

REPORT  
OF THE  
ASTRONOMER ROYAL  
TO THE  
BOARD OF VISITORS  
OF THE  
ROYAL OBSERVATORY, GREENWICH.

*Read at the Annual Visitation of the Royal Observatory, 1937 June 5*

# THE BOARD OF VISITORS.

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The Report here presented refers to the period from 1936 May 1 to 1937 April 30 and exhibits the state of the Observatory on the last-named day.

The Nautical Almanac Office has been placed under the direction of the Astronomer Royal and has been made a branch of the Royal Observatory. The Superintendent of the Office has been given the status of a Chief Assistant in the Royal Observatory. It is of interest to recall that the *Nautical Almanac* originated with Maskelyne, the first volume appearing in 1765, the year following his appointment as Astronomer Royal. He carried it on until his death in 1811, the almanacs for the years 1767 to 1816 inclusive having been produced under his direction. The Royal Observatory was founded, in 1675, "for perfecting navigation and astronomy." The *Nautical Almanac*, in the abridged and standard editions, caters for the needs both of the navigator and of the astronomer. It is appropriate, therefore, that it should again be produced, as it was initially, by the Royal Observatory.

#### I. New Instruments :—

*Reversible Transit Circle.*—In last year's report it was mentioned that the pivots of this instrument were slightly elliptical in shape and that further lapping of the pivots would have to be performed. This was carried out by the contractors

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*in situ*, the work being greatly facilitated by the use of a Krupp "Mikrotast" gauge, which had recently been purchased by the Observatory. With the aid of this instrument the figure of each pivot and the difference in the mean diameters of the two pivots could be investigated to an accuracy of about a twentieth of a micron in a comparatively short time. Measurements with the gauge were performed subsequent to each grinding operation, and indicated the portions of the pivot on which further work was required. The figuring of the pivots was completed on July 2, and the maximum departure of each pivot from the circular form is now about a quarter of a micron. This is a highly satisfactory result, which has been achieved by the use of the "Mikrotast" gauge, combined with the skill of Messrs. Cooke, Troughton and Simms' representative (Mr. T. Dwyer).

From a provisional determination with the optical pivot-testing apparatus it appears that the pivot errors (i.e., the errors arising from the combined effect of the two pivots) are of the order of a tenth of a second of arc or less. It was found that to obtain reliable results with the pivot telescope, it was necessary to perform the operations with the objective set successively in four positions 90° apart. This eliminates errors arising from tilt of the objective, and if such an elimination is not performed, the deduced pivot errors are apt to be spurious.

The equipment includes two tape chronographs, each with three pens for hand tapping, time and micrometer records respectively. This type of chronograph permits the employment of the method of observing close circumpolar stars described in *Cape Annals*, Vol. XI, p. 277. In this method the motor-driven wire is set to equatorial speed and by means of the reversing gear the star is made to transit the wire alternately backward and forward in the field of view. The observer records each transit on one pen of the chronograph by means of a tapping key, and the other two pens record the clock time and the reading of the micrometer head.

The normal method of observing consists of the maintenance, by the observer using the differential motion, of bisection while the travelling wire is driven across the field by the motor at a speed approximately equal to that of the star. This method is available up to three degrees from the pole, but for transits of stars as near to the pole as this the continued maintenance of bisection becomes an undue strain on the observer. Accordingly, provision has been made whereby an audible signal is given in the observing house whenever a contact is registered on the chronograph. When observing near the pole this device allows the observer to relax his

attention after the registration of a signal and to secure a fresh bisection shortly before the next contact is due. Its use can be extended to equatorial stars.

Some trouble was experienced with the registration of the chronographs. This led to the replacement of the original pens by syphon tubes. The chronographs now give every satisfaction.

The clamp and slow motion equipment was found to be unsatisfactory. As originally designed it was not available in all positions of the instrument. It was dismantled on July 8, returned to York for reconstruction, and remounted on September 4.

The solar eyepiece was sent back to York for the insertion of colour filters, as light from both the blue and red ends of the spectrum gave bright rings near the Sun's limb. It now appears to be satisfactory, but further tests are required in midsummer when the Sun's altitude is at its maximum.

After fitting the reconstructed clamp and slow motion on September 4, transit observations were begun using the motor driven micrometer. Comparison with the right ascensions of the FK3 catalogue showed that, relatively to that catalogue, the stars near the pole, when observed either above or below pole by the normal method (i.e., not the special circumpolar method) of observation, appeared to transit too early as compared with equatorial stars. The order of magnitude of the error was half a second of time at  $7^\circ$  from the pole. But observations by tapping transits across the fixed wires showed no appreciable deviations from the catalogue places. The trouble was thus definitely located in the micrometer and it persisted whether the motor and differential motion were employed or whether the moving wire was hand-driven. The effect was similar to that which would be produced if the moving wire lagged behind the micrometer screw by about 12 microns, corresponding to one second of arc.

If such a defect as this existed, the normal method of observing a circumpolar star would give a result different from that obtained by using the special method of observation described above, in which the moving wire is driven forwards and backwards at equatorial speed. A selection of circumpolar stars was observed employing both methods for each transit; a difference was revealed amounting to  $0^{\circ}.44$  at  $5\frac{1}{2}^\circ$  from the pole. This gives  $0''\cdot7$  as the lag of the wire behind the screw reading. On the other hand, observations on the collimators showed no backlash in the ordinary sense and it thus became apparent that the lag developed only when the micrometer was in continuous motion. But a further source of instability was

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revealed by placing the telescope in successive positions  $30^\circ$  apart and setting the moving wire either on one of the fixed wires, or on a speck of dust on the horizontal wire that forms part of the Z.D. micrometer. These observations agreed in showing a looseness of the R.A. wire system at one end of the field.

It was obvious that there was a serious constructional defect in the micrometer and after discussion with the makers it was returned on April 19 to York for examination and possible reconstruction.

The stability of the instrument on its pier appears to be very satisfactory. During the period when transits were made (September to March) the errors of collimation, level and azimuth remained extremely steady. Zenith distance observations of the same stars over a period of two months also revealed a highly satisfactory degree of stability.

Work on the determination of the division errors of the circles is in progress. Two supplementary microscopes are employed in conjunction with two of those intended for regular use. The extreme range of the errors of the five-degree divisions on the fixed circle is  $0.22$  seconds of arc. The investigation of the errors of the one-degree divisions is now in progress. In order to facilitate these determinations the mountings of the supplementary microscopes were slotted so as to permit the mounting of them in positions  $24^\circ$ ,  $26^\circ$ ,  $19^\circ$ , or  $21^\circ$  from the other microscopes (in addition to the separations of  $20^\circ$  and  $25^\circ$  employed in the determination of the twenty-degree and five-degree errors). Up to the present, observations have been made on the one-degree divisions with the microscopes set at  $24^\circ$  and  $26^\circ$  separation. The results from these two sets are in very close agreement and give an extreme range of approximately  $0''.4$ .

Moisture deposited during the winter left the paint on the instrument in a very bad condition, and advantage is being taken of the dismantling of the micrometer to clean and repaint the entire installation.

*Slit Spectrograph.*—This instrument, which is intended for use with the 36-inch Yapp reflecting telescope, was delivered by Messrs. Adam Hilger, Ltd., in April. It can be used with a dispersion of either one prism or three prisms. The optical parts are made of ultra-violet glass combined, in the case of one of the camera lenses, with crystalline quartz. Uniform broadening of the stellar spectra is effected by a plane parallel plate of ultra-violet glass, which is mounted immediately behind the slit, and which is rocked through a small angle by an electric motor and cam.

The prisms are of  $60^\circ$  angle and that employed in the one-prism system is also the first of the train of three in the three-prism system. The collimator lens, consisting of a single achromatic doublet of 2.05 inches aperture and 30 inches focal length, is also common to the two systems. For the single prism system the camera lens is another achromatic doublet of 2.2 inches aperture and 12 inches focal length, and the resulting overall dispersion is 18.8 mm. from  $\lambda 3610$  to  $\lambda 6560$  with a tilt of  $43^\circ.5$ . The components of the camera and collimator lenses are constructed of ultra-violet flint and crown.

For the three-prism system it was found that the combination of ultra-violet flint and crown did not permit of a very satisfactory aberrational correction under the required condition of small field curvature. The camera lens for this system has accordingly been constructed of ultra-violet flint and crystalline quartz. It consists of three components. Two of these, an ultra-violet flint and a quartz lens, form a contacted doublet, and the third component, which is of quartz, is separated by an air space. The combination is of 26.5 inches focal length working at  $f 13.2$  and, with a tilt of  $2^\circ 33'$ , the dispersions in angstroms per millimetre are 107 at  $\lambda 6780$ , 39 at  $\lambda 4900$ , 19 at  $\lambda 4080$  and 11 at  $\lambda 3540$ . Good definition is obtained without change of adjustment, over the range  $\lambda 3600$  to  $\lambda 6500$ .

The spectrograph body is supported within an outer casting, which also acts as the upper part of the temperature case. The temperature is controlled by a Cambridge Automatic Temperature Regulator. The flexure is satisfactorily small, the displacement of the image being 7 microns for a rotation of  $180^\circ$  in the most unfavourable position.

The instrument is provided with equipment for the Hartmann focal test and with half-aperture shutters for checking spectrophotometric calibrations.

A spectrograph carriage has been constructed by Messrs. Sir Howard Grubb, Parsons and Co., for the mounting and dismounting of the spectrograph. On the receipt of the spectrograph on April 8, it was mounted on the carriage and preliminary tests with an arc were carried out using the Hartmann shutter. Arrangements are in progress to mount it on the telescope and to carry out further tests.

*Free Pendulum Clock.*—The free pendulum sidereal clock, Shortt No. 40, presented to the Observatory by Mr. H. R. Fry, F.R.A.S., was delivered during the year. The slave clock is of a higher grade of construction than the standard slave clock; it is fully jewelled throughout and the consequent reduction in friction permits of a much lighter half-minute impulse. This makes it possible to run the slave-clock

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within much closer limits than the normal. The slave-clock is adjusted to have a natural losing rate of 1.5 seconds a day ; in order that synchronization may occur at alternate half-minutes, the acceleration at synchronization is required to be about one millisecond, as compared with 4 milliseconds in the standard form of slave. To ensure a consistent acceleration on synchronization of one millisecond, the synchronizing spring of the standard form of slave has been replaced by a gravity arm, carrying a small sliding weight. By adjusting the position of this weight, the acceleration on synchronization can be varied, permitting an exact adjustment to the desired value.

It is expected that the improvements in the design of the slave-clock will be reflected in a higher standard of performance of the free pendulum itself.

The slave clock was delivered in May and was carefully rated as an independent clock from May 19 to July 24. The special case for the free pendulum, supplied by Messrs. Metropolitan Vickers, Ltd., was meanwhile mounted and tested. The rating of the free pendulum was commenced on August 12. After some adjustments for rate of the free pendulum, the case was finally sealed in October.

The clock has shown a large secular change of rate, causing a change in clock error in 100 days, after allowing for the mean rate, of nearly two seconds. When allowance was made for the secular change of rate and for the mean rate, there was a range in the residual errors, over a three months' run, of about one-tenth of a second. The subsequent development of irregularities in both rate and arc was traced to variable friction of a blank ratchet wheel, introduced to prevent the gathering wheel of the half-minute circuit being pushed backwards on the return swing of the pendulum. The blank wheel has recently been replaced by a toothed wheel.

The photoelectric apparatus, for the purpose of taking time directly from the free pendulum, described in last year's report, has been constructed in the workshop and mounted in position. It is expected that the final adjustments, for centring and focus, will be completed in the near future.

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

With the increased junior staff at the Nautical Almanac Office and the proposals for the general increase of permanent and temporary staff to provide for the additional annual and temporary work recently undertaken for the Admiralty and the Air Ministry, further accommodation became essential. In October, the Admiral President of the Royal Naval College placed three additional rooms at the disposal of

the Office, which were immediately furnished and put into use ; pending the final decision as to the complement required for the extra work, consideration of the question of the future permanent accommodation of the Office has been deferred.

The extra accommodation made possible the redistribution of the staff, with the almost complete separation of mechanical and non-mechanical work, and has also allowed more space for the display of the books in the Nautical Almanac Office library. A card catalogue of these books, which has been urgently desired for many years and has now been made possible, is in preparation.

Louvred partitions have been erected in the East Wing of the Main Building of the Observatory. A projection micrometer and microphotometer are installed in the portion of the room thus screened off.

Part of the Upper Computing Room has been screened by partitions and will be used as a watch and chronometer repairing workshop.

The boundary fence on the west side of the Observatory has now been completely renewed.

The external painting of the following buildings and domes has been completed:— Main Building, New Store, Thermograph Hut, iron work of Yapp Dome and Reversible Transit Circle Pavilion, S.E. Dome, Sheepshanks Dome, Altazimuth Dome, Photoheliograph Dome, Shuckburg Dome and Small Transit Pavilion. In the Main Building, the lighting circuits in the Libraries, Workshop, Lower Museum and Staircase have been rewired, and lighting has been installed in the east and west attics. New electric light fittings have been installed in the Octagon Room.

The hut housing the Robinson Anemometer has been rebuilt.

In the Christie Enclosure a new 3-inch fire hydrant has been installed and portable extinguishers provided at various points. An electric cable has been laid from the feeder pillar to the new Cookson building.

New doors have been fitted to the old offices and the building repainted. A new store cupboard has been erected outside the new clock room. A portion of the new Cookson building has been screened off and converted into a small dark room for loading plate carriers.

At the Abinger Magnetic Station a small wooden house has been erected for housing the 50-volt battery used in coil magnetometer observations. A water main has been laid to the dark room. The office and residences have been painted externally. A lavatory has been added to the office buildings. The sewerage system has been

reconstructed. Work is proceeding in connection with the change of electric supply, which since March 11 has been taken from the new local mains.

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 spectrocope 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.

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 National Physical Laboratory (Aerodynamics Department)—

7-inch parabolic mirror.

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 National Maritime Museum—

Harrison's Time Machines Nos. 1, 2, 3 and 4, and the copy of No. 4 by Larcum Kendall.

The annual examination of the Observatory Library has been made. Fifteen 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. One book which was missing last year has since been returned, and one book which has been missing for a number of years has been replaced.

### 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  $0^\circ$  and  $+24^\circ$ , as well as the stars in Boss's Preliminary General Catalogue between declination  $+64^\circ$  and the pole — have been continued. Efforts are being made to obtain a minimum of five observations to every star. All but 870 of approximately 7,000 entries now have five or more observations, and the observing programme should be completed by the end of next winter. All of the stars north of declination  $+70^\circ$  are being observed both above and below pole.

During the year, 6,573 transit observations and 6,375 observations of zenith distance were obtained. These include the following :—

107 observations of the Sun.

86       "       "       Moon.

Major Planets.			Minor Planets.		
Mercury	..	4 observations.	Ceres	..	8 observations.
Venus	..	19       "	Pallas	..	15       "
Jupiter	..	13       "	Vesta	..	11       "
Saturn	..	5       "			
Uranus	..	11       "			
Neptune	..	12       "			

The observations of the Sun, Moon and planets are published yearly in the

*Greenwich Observations.* A copy of these results for the year 1936 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 .. ..	+ 0 <sup>s</sup> .106	1930 .. ..	+ 0 <sup>s</sup> .116
1924 .. ..	+ .113	1931 .. ..	+ .117
1925 .. ..	+ .114	1932 .. ..	+ .087
1926 .. ..	+ .118	1933 .. ..	+ .101
1927 .. ..	+ .113	1934 .. ..	+ .097
1928 .. ..	+ .114	1935 .. ..	+ .107
1929 .. ..	+ .109	1936 .. ..	+ .102

An amount + 0<sup>s</sup>.050 of these corrections is accounted for by the correction of — 0<sup>s</sup>.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
1936 ..	+ 2.80	+ 2.80			100	61

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

The corrections for the variation of latitude for 1936 are not yet available, due to the revision of the observing programme with the zenith telescope ; consequently the values given for 1936 are approximate.

The departure of the position of the Moon from the position given by pure dynamical theory continues to increase and is now greater than at any time since the year 1680 or, in other words, since just after the founding of the Royal Observatory.

*Cookson Zenith Telescope.*—During the year 216 plates were taken for latitude variation, and 7 for the determination of scale. Of this number, 176 latitude and 7 scale plates were taken on the new site.

The instrument was dismantled on June 8. After being thoroughly overhauled in the workshop, it was re-erected in the Christie Enclosure, close to the Reversible Transit Circle. The latitude of the new site is approximately 1" less than that of the old position in the Observatory Courtyard.

After the necessary observations and adjustments had been made, the instrument was brought into use on July 25, and the new programme of observations, to which reference was made in a previous report, commenced from this date. The number of stars used in the observing programme has been increased, and each group now comprises 6 or 7 pairs. Twenty-four groups, each extending over about one hour in right ascension have been selected, and three groups, centred round midnight are observed throughout the year.

To prevent undue heating of the brick building during the daytime, screens are now being erected outside the south and west walls, and also on the flat roof.

A definitive discussion of the observations, made during the 25 years in which the instrument has been in use at Greenwich, is now in progress. The preliminary values of the latitude variation have been applied to the observed zenith distances and mean positions for each year for each star-pair obtained. These results were analysed to give improved mean places and proper-motions for each star-pair, the general system of the proper-motions deduced from the discussion of meridian observations being retained. All the observations have been re-reduced, using the revised places and proper-motions. It is found that the component, in the

Greenwich meridian, of the secular motion of the Pole has never amounted, during these 25 years, to more than a few hundredths of a second of arc.

The effects of direction and strength of wind on the observed latitudes have been investigated, and the influence of the wind on the latitude values for each period of observation and on the group corrections has been determined. From the 25 years' observations, it is found that the total amplitude of the wind effect on the latitude is  $0''\cdot107$ . The maximum apparent displacement of the zenith to the south occurs when the wind is NNE, and the maximum displacement to the north occurs when the wind is SSW. No dependence of the displacement of the zenith on the strength of the wind has been found. The wind-effect is therefore not an effect that arises from the barometric gradient. The application of the wind correction results in an appreciable smoothing of the observed latitudes.

The residuals of each plate have been freed from the wind effect and an investigation of the lunar tidal effect on the variation of latitude is in progress. The final results have not yet been obtained, but it appears probable that the semi-amplitude of the lunar tidal effect will not exceed  $0''\cdot01$ .

It is also intended to make an investigation of the constant of nutation, for which a large amount of material is available, as 44 star-pairs have been under observation from 1911 to 1936, 22 pairs from 1919 to 1936 and 3 pairs from 1911 to 1929.

*28-inch Refractor.*—The observation of double stars with the 28-inch refractor is undergoing reorganisation. During the past year, while there has been no change in the technique of observation, there has been a large increase in the number of observations secured. This is due partly to increased observing staff and partly to the use of a new working catalogue. The previous working catalogue contained for the most part pairs which were difficult, either on account of a great magnitude difference or a small separation between the two components. It is now considered advisable to organise a programme containing less difficult pairs, since the atmospheric conditions at Greenwich are seldom such that the difficult pairs may be measured with certainty. Moreover there is now no great observatory in the northern hemisphere other than Greenwich that is prepared to devote the whole of the time of a large telescope to double star work. It seems therefore desirable that the 28-inch refractor should be put to a general remeasurement of all pairs in the northern hemisphere that show appreciable motion in a decade. The present working catalogue has been drawn up with this object in view.

During the year 692 observations on 238 pairs were secured. They were distributed as follows:—

191	observations of	73	pairs having a separation	> 2".0.	
295	"	92	"	"	2".0 — 1".0.
187	"	64	"	"	1".0 — 0".5.
19	"	9	"	"	< 0".5.

The practice of estimating the seeing on a scale of 5 has been adopted. The seeing has been below the average this year. The 28-inch object glass has been stopped down to 18 inches and even to 9 inches with advantage under certain conditions of seeing. During previous years it had been customary to use only one eyepiece, having a power of 670, but during the present year four eyepieces have been used, the powers ranging from 500 to 1000.

During the year the orbits of three visual binary stars have been computed, and the results communicated to the Royal Astronomical Society.

A comparison image micrometer, which is a modification of that designed and used by Mr. F. J. Hargreaves, has been designed at the Royal Observatory and constructed by Messrs. Casella and Co. An artificial star is produced by projecting the image of an incandescent filament on to a pinhole, and a real image of the illuminated pinhole is then formed by a second lens. The beam passes through a Wollaston prism, which separates it into two polarized beams, so that when viewed through the prism the star is seen as a double star, whose separation depends on the distance of the star image from the Wollaston prism. A Nicol prism is then interposed to provide, by its rotation, a means of varying the ratio of the light thrown into the two polarized images. By means of a second Nicol prism, the total brightness of the double image may be varied. The whole micrometer is capable of rotation about its axis. It is thus possible to produce an artificial double star whose distance, angle, relative brightness of the components and total brightness may be varied at will to match the double star under observation. The mounting of this micrometer on the 28-inch telescope is in progress.

*26-inch Refractor.*—The number of plates taken suitable for the determination of stellar parallaxes was 1023. 855 plates were measured and 26 parallaxes completed. The parallaxes of 25 stars were published in the *Monthly Notices* for November.

In continuation of the programme of determining the proper motions of stars  
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whose parallaxes have already been measured and for which an interval of at least 10 years has elapsed since the first plates, 53 photographs have been taken and the proper motions of 7 stars determined in R.A. and Dec. with a probable error of  $\pm 0''.003$ .

Constant work at the microscope when only one eye is employed is tiring and harmful to the unused eye. To meet this difficulty, the projection method of measuring photographs, suggested and put into practice by Dr. Schlesinger, has been applied to the micrometer for measuring stellar parallax photographs. The light from a small 50 watt filament lamp is condensed by means of a lens into a small spot on the plate, passing thence into the microscope objective. Using the eyepiece as an enlarging lens and with a small reflector above it, a magnified picture of the star image and micrometer wire system is projected on a screen coated with magnesium carbonate. This screen is adjusted to the measurer's most comfortable reading distance and measurement is performed with both eyes as in reading. The micrometer and measurer are shielded from strong extraneous light. The results show that there is at least no loss in accuracy of measurement, whilst the fatigue consequent on eyestrain is much reduced.

*Yapp 36-inch Reflector.*—In continuation of the programme of colour temperature work using the slitless spectrograph, 230 comparisons of 83 stars with standard stars have been secured. The measurement of the photographs is well in hand.

Photographs of the spectrum of Nova Lacertæ were obtained on five nights and of Nova Aquilæ 1 on one night.

It is axiomatic that a gradient comparison between two stars should be made with equal exposure times. In practice this is very difficult, if not impossible, and it is therefore necessary to determine the effect of unequal exposure times. This involves the determination of a quantity, depending on the optical train in conjunction with the plate, which in effect is the gradient for which the light fluxes at the wavelengths measured in the red and blue are equal (see *Monthly Notices* 96, 832). This gradient can be determined by observing the apparent difference of gradient of a star against itself, different exposure times being used, the light flux for the longer exposure being reduced by a coarse wire diffraction grating.

With a grating whose absorption is such that the exposure times for equal densities are as 1 : 25, photographs have been obtained on 14 nights and a provisional value determined.

*Observations of Eros.*—The work on the measurement of the several series of plates, obtained in connection with the 1931 opposition of Eros, whose measurement was undertaken at Greenwich, has been completed. One hundred and sixteen plates were measured during the year. The total number of plates measured at Greenwich in the course of this work was 1226.

The places of the secondary reference stars, required for the reduction of photographs of Eros taken with long-focus instruments, have been derived from the two series of plates taken specially for this purpose at Greenwich and the Cape. Both of these series were measured at Greenwich. The star places derived from the Greenwich and Cape plates have been combined with the places determined from other series of plates at the Bergedorf, Leipzig and Lick observatories, to give definitive positions for the secondary reference stars. The results of the Lick measurements were kindly forwarded in typescript, in advance of publication, by the Director of the Lick Observatory. The catalogue of secondary star positions is being published by the Royal Astronomical Society in the form of two Memoirs. The first will contain the positions of the stars south of the equator, about 1,500 in number; the second will contain the positions of the stars north of the equator, about 3,000 in number.

In the first of these Memoirs, corrections will be given to the positions of the primary reference stars in Dr. Kopff's catalogue. These corrections will be weighted means of the corrections indicated by the Bergedorf, Greenwich, Leipzig, Cape and Lick plates.

The reductions of the Eros plates is proceeding, using provisional places for the reference stars. Corrections will be applied later to refer the positions of Eros to the definitive positions for the reference stars. The reductions should be completed during the next twelve months.

*Astrographic Equatorial.*—During the period covered by this report five plates were exposed on Nova Lacertæ for the determination of photographic magnitude, and one plate was exposed on Comet Peltier. In addition, 32 plates have been taken by Mr. H. G. S. Barrett for the purpose of completing the observations of the Potsdam astrographic zones  $+32^\circ$  and  $+33^\circ$ , which were taken over by the Oxford University Observatory.

*Photoheliograph.*—Photographs of the Sun were obtained on 285 days, mainly with the Dallmeyer 4-inch photoheliograph. The number of photographs selected for preservation is 554, including 22 with double images of the Sun for the deter-

mination 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 336 days in the year 1936 and on 59 days in the first two months of 1937. The Director of the Kodaikanal Observatory has reported that plates were taken there on 329 days in the year 1936 and on 87 days during the first three months of 1937.

Photographs, in duplicate, have been received from the Royal Observatory, Cape of Good Hope, to 1937, February 12, and the single series to March 16. Ten photographs have been sent from the Kodaikanal Observatory and six other photographs are being despatched to complete the series for 1936.

The measurement of the combined series has been made from 1935, September 17, to 1936, November 24. The reductions of positions and areas of spot groups and their principal components have been completed from 1935, September 17, to 1936, August 27.

During the period covered by this report, sunspot activity has increased greatly. There have been about 25 groups whose maximum area exceeded 500 millionths of the Sun's hemisphere; of these, seven groups exceeded 1,000 millionths in area, the dates of central meridian passage being November 29.3, November 29.4, December 2.2, January 24.2, January 31.2, April 23.2 and April 24.6. The groups of spots with central meridian passage on January 31 and April 24 each exceeded 2,000 millionths in area. It may be noted that considerable magnetic disturbances were recorded at Abinger commencing on February 3 and April 24, the latter series of disturbances culminating in intensity early on April 27.

Daily sunspot numbers, based on Wolf's method of counting, have been supplied quarterly to Professor Brunner at Zurich for incorporation in the *Bulletin for Character Figures of Solar Phenomena*, published under the auspices of the International Astronomical Union.

Photographic prints of solar negatives from 1935 October 1 to 1936 June 30, have been supplied to the Director, Solar Physics Observatory, Cambridge. A duplicate set of negatives for the year 1935 has been sent to the Science Museum, South Kensington.

*Spectrohelioscope.*—Observations were made with the spectrohelioscope on 169 days ; on 26 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 72 as compared with 44 in the preceding twelve months and 4 in the year 1934-35. 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 *Zurich Bulletin*. A preliminary comparison has been made of the occurrence of sudden fadings of short-wave radio transmission (from data supplied by the International Union for Scientific Radiotelegraphy and by Cable and Wireless, Ltd.) and of bright  $H\alpha$  solar eruptions (particulars of which appear in the *Bulletin* published from Zurich under the auspices of the International Astronomical Union). The data for the period 1935 July 1 to 1936 December 31 have shown that there is a close relationship between the two phenomena, especially in the case of the larger and brighter solar eruptions, which would seem to imply the operation of a solar agency travelling with the speed of light. A memorandum on the subject, relating to the period 1935 July 1 to 1936 June 30, was sent to the President of Commission I of the Union for Scientific Radiotelegraphy (Dr. E. H. Rayner).

(b) Three hundred and thirty-one measures of radial velocity were made, of which 263 measures relate to dark markings associated with sunspots. The largest component of radial velocity recorded during the year was  $-300$  km./sec. on December 22, belonging to an absorption marking associated with a bright eruption. Another large velocity of  $+130$  km./sec. near a sunspot was recorded on April 25.

(c) As mentioned in last year's report, photometric measures are being made of prominences and disk markings by means of a lamp photometer and also a direct wedge photometer as accessories to the spectrohelioscope. The measures include (1) 322 observations of the mean maximum intensity (*not* total intensity) of prominences and bright and dark flocculi. (2) Seventeen sets of observations of the line contour of  $H\alpha$  given by prominences and dark markings and eight sets of the  $H\beta$  contour given by prominences.

An investigation has been made into the requisite corrections to the observed contours on account of finite resolving power and of scattered light. A paper describing the results and their application to the observed contours of  $H\alpha$  given by stable prominences and dark markings observed during 1936-37 is being communicated to the Royal Astronomical Society.

#### IV.—Time Service:—

Determinations of time have been made throughout the year by a rota of observers with the reversible transit instrument B. Observations were secured on 106 nights, the transits being registered on a syphon recording tape chronograph operated by a thermionic valve relay.

The personal equation machine, referred to in last year's report, was completed during the early summer, and a series of observations were made. Experience showed that certain modifications to the machine were required, and these have been made. For these observations, it was necessary to dismount the transit instrument from the transit pavilion, to remount it in the tank room on the roof of the Main Building and to refocus it on the artificial star of the personal equation machine. Whenever observations with the personal equation machine were in progress, time observations with the small transit instrument were therefore impossible. To avoid this inconvenience, an impersonal micrometer was accordingly constructed in the workshop and fitted to the similar transit instrument D. The transit instrument D is now mounted in the tank room on the roof of the Main Building, so that observations with the personal equation machine can be made when desired. Such observations will normally be made only on cloudy nights, when time determinations are not possible, and from time to time the instruments B and D will be interchanged. It is expected that a new series of measurements will be commenced in the near future.

The free pendulum clock Shortt No. 3 has been used as sidereal standard throughout the year and regular daily comparisons have been made with the reserve standard, Shortt No. 11. Steel suspension springs were fitted during the year to the Shortt free pendulum clocks Nos. 11 and 49. All the free pendulum clocks at the Observatory are now provided with steel suspension springs, in place of elinvar springs, whose behaviour was suspected to be capricious. The mean time free pendulum Shortt No. 16 was used throughout the year to control the mean time clocks, which provide the Post Office and broadcast signals, and also the rhythmic signal transmitter. This transmitter has been overhauled and has been

fitted with a new synchronizing spring. It was found that the synchronizing spring was too strong, so that the acceleration of the transmitter due to the action of the synchronizer was  $0^{\circ}\cdot 010$ . Synchronization normally occurs once during the emission of the rhythmic signals and, when it occurred, an undesirably large discontinuity was produced in the signals. The new spring produces an acceleration of  $0^{\circ}\cdot 004$ .

The Hardy sidereal clock, which was formerly the sidereal standard clock and is now employed in the Airy Transit Circle observing room, has been cleaned and overhauled. The clock Dent 2 is being renovated and fitted with its original mercurial mean time pendulum. When finished, it will be placed in the Octagon Room. This clock was converted from mean time to sidereal time and for many years was used as a reserve sidereal standard and was later used as a subsidiary clock, controlled by the Cottingham-Riefler sidereal clock.

The service of rhythmic radio time signals at  $10^{\text{h}}$  and  $18^{\text{h}}$  transmitted through the Post Office radio station at Rugby and also the hourly time signals to the General Post Office and the six-dot 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 Post Office Talking Clock.

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*.

The radio time signals from Paris (Eiffel Tower), Bordeaux and Nauen have been regularly received, in addition to the Rugby signals sent out from Greenwich, and the corrections determined. The corrections obtained for the time signals from Nauen and Bordeaux have been published monthly in the *Notices to Mariners* together with the corrections to the times of the Rugby signals. The cathode ray oscillograph apparatus is employed for the determination of recorder lag. At least one of the time-signals sent out by the British Broadcasting Corporation is recorded daily, as a control on the time of emission. 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 instrument at Greenwich and the corrections for final time determinations published by the Paris and Hamburg Observatories :—

1936.	Paris 9½ <sup>h</sup> Rhythmic.	Nauen 12 <sup>h</sup> Rhythmic.	Bordeaux 20 <sup>h</sup> Rhythmic.
	s.	s.	s.
January ... ..	−0·021	—	−0·019
February ... ..	−·042	—	−·039
March ... ..	−·012	−0·015	−·007
April ... ..	−·006	−·002	−·009
May ... ..	−·007	+·014	−·008
June ... ..	+·013	+·032	+·007
July ... ..	+·043	+·036	+·040
August ... ..	+·027	+·013	+·024
September ... ..	+·030	+·016	+·029
October ... ..	+·023	−·013	+·016
November ... ..	+·024	·000	+·022
December ... ..	+·009	−·017	+·006
Mean ... ..	+·007	+·007	+·005
Number of comparisons ... ..	299	243	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. Relative personal equations have been applied to the time observations.

A new radio time signal receiver has been constructed during the year by Messrs. Haynes Radio to the design of the Radio Department of the National Physical Laboratory. In general principles it resembles the receiver used at the National Physical Laboratory and described in the Report of the National Physical Laboratory for 1935, special attention having been given in the design to the constancy of the time lag in reception on all wavelengths. The receiver is designed for the long waves only, having ranges of 1,200 to 3,000 metres, 3,000 to 7,800 metres and 12,000 to 20,000 metres, but the addition of a short wave converter is now under consideration. In particular, it is desired to receive the American short wave signals, as no direct comparisons with Washington have been possible since the long wave signals formerly sent out from Annapolis were discontinued.

Parallel tests are at present being made with the new receiver and the old Marconi receiver, in order that any discontinuity on change over may be avoided.

The principle of recording the Greenwich sidereal standard clock signals simultaneously with the incoming radio signals is being used, as was done with the Marconi set. The clock contacts control a radio frequency oscillator, which acts as a low power transmitter. The receiver picks up both the clock signals and the radio time signals and passes them through the set to the recorder.

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 <sup>s</sup> .2 .. ..	118
	0 <sup>s</sup> .2 to 0 <sup>s</sup> .5 .. ..	105
	0 <sup>s</sup> .5 to 1 <sup>s</sup> .. ..	49
Greater than 1 <sup>s</sup>	.. ..	5

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

Return signals from the clocks at the Depots at Portsmouth and Devonport have been discontinued.

The Time Ball was raised each day and automatically released at 13<sup>h</sup> Civil Time, except on December 14, when it was not raised owing to a high wind, and on March 7, due to an accumulation of snow on the mast. It was also dropped in accordance with custom at 11<sup>h</sup> on November 11.

#### V.—Chronometers :—

The number of chronometers and watches belonging to the Admiralty now at the Observatory is 1,987. Of this total 224 chronometers, 390 chronometer watches, 275 deck watches (previously known as hack watches) and 130 pocket watches are being rated. Five chronometers are in regular use in the Observatory. The remainder, consisting of 317 chronometers, 439 chronometer watches, 168 deck watches and 39 pocket watches, are kept in storage.

In addition to Admiralty instruments, there are 12 chronometers and 52 watches deposited at the Observatory for various reasons.

During the year ending 1937 April 30, a total of 2,167 chronometer watches have been received and 2,175 issued. The number sent for repair was 1,319, viz., 1, the property of His Majesty The King, from the Royal Yacht "Victoria & Albert," 1,267 for the Admiralty, 33 for the Indian, 3 for the New Zealand, 4 for the Canadian, Governments, and 11 for the Royal Air Force.

During the year 30 chronometers and 65 chronometer watches have been sold out of surplus stock.

A scheme has been under consideration for undertaking a certain amount of repairing and adjusting of chronometers and watches at the Observatory. The number of persons engaged in the trade who are competent to undertake the adjustment of chronometers and watches to the fine limits required in Admiralty repairs is small, and, because there is little demand in commercial work for such high standards in adjustment, the competent adjusters are steadily becoming fewer in number. It is hoped that the scheme for undertaking repairs at the Observatory will provide a training in accurate adjusting. The scheme would be capable of gradual expansion, if experience proved that to be desirable. A room has been fitted out as a repair shop but the staff has not yet been appointed.

#### VI.—Nautical Almanac Office :—

During the year under review the work of the office has been devoted mainly to the routine calculation and proof reading involved in the preparation of the *Nautical Almanacs* for 1937, 1938 and later years, but has also included theoretical and preliminary work for other publications to be issued in due course.

*The Nautical Almanac and the Abridged Nautical Almanac.*—The *Nautical Almanac* for 1937 was published in August. In addition to the well-established features of previous years, predictions of occultations visible at Toronto, Montreal, Sydney, Melbourne, Wellington and Dunedin were given for the first time, and a greatly extended *General Index* was included, particularly to facilitate reference to the *Explanation*. The tables giving sunrise and sunset were completely remodelled in order to include tables of civil and nautical twilight, in addition to astronomical twilight, which alone had been given in previous years. The interpolation tables were rearranged and extended; various formulæ connected with the use of finite differences, many of which are not available elsewhere, were presented in tabular form, and a new method of inverse interpolation was developed. These tables with the appropriate explanation were reprinted for separate sale as *Interpolation and Allied Tables*.

The main alteration in the fundamental quantities used in the computation of the astronomical data has been the substitution of the nutation terms, calculated directly by Hollerith machine, for those previously taken from Newcomb's *Tables of the Sun*.

The last sheet of the *Nautical Almanac* for 1938 was passed for printing on April 20 and the Almanac was published in May. The main feature is the complete revision of the data provided for the reduction of occultations; all the previously published data for the reductions have been replaced by Occultation Reduction Elements, which are now 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. The corresponding reduction elements for 1937 are given in an appendix.

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 1941 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.

During the year, completed occultation predictions for 1938 for 19 stations were sent to various observatories and periodicals, while predictions for 13 of the 59 stations for 1939 have also been despatched.

The *Abridged Nautical Almanac* for 1937 was published in August and contained for the first time the extended twilight tables, reprinted from the standard edition. The edition for 1938 was passed for printing on April 13 and was on sale in May.

*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 practically 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. It has not been possible to start any of these methods yet, but 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 the office. The completed volume should appear late in 1938 or early in 1939.

A separate Occultation Supplement, "The Prediction and Reduction of Occultations," describing in detail the work at present undertaken by the office and, in particular, the new method of reduction that has been made possible by the tabulation

in the *Nautical Almanac* of the Occultation Reduction Elements, is now in the press and will be published in June. The material included was originally intended to form part of the explanation of the *Almanac*, but a separate booklet was considered advisable to allow greater scope and to limit the size of the *Almanac*.

At the meeting of the International Astronomical Union held in Paris in 1935, the following resolution was adopted :

“ That, as from the date of the adoption of the star places of the FK3, the apparent places of the 1535 stars in the FK3 and its supplement be published in a single volume under the auspices of the International Astronomical Union, with all necessary explanations in English, French and German. It is recommended that the national ephemerides publish the apparent positions of not more than 200 stars, and that these stars be selected from the FK3. It is further recommended that the printing be undertaken by Great Britain, and the calculations shared by France, Germany, Spain and the United States.”

Approval of this arrangement as regards the part of the work to be undertaken by Great Britain has been given by the Admiralty and preliminary negotiations with the directors of the other four almanac offices have begun. It is expected that the separate volume of apparent places of stars will first appear for the year 1941.

The tables of the six trigonometrical functions for every second of time, copy for which was prepared in 1932, have not yet been published, owing mainly to the high cost of printing and publication. The completion of the copy for these tables is in hand, and it is anticipated that the printing will now go forward.

*Air Almanac and Altitude-Azimuth Tables.*—The Nautical Almanac Office has recently undertaken the compilation of a special *Air Almanac* for the Air Ministry. The purpose of this almanac will be to make possible the navigation of aircraft by astronomical observations, and for this reason the tabulation of the right ascension of the heavenly bodies, as given in the *Abridged Nautical Almanac*, is to be superseded by the direct tabulation of the Greenwich hour angle, at small intervals of time. The efficiency of this tabulation is greatly facilitated by the lower degree of accuracy (one minute of arc) that is justified by the conditions of observation in the air; the necessary interpolation tables are thus very much simpler than would be the case for a similar almanac designed for use at sea, where the accuracy required is 0.1 minutes of arc in the tabulated data.

The proposed *Almanac* is to consist of a strong cover containing the permanent explanation, introduction and interpolation tables, together with an attachment by which a thin card can be readily inserted between the front cover and the first sheet of the interpolation tables. The ephemeral data will be printed on thin cards, each of which will give all the necessary information for two days, in such a way that when one of the loose sheets is attached to the permanent cover the navigator will have immediate and easy access to all the astronomical data he requires with the minimum turning of pages.

The design of this almanac has been discussed in detail with representatives of the Air Ministry and the Admiralty, and the final form has been settled. The preparation of copy for the last three months of 1937 is already in hand, and the first issue of the permanent binding and of the ephemeral sheets for October to December, 1937, will be possible early in September.

The conditions in which the air navigator has to work and the great speed of modern aircraft demand that the determination of a position line should be possible with the minimum of calculation and in as short a time as possible. The *Air Almanac* will give him the astronomical data in a convenient form, but the present methods for the subsequent computation are not suitable for conditions in the air; the Air Ministry have consequently suggested the provision of extensive altitude and azimuth tables to give the solution of the spherical triangle directly. The general outline and scope of such tables have now been developed in the office, and the preliminary exploratory work together with an extensive auxiliary table commenced. The completed tables will occupy six volumes each of about 250 pages, and it is hoped that the first of these may be available about the middle of 1938, while the whole project is to be completed early in 1940. Intensive work on these tables cannot be started until the new National machine and the additional staff are available.

*Machines.*—The present equipment of the Office consists of Brunsviga, Mercedes and Monroe 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. Two obsolescent machines, a Brunsviga, Model II and a Mercedes, Model 18 were replaced in June by the latest models available, namely a Brunsviga 20 and a Mercedes, Model 38 MSW.

The sexagesimal National machine (with a keyboard designed to add in degrees, minutes and seconds) has been in continuous use ; the new methods of systematic interpolation, developed for use with this machine, have been applied with success to the many sub-divisions required in the computations of the ephemerides of the Sun, Moon and planets. The use of the machine for the preparation of accurate and legible printer's copy has been greatly extended, so that most of the copy for the *Nautical Almanac* is now prepared by this means.

An order has recently been placed for the supply of a 12-bank decimal National machine, mainly to be used for the preparation of Altitude-Azimuth tables for the Air Ministry.

The occultation machine, built in 1934 by Mr. A. C. S. Wescott, after the design of the late J. D. McNeile, has again been used with great success in the prediction of occultations for over 50 stations. Its use has enabled this greatly extended scheme to be devised and carried through ; without it, such a comprehensive network of predictions would have been well-nigh impossible. During the year 11 stations have been added to the earth and preliminary times for all the 64 stations for 1939 were completed in December.

#### 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 1936 December 31, and with provisional constants to the present time.

The tabulation of results for 1936 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 1936 are given below. The values for the years 1933, 1934 and 1935 are given for comparison.

		Horizontal.	Vertical.	
	Decl. W.	Intensity.	Intensity.	Inclination.
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
1936.. ..	11° 20'·0	0·18524	0·43007	66° 41'·8

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.

From 1937, March 11, electric supply (alternating current) has been obtained from the local power mains which were brought into the neighbourhood during the previous autumn. In connection with the change to higher voltage, thereby involved, a certain amount of re-wiring was necessary and the opportunity was taken to add provision for heating the observing houses. This should go far to overcome the observing difficulties which develop on the many damp days during autumn and winter.

Disturbance of the traces by artificial magnetic fields due to electric traction appears to be increasing and at times is very serious, particularly during spells of wet weather. It has been suggested that the armoring of the electric mains recently laid in the neighbourhood provides a path for the stray currents which are responsible for creating these fields. Tentative experiments have been made, designed to locate the origin of the trouble, but they have not led to knowledge more precise than that the worst disturbances coincide with the movement of trains near West Clondon, a station on the Southern Railway about eight miles from the observatory.

Apparatus for recording variations in vertical intensity, designed by Dr. E. P. Harrison, of H.M.S. "Vernon," and depending on a novel principle (the variation of impedance in nickel iron alloy) was installed by him in the recording chamber on November 30 with a view to testing its capabilities under observatory conditions. Certain alterations and improvements in detail have been made from time to time and the experiment is still proceeding.

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.

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

The marine magnetometer-inductor that will be used on R.R.S. " Research " has been received at Abinger and is at present undergoing tests.

Lieut.-Com. D. H. Fryer was frequently at the station between June 29 and July 24, obtaining practice in magnetic observation.

The quinquennial revision of the Admiralty charts of magnetic declination was completed in October, 1936.

#### 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.

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. Interpretation of the records is complicated by the presence of parasitic currents partly of thermo-electric origin.

Regular records for measurement of the amount of solid matter polluting the air have been continued using an Owens automatic filter. Tabulation of the results shows that there has been little change in the average amount since the last report. In the summer months there was an apparent reduction of about 10 per cent. ; in the ensuing winter the improvement was not more than 5 per cent. There were no days on which pollution was so strikingly bad as on the worst days of 1934. The reduction in solid pollution on Saturdays appears to average about 5 per cent., while a further reduction of about the same amount occurs on Sundays.

The gaseous pollution of the atmosphere by sulphur dioxide has been measured daily. The same general features have been noticed with regard to the incidence of gaseous pollution as were mentioned in the last report. The days of worst pollution were November 25 and 28 when the amount was estimated to be, respectively, 0.262

and 0.222 parts per million. The average pollution during the year ending 1937, April 30, was 0.056 parts per million by volume. This is an increase of about 25 per cent. on the amount for the corresponding period twelve months earlier.

The tabulation of meteorological results for 1936 is complete and the copy for press is well advanced.

The following details of the weather refer to the period of twelve months ending 1937, April 30.

The mean temperature was  $50^{\circ} \cdot 5$ , which is  $1^{\circ} \cdot 0$  higher than the average of 75 years 1841-1915. The highest temperature in the shade was  $87^{\circ} \cdot 8$  registered on June 21. Temperatures exceeding  $80^{\circ}$  were recorded on 11 days. The lowest temperature was  $23^{\circ} \cdot 7$  on March 10. Temperatures of freezing point or below were recorded on 35 days, of which 13 were in March. The mean daily horizontal movement of the air was 282 miles, which is 3 miles below the average for 50 years 1867-1916. The greatest daily movement was 675 miles recorded on December 14; the least daily movement was 94 miles, on December 26. The greatest motion in one hour, 37 miles, and the greatest pressure reached, 24.0 lbs. to the square foot, were recorded on December 14.

The duration of bright sunshine recorded was 1151.2 hours, or 25.7 per cent. of the possible total. This is the smallest amount of sunshine for 40 years. There were 66 entirely sunless days, 39 being in the three months November to January. No day in June was entirely sunless. There were only 22 entirely cloudless nights in the whole twelve months, that is, nights on which a complete unbroken trace of Polaris was obtained by the Night-sky Camera.

The number of nights on which no trace of  $\delta$  Ursae Minoris appeared on the plates was 84, and on a further 56 nights the record was not more than 10 per cent. of the whole time of exposure. A comparative analysis of the records for four successive periods of twelve months from 1933, May 1, is given below:—

*Measurable trace of  $\delta$  Ursae Minoris expressed as percentage of the total amount possible.*

	No trace.	Up to 10%.	90% to 99%.	100%.
1933-34 ..	54 Nights.	58 Nights.	28 Nights.	43 Nights.
1934-35 ..	61	43	25	39
1935-36 ..	60	39	29	36
1936-37 ..	84	56	21	21

The total rainfall was 29·87 inches, that is, 5·63 inches more than the average for 75 years 1841-1915. Measurable rain fell on 195 days. The wettest month was February with 3·94 inches, and seven months had totals either in excess of or closely approaching 3 inches. The remarkable succession of rainy days since the beginning of 1937 has provided a total of 12·85 inches of rain in the period January 1 to April 30. This total has never yet been approached in Greenwich records for the corresponding period of the year. The year which previously had the distinction of being wettest in the early months was 1866 and in that year the present total was not reached until May 27.

The small amount of sunshine, the large proportion of cloudy nights and the high rainfall agree in confirming the experience of the observing staff that the past year was the worst year for observing experienced at Greenwich for many years.

IX.—Printing and Distribution of Greenwich Publications :—

The Volume of *Greenwich Observations* for 1935 and its separate parts has been forwarded to H.M. Stationery Office for printing.

X.—Personal Establishment :—

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

(a) Observatory Staff.

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

Assistants.—C. R. Davidson, F.R.S., 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, E. G. Martin, P. L. Rickerby, G. W. Rickett, A. Shortland, L. S. Symms, G. F. Wells.

Temporary Junior Assistant.—P. S. Laurie.

Clerical Assistants.—Miss J. Auckland, Miss M. L. Bullock, Miss V. M. Dowler, Miss G. I. Gennery, Miss V. M. Hall, Miss C. M. Lark, Miss E. M. Moore, Miss D. P. Young.

Established Clerk, Grade IV.—Miss F. E. A. Jeffries.

Temporary Clerks, Grade IV.—Miss M. C. Cumberledge, F. E. Deeks, W. Dennis, Miss M. E. French, W. G. Grimwood, L. J. C. Stockwell

Secretary and Cashier.—H. G. Barker.

Temporary Typist.—Miss M. Brickman.

(b) Nautical Almanac Office Staff.

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

Assistant.—H. W. P. Richards, B.Sc.

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

Junior Assistants.—A. E. Carter, Miss M. R. Rodgers, E. Smith.

Clerical Assistants.—Miss Y. F. Hall, Miss D. J. Ifield, Miss M. C.  
Scadeng, Miss W. D. White.

Clerical Officer.—R. Gornall.

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, Mr. Stockwell.
Transit Circle, Declinations	..	Mr. Symms, Miss Gennery, Miss Young.
Transit Circle, Ledgering and Miscellaneous Reductions		Mr. Cullen, Mr. Blackwell, Miss Lark, Miss Bullock, Miss Dowler, Mr. Grimwood.
Cookson Zenith Telescope	.. ..	Mr. Acton, Mr. Symms.
Time Department	.. ..	Mr. Smith, Mr. Rickett, Mr. Finch, Mr. Harris, Mr. Shortland.
Thompson and Yapp Equatorials	..	Mr. Davidson, 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 Spectroheliograph		Mr. Newton, Mr. Barton, Mr. Laurie.
Magnetic and Meteorological	..	Mr. Witchell, Mr. Stevens, Mr. Wells, Mr. Rickerby, Miss Moore, Mr. Dennis, Mr. Deeks.
Secretariat and Library	.. ..	Mr. Barker, Mr. Chamberlain, Miss Brickman.

Mr. Sadler was appointed Chief Assistant, as Superintendent, of the Nautical Almanac Office with effect from August 26.

Mr. W. Bowyer, Assistant, retired on October 31 after more than 44 years' service at the Observatory, 40 of which were in an established capacity. During the Great War Mr. Bowyer dealt with an enormous amount of chronometer work in a highly successful manner. Since 1917 he had been in charge of the Time Department, the activities of which expanded considerably during his regime, of particular importance being the development of radio time signal work, and the introduction of free pendulum clocks. He has been succeeded by Mr. H. M. Smith.

Mr. H. W. P. Richards was appointed Assistant at the Nautical Almanac Office on April 19. Mr. W. A. Scott was appointed Junior Assistant, Higher Grade, in an acting capacity, with effect from February 11.

Mr. D. J. R. Edney retired on July 19. He had been at the Observatory for nearly 45 years of which over 40 were passed in established service. Since 1920 he had performed the duties of secretary and cashier to the Observatory. He has been succeeded by Mr. H. G. Barker.

The approved normal complement of the Nautical Almanac Office provides for one Assistant, four Junior Assistants, and two Clerical Assistants, in addition to the present staff, while it is proposed that one Assistant, one Junior Assistant and two Clerical Assistants should be engaged temporarily during the preparation of the Altitude-Azimuth tables. Owing to the difficulty of absorbing new and untrained staff, the appointment of two Junior Assistants and one Clerical Assistant will not be made for eighteen months or two years, provision being made during this time for the continuation of the employment of outside piece-workers; it is intended eventually to reduce the amount of work done outside the office to a minimum. Mr. R. Gornall is on loan from the Hydrographic Department of the Admiralty, in lieu of a Clerical Assistant, and is in charge of the secretarial and clerical duties of the office.

At the Observatory the replacement of unestablished computers by permanent staff, referred to in previous reports, is approaching completion.

The staff of workmen now employed at the Observatory consists of a foreman of observatory, two joiners, a mechanic, a gate porter, four messengers, two 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 Professor Hertzsprung, Director of the Leiden Observatory, M. A. Lambert, of the Bureau International de l'Heure at Paris, M. Lyot of the Meudon Observatory, M. Chalonge of the Paris Observatory, Professor A. Kopff, Director of the Astronomisches Rechen-Institut of Berlin, Miss Cannon, Dr. Menzel and Dr. Boyce of the Harvard Observatory and the Ranee of Bobili.

Professor Kopff also visited the Nautical Almanac Office.

A party of delegates to the General Assembly of the International Council of Scientific Unions visited the Observatory on April 29.

Dr. P. Slavénas of the Kaunas Observatory, Lithuania, studied the work of the Observatory for a week in July.

M. Vandekerkhove, of the Royal Observatory of Belgium, worked at the Observatory from November 20 to December 29. He was engaged in a study of the methods employed in the Colour Temperature programme.

Eight students of the advanced class at the Military College of Science, accompanied by three instructors, under the superintendence of Professor C. Wright, visited the Nautical Almanac Office on March 22, to inspect the machines and methods of calculation.

Mr. H. G. Scott Barrett, whose services have been lent to the Observatory by the Radcliffe Trustees, continues to render valuable assistance in the reduction of the Eros photographs. A portion of Mr. Barrett's time has been given to the Oxford University Observatory, for work on the additional Carte du Ciel programme undertaken by that Observatory.

The Astronomer Royal, Mr. Greaves and Mr. Witchell attended the General Assembly of the International Union of Geodesy and Geophysics, held in Edinburgh in September.

The Astronomer Royal represented the International Astronomical Union at the General Assembly of the International Council of Scientific Unions, held in London in April.

At the invitation of the Postmaster-General, the Astronomer Royal attended the ceremony for the inauguration of the Post Office Talking Clock, at the Holborn Telephone Exchange on July 24, and made the first "Time" call. The Talking Clock, which is controlled by hourly signals from the Observatory, makes accurate time widely and continuously available and provides a service that is much used and appreciated.

The work of the Nautical Almanac Office, at the time of the transfer of the Office to the Observatory, to which reference was made at the beginning of this report, was heavily in arrears, the Standard and Abridged *Nautical Almanacs* for 1937 not having been published until August, 1936. The arrears of work have been reduced by three months, the *Almanacs* for 1938 having been published in May, 1937. This improvement in the position of the work has been due in large measure to the enthusiasm, energy and organising ability of the new Superintendent, Mr. D. H. Sadler, whose efforts have been well supported by the entire staff of the Office.

The new volume of Apparent Places of Stars, which will be produced annually by the Nautical Almanac Office, commencing with the volume for the year 1941, will be made possible by international co-operation. The extensive preliminary work of obtaining mean places and proper-motions of the stars on the most accurate fundamental system has been undertaken under the direction of Professor Kopff at the Rechen-Institut, Berlin. The computation of the apparent places of the stars will be shared by the offices of the *American Ephemeris*, the *Connaissance des Temps*, the *Berliner Jahrbuch* and the *Almanaque Nautico*. The Nautical Almanac Office will be responsible for the preparation of the volume and for its passage through the press. The new volume will prove of great convenience to astronomers, surveyors and others who require to determine time, as it will contain sufficient stars to meet the requirements of all such observers. At present, it is necessary to extract apparent places from the several national ephemerides, each of which contains a different selection of stars.

Approval has been given for the supply of a quartz crystal oscillator clock and arrangements have been made for the necessary equipment to be provided, and assembly to be undertaken, at the National Physical Laboratory, where the work will be under the supervision of Dr. E. H. Rayner. The quartz vibrator will have a frequency of vibration of 100 kilocycles per sidereal second. Demultiplier circuits from the controlled oscillator will provide a frequency of 500 cycles per sidereal second, which will be amplified to drive a phonic motor, designed to give impulses at one-

hundredth of a second, one-tenth of a second and one second intervals. A temperature variation of less than one-hundredth of a degree Centigrade will be ensured by means of a thermostat, and the quartz vibrator will be adjusted to have a temperature coefficient not greater than 5 parts in 100 million.

It is expected that the quartz oscillator clock will enable the Observatory to distribute time with an accuracy sufficient to meet the present-day demands for high precision in frequency control. The distribution of time necessarily depends upon *predicted* clock-errors and, in spells of cloudy weather, the clock errors may have to be carried forward, without observational check, for two weeks or even longer. The most accurate pendulum clocks yet constructed (the Shortt free-pendulum clocks) are liable to small erratic changes of rate, of the order of 0.01 or 0.02 seconds per day. Even with three standards for inter-comparison, an error of 0.05 seconds is easily possible at the end of a long cloudy spell. Corrections to the times of signals are determined and published monthly when the final clock error curve has been constructed. Though for some purposes these corrections enable the highest accuracy to be obtained, there are other purposes for which it is necessary that the errors of the time signals should be kept as small as possible. Quartz oscillator systems have proved stable, over limited periods of time, to the order of 0.001 seconds per day, though it is doubtful whether they are superior over long periods of time to free-pendulum clocks. It is probable that this type of clock will ultimately be considered as an essential part of the equipment of any observatory that is responsible for the determination and distribution of time.

Investigations connected with the new Reversible Transit Circle have occupied much of the time of several members of the Staff. The determination of the division errors of the fixed circle is well advanced, the errors of the 20°, 5° and 1° graduations having been obtained. It is estimated that one year's further continuous measurements will be required for the determination of the errors of all the graduations. The errors so far determined are satisfactorily small and the graduations themselves are excellent for setting on with the microscopes. Glass circles as large as 24 inches diameter had never previously been made and their construction raised a number of new problems. The makers, Messrs. Cooke, Troughton and Simms, Ltd., are to be congratulated on the success that has attended their efforts. The investigation of the anomalous results obtained in observing transits of stars at different declinations has taken much time in a year of particularly bad weather. The results are of interest, as they suggest some ways in which small systematic differences between various

instruments can occur. It is fortunate, perhaps, that in the new instrument such effects were present in rather larger magnitude than usual, as this may lead to their complete elimination.

Reference was made in a previous report to the interference with observations at low altitudes caused by the installation of mercury vapour discharge lamps for lighting certain streets in the near neighbourhood of the Observatory, and the possible extension of such lighting along the roads across Blackheath was viewed with much concern. The Greenwich and the Lewisham Borough Councils have had this question under consideration. They are both anxious to avoid interference with the work of the Observatory as far as they possibly can. Extensions of the mercury vapour lighting have meanwhile been held in abeyance so that the possible alternatives could be thoroughly investigated. The two Councils are acting in co-operation and their assistance in this matter is much appreciated.

H. SPENCER JONES.

Royal Observatory, Greenwich,  
1937, May 6.