the Nautical Almanac Office in April, to discuss the application of the National Machine to certain problems in ballistics.

Mr. H. G. Scott Barrett, whose services have been lent to the Observatory by the Radcliffe Trustees, is still rendering valuable help in the reduction of the Eros photographs.

The Astronomer Royal visited the Bureau de l'Heure at the Paris Observatory in December for the purpose of studying some of the methods and apparatus used in the determination and transmission of time and in the reception of time signals.

The completion of the programme of observations with the Airy Transit Circle, each star having received five or more observations, has been made possible, despite unfavourable observing conditions during the winter months, by the keenness of the transit circle observers and by intensive teamwork in the observation of the bad patches in the programme. The completion of this programme marks an epoch in the history of the Observatory. For more than 87 years the Airy Transit Circle has been the fundamental instrument of the Royal Observatory ; more star transits have been obtained with this instrument than with any other meridian instrument. The long series of observations with one instrument has been of the greatest value for fundamental astronomy.

At the time the telescope was installed, in the year 1850, it was much superior to any existing instrument, but with the lapse of years and the increase in accuracy that has become possible it has been realised that there exist systematic sources of error that cannot be eliminated with a non-reversible instrument.

Though no further use will be made of this instrument for fundamental observations, it still remains a suitable instrument for differential observations. A new object glass and either a re-graduation of the circle or a new circle would be necessary if the instrument were to be employed in the future for differential observations. The object glass was repolished and refigured in 1891 and 1906; the lenses are so thin that a further repolishing, which is now needed, is not possible. With continual cleaning of the circle, many of the graduations have become barely visible and some have completely disappeared; some of the worst divisions were re-cut a few years ago, but the general state of the circle is now such that nothing short of complete re-graduation would be satisfactory.

The Prime Meridian Conference, which met at Washington in 1884, recommended the adoption of the meridian passing through the centre of the transit circle at the Observatory at Greenwich as the initial meridian for longitude. Even if no further observations are made with this instrument, it will be retained in its present position because of its historical interest.

The reversible transit circle is being subjected to a very detailed investigation before being put into routine use on a definite programme. Much information is being accumulated on possible sources of systematic error in meridian observations. The present indications are that a great deal of preliminary observations will be needed before the special peculiarities of the instrument have been thoroughly investigated and understood. The two most experienced of the present transit-circle observers, Messrs. Cullen and Acton, are devoting much of their time to work with the new instrument.

Considerable progress has been made at the National Physical Laboratory with the construction of the quartz crystal oscillator clock, referred to in the last report. Preparations, in anticipation of its completion, have been made at the Observatory and it is hoped that the clock will be installed during the present year.

Reference was made, in last year's report, to disturbance of the traces at Abinger by artificial magnetic fields due to electric traction. At times, particularly during spells of wet weather, the disturbances produced by trains on the line to Guildford have been serious. The electrification of the line through Holmwood to Portsmouth has recently been completed. The regular service of electric trains on this line has not yet commenced but there has been experimental running on a number of occasions,

when very marked disturbance of the traces resulted. These disturbances are much in excess of the normal disturbances produced by trains on the Guildford line. If disturbances of the same magnitude prove to be normal, when the regular service is in operation, it will be a matter for serious consideration whether the further continuance of magnetic work at Abinger is justifiable.

The interference with observations at low altitudes, caused by the installation of mercury vapour discharge lamps for lighting certain streets in the neighbourhood of the Observatory, has been mentioned in previous reports. The Greenwich Borough Council, having decided to improve the lighting of Charlton Way, the road running along the southern wall of Greenwich Park, has installed a system of high pressure gas lighting, in which the lamps have a horizontal cut-off, so that no light from the lamps is thrown up into the atmosphere. The interference produced by this type of lighting is much less than that produced by the type of mercury vapour lighting of which complaint had previously been made. The efforts of the Greenwich Borough Council to reduce as far as is possible the interference with the work of the Observatory, arising from improvements in lighting along main thoroughfares near the Observatory, are gratefully acknowledged.

H. SPENCER JONES.

Royal Observatory, Greenwich.
1938, May 9.

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