# REPORT

OF THE

# ASTRONOMER ROYAL

TO THE

# BOARD OF VISITORS

OF THE

## ROYAL OBSERVATORY, GREENWICH

*Read at the Annual Visitation of the Royal Observatory,* 1939 *June* 3.

# THE BOARD OF VISITORS

| | | *To serve until June 30th.* |
|---|---|---|
| The President of the Royal Society .. | Sir William Bragg. | |
| The President of the Royal Astronomical Society .. .. .. .. .. | Prof. H. C. Plummer. | |
| Nominated as Fellows of the Royal Society | Prof. A. Fowler .. | 1939 |
| | Sir George Simpson .. | 1940 |
| | Prof. E. V. Appleton .. | 1941 |
| | Prof. G. P. Thomson .. | 1942 |
| | Prof. R. H. Fowler .. | 1943 |
| | Dr. C. G. Darwin .. | 1944 |
| Nominated as Fellows of the Royal Astronomical Society .. .. .. | Prof. F. J. M. Stratton | 1939 |
| | Dr. Wilfred Hall .. | 1940 |
| | Rev. T. E. R. Phillips | 1941 |
| | Sir Frank Dyson .. | 1942 |
| | Prof. E. A. Milne .. | 1943 |
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| Plumian Professor of Astronomy at Cambridge .. .. .. .. .. | Prof. Sir Arthur Eddington. | |
| Hydrographer of the Navy .. .. | Vice-Admiral J. A. Edgell. | |
| Secretary .. .. .. .. .. | Mr. W. E. Llewellyn. | |

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The Report here presented refers to the period from 1938 May 1 to 1939 April 30 and exhibits the state of the Observatory on the last-named day.

I.—Instruments and Apparatus :—

*Reversible Transit Circle.*—The programme for laying the foundations of a system of right ascensions, as stated in the Report for last year, has been continued. Since its inception during the autumn of 1937 the number of transits observed to date totals 4,333, as follows :—

| | | |
|---|---|---|
| Clock stars | 2,134 | observations. |
| Zenith stars | 784 | ,, |
| Azimuth stars | 1,415 | ,, |

1,501 collimations and 1,975 levels were taken in the course of these observations.

As the work progressed it became apparent that real, and in some cases rapid diurnal changes in collimation and level were taking place, which might offer an explanation of the spurious drift of clock error mentioned in the last report. Intensive observations of both collimation and level were therefore begun in July. Starting at 9h. in the morning, continuous observations were made throughout the

day and into the night hours, with the exception of the hours before and after noon when the sun shines directly on the telescope. In August transits of clock, zenith and azimuth stars were included in this continuous series and efforts were made to get a run of observations throughout the day to 2h. the following morning. In this programme roughly 40 per cent. of the observing time is taken up with the determination of instrumental errors.

It became apparent that the variations of both collimation and level showed some correlation with temperature changes, and a number of thermometers were therefore introduced and readings taken at the times of the observations. In this way it has been possible to show that the main cause of the diurnal changes of collimation is a temperature difference between the micrometer screw and the eyepiece box, amounting sometimes to 2° Fahrenheit. As the end of the micrometer screw is at one end of the box, a temperature difference of this type will displace the cross wires relative to the box, and so change the collimation. In the same way the changes of level are apparently almost entirely due to temperature differences between the two piers, as measured by thermometers in metallic contact with the surfaces. It was found possible to express the level, with a probable error of about $0''\cdot1$, by the following formula

$$\text{level} = A + BT + C\,(T_E - T_W) + D\,(T'_E - T'_W),$$

where T is the temperature of the oil bath at the base,

$T_E$ and $T_W$ are the temperatures of the east and west piers measured on the inside about a foot below the pivots,

$T'_E$ and $T'_W$ are similar temperatures measured about 2 feet from the ground,

and A, B, C and D are constants.

These changes of temperature difference between east and west piers, and consequent variations of level, are undoubtedly due to the circumstance that the pavilion shields one pier more than the other from any wind that is not due north or south.

The adopted collimation and level errors are now derived from smoothed curves drawn through the values given by the observations. This system of reduction has practically eliminated drift in the clock error. There still remains the possibility of diurnal variations in the azimuth error. From the data already reduced this appears to be negligible or very small.

Given fair definition, the accuracy of the star observations is greater than that of the determined instrumental errors. In general the collimation is not an easy observation. Wooden screens were fitted in December to the roofs and the south and west walls of both collimator houses. This has helped to give better definition of the images of the collimator wire at night.

Observations have been made for the adjustment of the R.A. and Z.D. wire frames, and have given satisfactory accordance with previous determinations.

The errors of the quarter-degree divisions of the fixed circle have a range of 0″·63. The remaining division errors will be based on those adopted for the quarter-degrees, and are being determined from observations with the six ordinary microscopes. The amount of work involved is large, but two arcs of 120° have been completed and indicate an extreme range of approximately 0″·75.

A few observations of horizontal flexure in both east and west positions indicate a value of roughly 0″·3. Reliable observations can only be made when exterior and interior temperatures are similar and stable. Much useful work has been accomplished this year with the assistance of two more observers. The termination of the zone programme with the Airy transit circle last May enabled Mr. Acton to give more assistance and since October last Mr. Barton has given much of his time to this work.

*Yapp 36-inch Reflector.*—The declination setting and guiding motor failed on November 23; it was disconnected, and one of the hand clamp wheels was connected to the declination screw instead. This provided a hand control that was very responsive and satisfactory in its working, but often rather inaccessible. The motor appeared to be worn out, and was also burnt out. A new one was supplied by Messrs. Sir Howard Grubb, Parsons and Co., and was fitted on February 6. This one also failed on March 29; several sections of the armature were burnt out. The improvised hand control was again fitted. It appears probable that the mercury switches sometimes close in the wrong order, so that the armature circuit is made before the field circuit; examination of the switches failed to show this, but they have always been a little uncertain in their adjustment. The flexible leads are too thick and too crowded, and the tubes are too lightly held and become displaced under stresses from the leads. As an alternative to rebuilding the switching arrangements and supplying another motor, methods of adapting the hand control so as to make it accessible in all positions are under consideration.

The telescope drive is only satisfactory when there is an appreciable positive load on the mechanism. At any one hour angle this can be achieved by throwing the telescope out of balance, but the great freedom of the bearings makes it in fact desirable to have the balance good whenever the telescope is unclamped; also the lack of balance would vary with the position. The Thompson and astrographic refractors have finite arcs with a weight permanently pulling them against the drive; the same effect has now been attained for the Yapp by fitting a series of eight studs at equal distances round the arc, and hanging a weight over a pulley so that it can be attached to one after another of these, as the arc carries them round. A bell is arranged to ring whenever the weight approaches the top of its run.

The hyperboloid cassegrain was tested by Mr. Hargreaves, while the slitless spectograph was still in use, and was found to show many small irregularities and one marked deformation. It also had a strongly turned edge. He was accordingly commissioned to refigure it, and completed the work by the time it was needed. His method was to figure a concave hyperboloid to the correct shape by the usual procedure, and then to fit the convex to it by interference fringes. He reports that the figure is now correct, except for the extreme edge, which is not used. The cassegrain was used silvered until April 3. There is some indication of spherical aberration when conditions are good, but this is believed to be in the main mirror. After April 3 the cassegrain was sent to Messrs. Sir Howard Grubb, Parsons and Co. for aluminising, and was remounted on April 18.

*Slit Spectrograph.*—A number of focus tests, at various temperatures, were made with the spectrograph on its stand, between May and August, and these were continued, along with other work, after it was mounted on the telescope in November. A certain amount of aberration, mainly coma, is noticeable with the three-prism arrangement; in a Hartmann test the half of the beam that passes through the thin parts of the prisms is well defined in the ultra-violet, and the half that passes through the thick parts is well defined in the red. In each case, therefore, the central part of the camera lens gives good definition; the edges give a very noticeable blurring by comparison. The camera lens turns with the arm, as different spectral regions are brought to the centre of the plate, but since the lens is close to the pivot of the arm it does not actually move much, and the wave-length whose beam is centred on the lens is therefore nearly invariable. Some experiments have been made on the effect of moving the pivot so as to centre different regions on the lens, but more remains to

be done. With the one-prism arrangement the aberrations appear more serious; it is also doubtful whether coma alone can explain them. In both arrangements it may prove advantageous to stop down the camera lenses.

With the three-prism arrangement, even before the cassegrain was aluminised, spectra of B stars were obtained in which lines are measurable beyond the Balmer limit and the blue-green is still only moderately exposed; with a slit width of 0·02 mm. and a spectrum width of $\frac{1}{3}$ mm. this required about 40 minutes for a star of magnitude 3·0 under average Greenwich conditions. The entire region below $H\beta$ is in satisfactory focus. It is also possible to have an extensive region in the violet and ultra-violet in focus and simultaneously a short region in the red, as the focus curve has an inflection.

The fan motor inside the spectrograph case failed on January 13. This motor was a variable speed A.C. motor of the universal type; it was completely inaccessible and invisible, and in order to put it right it was necessary to shore up the telescope, dismantle the spectrograph case, and dismantle and extract the spectrograph. It was then found that the motor ran at 7,000 rev./min. with a 50 : 1 worm reduction gear, and that the carbon brushes had worn out, which is not surprising. The motor, rheostat and worm drive were remounted on a padded board outside the case, and a hole was drilled through the case for the fan spindle. This involved using only one fan, whereas there had been two before. The arrangement appears moderately satisfactory, though it is extremely noisy; it would probably be preferable to increase the fan speed, and certainly to decrease the motor speed, which could easily be achieved by a more suitable choice of motor.

A number of modifications to the arrangements for obtaining the comparison spectrum have been effected. In the original arrangement there were two small prisms that could be moved in opposite directions, parallel to the slit, by a double-ended screw, so as to vary the separation of the comparison spectra. Under each prism there was also a pair of windows, and these two pairs were so arranged that either a pair of comparison spectra wide apart or a pair close together could be obtained (for Hartmann tests), the switch from one to the other being made by moving the whole assembly at right angles to the slit by means of a rack and pinion. Unfortunately this motion was shared by the prisms, with the result that the source of light, as seen from the slit, also moved, and there was no guarantee that the beam would be equally full in both positions. It was also found that the prisms did not

always remain parallel to each other. Finally, each of the two adjacent ends of the prisms limited the solid angle of that part of the beam that was close to it, so that it filled only half of the collimator : this is inevitable if the prisms have square ends ; if they have not, the two spectra cannot be brought very close together. Accordingly the two prisms and the windows were done away with, and a single central prism employed, which does not share the rack motion. The double-ended screw was put out of action, and the rack is now used to traverse a specially made aperture-plate across the slit. This plate, which was made in the observatory, is cut so that either the centre part of the slit can be exposed under any desired part of a V aperture, or alternatively the centre can be covered by a V-shaped tongue and the adjacent parts exposed. The whole slit can also be exposed at once. The tolerance on the plate's dimensions is fairly small, and the required accuracy was obtained by projecting a silhouette of the plate, during the work, on to a drawing ten times natural size.

The original reason for having two prisms was to enable the comparison to be put on during the stellar exposure. This is now impossible, but it had already proved undesirable, owing to the special method of spectrum widening employed. The rocking plate that is fitted under the slit for this purpose must in fact be arrested during the comparison exposures, or else the lines will be displaced along their length by uncertain amounts (if the comparison exposure is short compared with the period of rocking), or rendered barrel-shaped (if it is long). It is undesirable to continue the stellar exposure with the rocking plate stopped, and the only possibility is thus in any case to interrupt the stellar exposure when the comparison is being applied. In order to make sure that the rocking plate is then in its central position, it has been fitted with an indicator.

It was found that the direction of travel of the rack and pinion was not accurately perpendicular to the slit, and also that the slit jaws were not in the same plane. The slit assembly was therefore returned to Messrs. Hilger for adjustment in these and other minor respects.

Guiding on faint stars had proved difficult, since no part of the V aperture was visible when it was set sufficiently wide to include even moderate atmospheric dispersion. After some experiments with a line scored on the slit jaws nearly up to the edge, it has been found best to set the tip of the V tongue just clear of the slit and use it as a reference mark. It can be racked further away if there is doubt whether the slit is really bisecting the image, and closer up if it is too hard to see.

It has now been found that the orientation of the rocking plate with respect to the slit is incorrect; the star's lines are slanted with respect to the comparison by a little over a degree. This had been suspected with three-prism B-type spectra $\frac{1}{3}$ mm. wide, but not very definitely; with late type one-prism spectra $\frac{1}{6}$ mm. wide it was evident, and it was measured on a wider spectrum. The mechanism is accordingly being returned to Messrs. Hilger once more. The orientation of the slit with respect to the prisms is also not quite correct.

*Microphotometer.*—A microphotometer of the Oxford pattern has been ordered from Messrs. Casella. A number of optical bench tests were made, to see whether the deflections with narrow slit could be increased over those obtained with the original design, and it was found that an infra red achromat, supplied for trial by Messrs. Hilger, appreciably improved the performance if it was mounted after the second microscope lens. The design has accordingly been modified so as to include this. The microphotometer is in an advanced stage of construction, and delivery during the early summer is expected.

*Instruments for Eclipse Observations.*—A portable equatorial mounting has been designed in co-operation with Messrs. Sir Howard Grubb, Parsons and Co. It will be able to carry either the astrographic refractor or a $12\frac{1}{4}$-inch cassegrain reflector and spectrograph, and is being constructed with funds supplied by the Royal Society and the Joint Permanent Eclipse Committee. With the astrographic refractor it will be used for re-measuring the Einstein effect; as was indicated in the last Report, it is designed to permit of accurate and very rapid switching from the eclipse field to a comparison field and back during the eclipse. With the reflector and spectrograph Mr. Davidson and Dr. Woolley are planning to determine the apparent magnitude of the sun at two wavelengths, taking advantage of the good sky and fair altitude of the eclipse site, probably after the eclipse. It is also planned to use the mounting for other purposes.

Before deciding to use the astrographic lens, experiments were performed with the 12-inch Sheepshanks triplet of the Cambridge Observatory. This lens, which has a focal length of 19 feet and is panchromatically corrected, was kindly lent by Sir Arthur Eddington, O.M. It was hoped that its use with panchromatic plates might give a more favourable ratio of star light to coronal light than ordinary plates used with the astrographic. Bench tests showed that the colour corrections were small well into the red, and that the temperature variation was less serious than had

been believed; it was then mounted in an old eclipse tube inside the tube of the 30-inch reflector. Star tests confirmed the bench tests, but showed that the lens, which is somewhat yellow, was appreciably slower than the astrographic, and also that its general aberrations were larger. The proposal to use it had therefore to be abandoned.

The mounting has, however, proved useful for testing out a rough model of the spectrograph to be used with the reflector on the portable equatorial. This is a combination slit and slitless spectrograph of new design, employing a modified Littrow mount arranged so as to widen the spectra by astigmatism and thus avoid intermittency effects. It appears to be very satisfactory. A spectrograph of this design, to fit the portable equatorial reflector, is now under construction in Cambridge.

The main mirror for the reflector will be of pyrex glass, and the cassegrain of fused quartz. The pyrex blank has already been obtained and pierced, and is now being rough ground. Mr. W. MacIntyre has very kindly undertaken to figure both mirrors without charge, thus making a most valuable contribution towards the success of the expedition.

The three-prism spectrograph with 6-foot collimator and camera mentioned in last year's Report is now nearly complete. The prisms and lenses, which pass a full beam $2 \times 2$ square inches over most of the wavelength range used, have been supplied by Messrs. Hilger and were specially computed to give a flat field. The definition appears to be excellent. The slit was made by Messrs. Casella; it has polished stainless steel jaws inclined a few degrees for guiding. A repeating back camera has been designed and constructed in the observatory workshop, where all the other mechanical parts have also been made. Most of this work was done at the cost of the Joint Permanent Eclipse Committee, and the repeating back will remain the property of the Committee. The camera will make 15 eclipse exposures and 2 or 3 calibration exposures on a single $10 \times 15$ inch plate, shifting the plate quickly between exposures; the entire operation of plate-holder and shutter is accomplished by turning a single crank at a uniform speed. The spectrograph will be fed by a coelostat and concave mirror; one plate will be exposed at second contact, and another at third.

A half prism, figured in train with the three prisms so as to give an effective seven-prism combination when used in the Littrow arrangement, was supplied by Messrs.

Hilger at the same time as the prisms. The overall accuracy is $\lambda/4$, and the train will be used to study solar line contours after return from the eclipse expedition. It is possible that a new lens will be required for this, as the present two are corrected for use together.

*Magnetograph.*—Mention was made in the last Report of the proposal to install a set of La Cour instruments for quick-run recording and of the preparations that had been made in anticipation. The duplicate set of variometers (similar in all respects to those erected in 1937) was obtained in October 1938, together with recording mechanism of Dr. La Cour's design giving a time-scale of 3 millimetres to the minute. After a preliminary trial in the smaller testing hut, from November 2 to February 23, the magnetograph was set up in its permanent position in the magnetograph house on the latter date.

The A.C. generator used in conjunction with the Dye vertical force magnetometer was not sufficiently constant in speed. A governor was constructed in the observatory workshop and is performing satisfactorily.

*Small Transit Instrument.*—The pivots of the small transit C have been ground in the workshop, with tools made for the purpose. An accuracy considerably higher than that attained by Messrs. Cooke, Troughton and Simms has already been reached, but the work has been temporarily set aside for other matters. The problem is more difficult than in instruments provided with weight-relieving gear as the length of bearing-surface has to be greater. As a result of the work already done it is expected that there will be no difficulty in getting two pivots equal, circular, and cylindrical with maximum errors from a mean diameter of only two-tenths of a micron; they cannot, however, be guaranteed to be absolutely coaxial.

*Quartz Crystal Clock.*—The crystal clock referred to in several previous Reports has finally been delivered, after a short period of testing at the National Physical Laboratory. It has been installed in the cellar prepared for it, and is in process of being wired up.

*Spectrohelioscope.*—All temporary fittings on the spectrohelioscope have now been replaced by permanent metal parts.

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

The winch and gear bracket employed in the new shutter mechanism for the 28-inch dome was adapted from an old casting. It proved unequal to the treatment it received during repainting of the dome, and the construction of a new bracket was shared between the Observatory and the Royal Victoria Yard, Deptford. The

drawing and pattern-making was done in the workshop, and the casting and machining at Deptford. The dome was out of action from June 27 to September 19, during which time, however, it was painted inside and out.

Shortly after work with the 28-inch had been resumed, the dome rail fractured. Examination showed that not only had one large piece broken away, but also there were a number of other minor breakages and danger spots. In fact it was recognised that the rail was nearly worn out. Its replacement would, however, be expensive, since it is a special casting integral with the rack for the dome-revolving mechanism. It was therefore decided to repair the fractures by welding, as a temporary measure. The dome was out of action on this occasion from November 8 to November 19. On April 10 a further fracture occurred. There is no doubt that the condition of the wheels is in large measure responsible for these fractures. The wheels are of cast iron, rather narrow, and they have worn a groove in the rail. When they ride up the side of this groove, the load comes on the edge of the wheels, and causes them to chip. Large chips have been detached from all ten wheels in this way, and if a wheel subsequently rides over such a chip the load is very high locally; there may also be a severe bump. Various firms are being consulted as to the best procedure, and it is possible that by turning the wheels down and fitting steel treads, rounded more or less to suit the groove in the rail, a fairly safe temporary solution may be found, provided that the rail can be repaired again. The previous welding was done with oxygen, and the contraction on cooling has resulted in a crack in the main web of the rail. Electric welding would be safer in this respect, but is less homogeneous. There is no doubt that really adequate proposals would have to be much more radical. At present the telescope is not entirely out of action; the dome has been placed in a position that allows a selection of stars to be observed without moving it, provided conditions are suitable for the star in question at the time required.

In Flamsteed House the larder has been converted for the accommodation of batteries for the regular time service and also of the high-capacity cells required to provide current for the crystal clock in the event of an interruption of the mains supply. A partition has been erected in the laundry to form a new larder, which has been fitted with shelves and new lighting points. A new domestic boiler has been installed in the kitchen, and the floor of the laundry has been relaid with wood blocks.

About 60 feet of 2-inch main gas piping has been renewed in the courtyard. New wires have been laid in conduits to the Rugby room, new battery room, and small transit pavilion. The courtyard has been surfaced with tar macadam.

A portion of the flooring and joists in the lower computing room has been replaced with concrete. Parts of the cornice surrounding the photoheliograph dome have been removed, pending repairs, as their condition was dangerous. Minor alterations to the benches in the watch-repairing room have been undertaken, and the floor has been covered with corticene. Portable two-tier shelves have been made, that can be added to the tables in the upper chronometer room when the number of watches being tested is exceptional.

In the main building, structural alterations have been carried out on the museum floor so as to add to the size of the Secretary's Office. The lighting system in the south wing has been rewired. The accommodation in the ladies' lavatory has been increased, a wash basin and Ascot heater have been added, and a separate entrance to the adjoining photographic dark room has been constructed. Work on the ladies' room in the old building has been postponed until completion of the new battery room. New cupboards for storing parallax plates have been made, and also one for the spares of the Reversible Transit Circle. A table has been made for apparatus at Abinger, and a long table has been altered to serve as a foundation for optical benches, etc., in the laboratory. The windows in the Astronomer Royal's Office have been fitted with draught-proof sashes.

Following on the improvement produced in the Cookson results by erecting louvre screens on the south and west of the building, the roofs and south and west sides of the two collimator houses were similarly treated. Determinations of collimation are still usually difficult, but the conditions soon after sunset on fine days are better than they were.

At Abinger a wood block floor has been laid in the old testing hut and a new motor has been fitted to the fresh-water pump. The old main battery has been dismantled. A pier has been built for a small transit instrument to be used for the determination of time.

The following painting work was done during the year :—

Exteriors : Sheepshanks Dome, Altazimuth Dome, Yapp building, steel work on Reversible Transit Circle Dome, Collimator houses, Magnetograph house and annex, 28-inch Dome, railings on north boundary, boxes containing fire apparatus, main gates. At Abinger, the magnet houses.

Interiors : 28-inch Dome, staircase and lower landing, upper and lower Chronometer Rooms, ceiling of Watch Repairing Room, new partition and part of walls on museum floor of main building. At Abinger, some decorating of the Caretaker's quarters.

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.

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

III.—Astronomical Observations :—

*Transit Circle.*—The Sun, Moon and planets have been regularly observed, together with accompanying clock and azimuth stars. Progress on the preparation of the star catalogue based on the observations from 1931–1938 has been held up, as the staff is fully occupied with the reductions of the observations with the new Reversible Transit Circle and the determination of the division errors.

During the year 2,090 transit observations and 2,201 observations of zenith distance were obtained. These include the following :—

124 observations of the Sun.
79 ,, ,, Moon.

| Major Planets | | Minor Planets | |
|---|---|---|---|
| Mercury .. | 6 observations. | Ceres .. | 13 observations. |
| Venus .. | 36 ,, | Vesta .. | 9 ,, |
| Jupiter .. | 24 ,, | | |
| Saturn .. | 19 ,, | | |
| Uranus .. | 19 ,, | | |
| Neptune .. | 17 ,, | | |

The observations of the Sun, Moon and planets are published yearly in the *Greenwich Observations*. The results for the year 1937 are not yet ready for the printer.

The observations of the Sun in recent years 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 .. .. | + 0ˢ·106 | 1931 .. .. | + 0ˢ·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 | 1938 .. .. | + ·102 |

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

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

| | Longitude | | Latitude | | No. of observations | |
|---|---|---|---|---|---|---|
| Year | 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 |

| Year | Longitude | | Latitude | | No. of observations | |
|---|---|---|---|---|---|---|
| | Limb | Mösting A | Limb | Mösting A | Limb | Mösting A |
| | ″ | ″ | ″ | ″ | | |
| 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 |
| 1938 .. | + 2·3 | + 1·8 | — | — | 93 | 48 |

The corrections in longitude for 1937 and 1938 are approximate and based on the mean values O − C in right ascension.

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

The Greenwich observations of the Sun from 1750 have been combined with observations at other observatories and have been used, in conjunction with observations of the Moon and Venus and observations of transits of Mercury, to investigate the changes in the rate of rotation of the Earth. The fluctuations in the mean longitudes of the Moon, the Sun, Mercury and Venus are found to be strictly proportional to the respective mean motions and may therefore be attributed to changes in the rate of rotation of the Earth caused by changes in its moment of inertia. These changes occur rather suddenly and at irregular intervals. The secular accelerations of the Sun, Mercury and Venus are proportional to their mean motions ; these accelerations, together with the portion of the secular acceleration of the Moon that is not accounted for by the attractions of the planets, are attributed to the effects of tidal friction. The decrease in the angular momentum of the Earth, associated with the slowing down of the Earth by tidal friction, is compensated by an increase in the orbital angular momentum of the Moon. The changes in the elements of the Moon's orbit cannot be determined in detail theoretically and are too small to detect by observation ; it is not possible, therefore, to make a theoretical estimation of the ratio of the secular accelerations of the Moon and Sun. Comparison of the secular accelerations derived from the observations of the past two hundred years with the average secular accelerations of the past two thousand years, found from ancient observations of eclipses and occultations, leads to the conclusion that the effects of tidal friction have decreased. The results are being communicated to the Royal Astronomical Society.

*Cookson Zenith Telescope.*—During the year 283 plates were taken for latitude variation, and 4 for the determination of scale.

The definitive discussion of the observations for the years 1911–1936, together with the detailed results for the years 1927 to 1936, are being published as a Greenwich Volume, which is now in the press. The star-places derived in this discussion have been compared with the new revised Auwers system (FK3) and with the system of the Boss *General Catalogue*. They substantiate the accuracy of the FK3 system of declination, within the range of declination concerned, and indicate that the Boss system requires some correction.

Preliminary values of the variation of latitude, 1936–1938, based on observations according to the new programme commenced in July, 1936, have been published in *Monthly Notices of the Royal Astronomical Society*, Vol. 99, No. 3.

28-*inch Refractor.*—Work has been greatly hampered during the year by failure of the dome shutter mechanism and fracture of the dome rails. In addition there has been much bad weather. During one period of two months in the winter only one star was measured, owing to this last factor alone.

Nevertheless 273 observations of 92 pairs were secured. They were distributed as follows :—

| | | | | |
|---|---|---|---|---|
| 31 | observations of | 12 | pairs with separation | $> 2''{\cdot}0$. |
| 52 | ,, | 20 | ,, ,, | $2''{\cdot}0 - 1''{\cdot}0$. |
| 118 | ,, | 39 | ,, ,, | $1''{\cdot}0 - 0''{\cdot}5$. |
| 72 | ,, | 21 | ,, ,, | $< 0''{\cdot}5$. |

In addition, Dr. G. V. Simonov, of the Lembang Observatory, Java, obtained 114 observations of 44 pairs, mostly of small separation.

The observations were all made with the comparison image micrometer, which continues to prove superior to the filar micrometer, especially for the closer pairs. The increased percentage of observations of stars with separation less than $1''$ is wholly due to its use.

It is becoming increasingly difficult to observe faint stars with the 28-inch; under good conditions a double with components of $9^{m}{\cdot}5$ is very difficult and with

components of $10^m \cdot 0$ practically impossible. This is no doubt due to the aggregate effect of a number of causes, the most important of which is the increasingly bad seeing at Greenwich.

The interferometer mentioned in last year's report was tried out on two nights. Measures were made of two close pairs, but owing to bad seeing the positions of minimum visibility of the fringes were very indefinite and the observations untrustworthy. It is intended to try the method again under better conditions.

*Thompson Equatorial.*—With the 26-inch refractor, 1,238 plates suitable for parallax determinations were obtained during the year ; 1,167 plates were measured and 38 parallaxes completed. The *Monthly Notices* for November contained the results for 33 stars. In addition, 75 photographs for proper motion determination have been secured, and 79 have been measured.

*Yapp 36-inch Reflector.*—With the slitless spectrograph, 87 further comparisons of 34 stars with standard stars were secured, the colour temperature programme being completed by September. Seven plates were taken at the telescope to determine $\phi'_o$, and seven in the laboratory to determine $\varepsilon$, these quantities being necessary to correct the spectrophotometric observations for the time effects (see *Monthly Notices*, Vol. 96, p. 828). All the colour temperature photographs were measured and reduced by December, and the discussion and detailed results for 250 stars will go to press very shortly.

The slitless spectrograph was dismounted on November 8 and replaced by the slit spectrograph.

*Slit Spectrograph.*—In addition to experimental work, a provisional observing programme has been begun, consisting of one-prism exposures, for the ultra-violet, on yellow and red giant spectroscopic binaries, to see whether a hot companion can be detected in this region of the spectrum even though its lines are smothered at longer wavelengths. Comparison stars of similar spectral types, that are not spectroscopic binaries, are also photographed, and in some cases fainter B-type spectra have been deliberately superimposed on these. The plates will be studied with the microphotometer. Conditions have been unfavourable, and so far spectra of only 4 binaries and 4 comparison stars have been secured. Arcturus gives a spectrum measurable down to about 3375 A and over-exposed at all wavelengths longer than H and K in one to two minutes, with a slit of 0·05 mm., but the majority of the programme stars are at least four magnitudes fainter than Arcturus.

*Observations of Eros.*—The reduction of the measures on plates taken at Johannesburg with the 10-inch lens, and at Melbourne with the 13-inch astrographic refractor, has been completed and the resulting positions compared with the ephemeris. The Cape Astrographic results—532 positions—have been received from the Royal Observatory, Cape, and have been tabulated.

The Tabular Place has been computed and compared with the positions obtained from photographs taken at the following observatories :—

| | | |
|---|---|---|
| Algiers | 412 | positions |
| Leipzig | 56 | ,, |
| Poulkovo | 20 | ,, |
| Prague | 44 | ,, |
| Uccle (Zeiss 30-cm. lens) | 36 | ,, |
| Uccle (Astrographic) | 25 | ,, |
| Zö-Sé | 238 | ,, |

The visual observations—85 positions—made with the 26½-inch refractor at the Union Observatory, Johannesburg (*U.O.C.* No. 88) have been reduced and compared with the ephemeris. Comparison with the ephemeris of the visual observations made with the 65-cm. refractor at Berlin-Babelsberg, and at the Royal Observatory, Padua, is in hand.

Sixteen plates taken with the astrographic refractor during the opposition of 1935 have been measured, and the measurement of the plates taken during the opposition of 1937-38 has commenced.

A series of 26 plates, covering the path of Eros at the opposition of 1937-38, each having a field of 5° × 5°, has been received from Hamburg Observatory, Bergedorf, through the courtesy of Dr. R. Schorr. These will be measured and the positions of the reference stars required for the reduction of the plates taken during the opposition of 1937-38 will be determined.

The astrographic refractor was dismounted at the beginning of March and the tube of the photographic telescope has been sent to Messrs. Sir Howard Grubb, Parsons and Co. to be fitted to the portable eclipse equatorial mounting.

*Photoheliograph.*—Photographs of the Sun were obtained on 292 days. The number of photographs selected for preservation is 598, including 32 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 327 days in the year 1938 and on 58 days in the first two months of 1939. The Director of the Kodaikanal Observatory has reported that plates were taken there on 328 days in the year 1938 and 85 days during the first three months of 1939.

Photographs in duplicate have been received from the Royal Observatory, Cape of Good Hope, to January 24, and the single series to March 9. Eleven photographs have been sent from the Kodaikanal Observatory to complete the series for 1938. The Director of the Mount Wilson Observatory has kindly presented a negative copy of a photoheliogram for 1937 November 3 to complete the series for that year.

The measurement of the combined series has been made from 1937 April 28 to 1938 April 28. The reductions of positions and areas of spot groups and their principal components have been completed from 1937 January 24 to 1937 December 31. The copy for press of the *Greenwich Photoheliographic Results* is being prepared.

Although there are indications that the peak of the maximum phase has now been passed, the Sun was very active generally throughout the year, especially during July. There have been during the last twelve months about 30 groups of spots whose maximum area each exceeded 500 millionths of the Sun's hemisphere. Groups notable for their size were those with central meridian passage on the following dates : July 15·1 (maximum area 2,400 millionths), September 27·7 (1,800 millionths), October 11·9 (2,900 millionths), November 10·8 (2,100 millionths) and November 28·8 (1,950 millionths).

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, and to the Controller (Engineering), British Broadcasting Corporation, as soon as possible after the first appearance of each group. Advance notification has also been given to the Engineer-in-Chief, General Post Office, and to the Superintendent, Eskdalemuir Observatory, of the occurrence of spots having an area of 1,000 millionths or greater (or of smaller spots showing unusual activity spectroscopically).

Eleven big groups of area equal to or greater than 1,000 millionths were reported during the year. In seven cases a magnetic storm occurred within two days preceding and four days following the time of central meridian passage of the respective sunspot. Of these seven storms, three were recorded at Abinger as " great " storms. On the other hand, " great " storms occurred on August 3–5 and February 24–25 when no large spot was near the central meridian.

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.

*Spectrohelioscope.*—Observations were made with the spectrohelioscope on 193 days ; on 35 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 $H\beta$. In general, observing conditions were poor during the year for observations with the spectrohelioscope.

(*a*) The number of bright eruptions observed during the year was 89, as compared with 109 in the preceding twelve months. The occurrence of eleven major eruptions was reported by telephone, while they were in progress, 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*.

(*b*) 217 measures of radial velocity were made, of which 188 relate to dark markings associated with sunspots. The largest component of radial velocity recorded during the year was $-265$ km./sec. on September 23, belonging to an absorption marking associated with a sunspot. On five other occasions, radial velocities between 95 and 160 km./sec. were recorded.

(*c*) 48 photometric measures were made of prominences and disk markings by means of an accessory lamp photometer, and 29 measures with a direct wedge photometer. Photometric measures of six prominences were made with the lamp photometer both in $H\alpha$ and $H\beta$.

In addition to these measures, trials were made with a modified form of direct comparison photometer intended especially for the rapid measurement of the peak intensities of bright chromospheric eruptions on the Sun's disk. In this photometer, which has been constructed in the workshop of the Observatory, a thick subsidiary line-shifter is introduced extending half-way up the primary line-shifter of the spectrohelioscope. When turned through the appropriate angle, this secondary line-shifter displaces the lower half of the beam before it passes the selecting slit of the instrument, so that light from the continuous spectrum $\pm$ 15·0 A from $H\alpha$ fills the lower half of the field of view of the eyepiece, whilst in the other is seen the bright region in $H\alpha$. Equality in brightness is then produced by means of a calibrated neutral wedge; the wedge readings, after correction for the effective absorption of the subsidiary line-shifter, give the ratio of the peak intensity of flocculus to the intensity of the continuous spectrum. A graticule can be inserted in the field of view for the estimation of the area of the bright eruption under observation. A paper describing the apparatus as an attachment to the spectrohelioscope was published in *Monthly Notices*, Vol. 99, No. 5. The two 3-inch mirrors of the spectrohelioscope and the 5½-inch original mirror of the coelostat were realuminized in January.

IV.—Time Service.

Determinations of time have been made throughout the year with a rota of observers with the Transit Instrument B. Observations were secured on 114 nights altogether, but 12 of these, made by observers who had recently been added to the rota, were not used in determining final values of clock correction. Further determinations of the absolute personal equation for the various regular observers are to be desired, but have not been possible on account of pressure of other work. Relative personality corrections, determined on the basis of the observational results, are applied. The Cooke level normally used with the instrument was broken on June 25, and was replaced by a Kern level which proved appreciably less satisfactory. A new Cooke level was substituted on October 17. The comparison of results obtained with these different striding levels indicated that, in the past at least, errors of level may well have been the most important single factor in the scatter of the observed clock errors. The present level is more stable and more rapid than any previous one, and the scatter is appreciably smaller than it has been before.

The principle of employing a mean clock, as described in last year's report, has been further extended and has proved of great assistance. Comparisons of individual

clocks with the mean show that in addition to sudden changes of rate they also have a tendency to wander from a steady rate and then to return ; thus a linear interpolation between two clock errors, determined say a week apart, may give results several hundredths of a second out. This effect is greatly reduced by using the mean of a number of clocks, but it is hoped that the quartz crystal clock, recently delivered at Greenwich, will enable the effects of the fluctuations and discontinuities in rates of the pendulum clocks to be completely eliminated.

As in previous years, the daily errors of the free pendulum clock Shortt No. 13 at Teddington, relative to the 10h. Rugby Rhythmic Signal have been forwarded to Greenwich by courtesy of the Director of the National Physical Laboratory. In addition, the Astronomer Royal for Scotland arranged to communicate the errors of the standard clock, Shortt No. 4, of the Royal Observatory, Edinburgh. Thus there are now two clocks, which are free from any disturbance local to Greenwich, incorporated in the mean clock.

The following table shows the composition of the mean clock at different dates throughout the year :—

| | | |
|---|---|---|
| May 1 to Aug. 31 .. .. .. | Shortt Nos. | 3, 11, 13, 16, 40, 49. |
| Sept. 1 to Dec. 28 .. .. | ,, | 3, 4, 11, 13, 16, 40, 49. |
| Dec. 28 to Dec. 30 .. .. | ,, | 3, 4, 11, 13, 16, 40. |
| Dec. 30 to Jan. 31 .. .. | ,, | 3, 11, 16, 40. |
| Jan. 31 to Mar. 27 .. .. | ,, | 3, 4, 11, 13, 16, 40, 49. |
| Mar. 27 to Apr. 30 .. .. | ,, | 3, 4, 11, 13, 16, 40. |

The free pendulum remontoire of clock Shortt No. 49 failed on two occasions, December 28 and March 27. In view of the erratic behaviour of this clock, the Synchronome Company has been asked to carry out a complete overhaul of the master and slave.

Shortt Nos. 4 and 13 were dropped from the mean during January on account of electrical faults which rendered their rates uncertain. All the clocks at Greenwich were affected by earth tremors at mid-day on June 11. The sidereal clocks in the inner cellar were all affected on April 2 when owing to a failure of the thermostat relay the temperature rose to over 100° F. The normal controlling point was not reached until the following morning. An improved type of thermostat relay was fitted on April 3.

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. The photoelectric cell apparatus on Shortt No. 40 has been out of action pending the provision of improved relay equipment.

The service of rhythmic radio signals at 10h. and 18h. transmitted through the Post Office Radio Station at Rugby and also the hourly time signals to the General Post Office and the six dot signal to the British Broadcasting Corporation sent every quarter hour, have been transmitted regularly. The hourly signals to the Post Office are utilised for the automatic correction of the Talking Clock, a service which has been further extended during the year. As in previous years, Shortt No. 16 has been used to control the transmitting clocks for all these signals; they are all corrected magnetically, as necessary, throughout the day as a result of inter-comparisons between No. 16 and the other free pendulums.

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.

A short-wave receiver has been installed in order to continue direct comparisons between Greenwich and Washington which have been in abeyance since June, 1934, when Annapolis ceased to transmit on the long wavelength. The Arlington (NAA) signal on 9·425 megacycles has been recorded regularly since the beginning of January, the signals being taken at the times of best reception, which occur when there is darkness over the Atlantic. During January and February the 9h. signal was obtained with comparative ease; in early March it was found necessary to receive the 8h. signal which, as conditions deteriorated, was replaced by the 7h. signal. Satisfactory records of this signal were no longer possible in April, and the 23h. and 0h. signals are taken at present. This work has involved appreciable dislocation of schedules, and self-sacrifice on the part of the observers concerned; it has only been made possible by the great keenness of the junior members of the Time Department. To provide for its continuance on a more official basis is hardly possible with the present staff.

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 Paris, Nauen, Bordeaux and Arlington.

The cathode-ray oscillograph has been employed for the determination of recorder lag. The six dots time signals radiated by the British Broadcasting Company 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.

| 1938. | Paris 9½ hr. Rhythmic. | Nauen 12 hr. Rhythmic. | Bordeaux 20 hr. Rhythmic. |
|---|---|---|---|
| | s. | s. | s. |
| January... ... ... ... | −0·022 | +0·008 | −0·022 |
| February ... ... ... | − ·019 | − ·001 | − ·017 |
| March ... ... ... ... | + ·012 | + ·003 | − ·005 |
| April ... ... ... ... | + ·006 | + ·012 | + ·006 |
| May ... ... ... ... | + ·027 | + ·020 | + ·026 |
| June ... ... ... ... | + ·014 | + ·004 | + ·011 |
| July ... ... ... ... | − ·006 | + ·007 | − ·007 |
| August ... ... ... ... | − ·002 | + ·007 | + ·002 |
| September ... ... ... | − ·001 | − ·003 | + ·003 |
| October ... ... ... | ·000 | − ·025 | + ·007 |
| November ... ... ... | − ·004 | − ·035 | − ·002 |
| December ... ... ... | + ·003 | − ·011 | + ·002 |
| Mean ... ... ... ... | + ·001 | − ·001 | + ·001 |
| Number of comparisons ... | 341 | 301 | 354 |

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 recording apparatus at Greenwich, but it is not known what corrections are applied at the foreign stations.

Further investigation of the magnitude of lags which may occur in any system employing mechanical relays has suggested the desirability of using thermionic relays exclusively on all time circuits. A thermionic relay may be designed to have a lag which for all practical purposes is negligible. The design of such relay units has been discussed with representatives of the research staff of the General Electric Company and sample units have also been submitted by Messrs. Marconi-Ekco. The co-operation of these companies is appreciated. These developments,

together with the further investigation and improvement of accuracy in the apparatus for the reception of signals, have been seriously delayed by the present conditions in the Time Department where the work has been increasing for several years; during the past year exceptional additional demands have been made. The increase of load which has resulted has been partly relieved by temporary transfer of staff from other departments, but an appreciable increase in staff appears unavoidable.

It has been decided to install at the Abinger Magnetic Observatory the necessary apparatus for the maintenance of a subsidiary time service which could take over, whenever required, the more essential duties of time signal distribution normally carried out from Greenwich. The transit instrument D, which had been used in connection with the personal equation machine, has been mounted there, and pending the provision of additional equipment, the Dent clock formerly used as the sidereal standard clock at Greenwich and the mean time Dent regulator 2016, previously kept as reserve time signal transmitter, have been erected in the old battery room, which was cleared and partitioned to enable a reasonable temperature control to be maintained. Temporary chronograph equipment has also been installed.

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 $0^s \cdot 2$ .. .. .. | 93 |
| $0^s \cdot 2$ to $0^s \cdot 5$ .. | 95 |
| $0^s \cdot 5$ to $1^s$ .. .. | 86 |
| Greater than $1^s$ .. .. .. | 16 |

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

The Time Ball was raised and dropped correctly throughout the year except on October 4, November 20, on account of high winds; December 23, January 25, snow on mast; November 14, January 22, technical failures. It was dropped in accordance with custom at 11h. on November 11.

*Chronometers.*—The number of chronometers and watches belonging to the Admiralty now at the Observatory is 1,739. Of this total 180 chronometers, 522

chronometer watches, 337 deck watches and 77 pocket watches are being rated or held in reserve for issue on service. Eight chronometers are in regular use in the Observatory. The remainder, consisting of 205 chronometers, 123 chronometer watches, 242 deck watches and 45 pocket watches, are in storage.

In addition to Admiralty instruments, 66 chronometers and watches, the property of other Departments, are deposited at the Observatory for repair, testing or storage.

During the year ending 1939, April 30, a total of 4,170 chronometers and watches has been received and 3,662 issued. The number sent for repair was 1,674, viz., for the Admiralty 1,599, for the Royal Air Force 21, and for other governments as follows : Australia 1, Canada 2, India 46, New Zealand 3. An additional 100 deck watches had their dials numbered and were recased in the watch repair shop. A machine for printing numbers on dials has been added to the equipment of the shop, and a stock of spare parts for watches of foreign manufacture is being accumulated.

Two chronometers belonging to H.M. The King were received from the Royal Yacht for repair and subsequent testing.

The above figures show a great increase in the amount of chronometer and watch rating during the year. They are exceeded only by those of 1916–1919. Moreover, the tests involved in trial before purchase in the case of new stock are more extensive than those incidental to repair of used instruments. Nine hundred new watches were added during the year, and the preparation of specifications and other formalities involved also imposed an extra load on the staff.

Steps are being taken to decentralise the stock of chronometers and watches now held at the Observatory. The rating of instruments held in other places will be continued, and information will be communicated to the Observatory for supervision.

The watch repair shop has continued to prove indispensable. The employment of two additional repairers has been authorised, but it has not been possible to obtain suitably qualified men for both vacancies and so far only one has been filled. The staff of the repair shop have given assistance in the selection of suitable movements for purchase.

The ledgering system for chronometers and watches dealt with at the Observatory has been substantially modified and a card index has been introduced.

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 regular publications issued by the Office, at present four in number—the *Nautical Almanac*, the *Abridged Nautical Almanac*, the *Air Almanac* and the *Astronomical Navigation Tables*.

As foreshadowed in last year's report, the rearrangement of staff and duties, then recently introduced, has formed the basis for an organisation which, although formal in character, has sufficient flexibility to meet the peculiar requirements of computational work. While this organisation may still be regarded as in its experimental stage, the experience gained during the past year shows that its continuance, with perhaps minor modifications, will ultimately lead to a working unit which will be able to deal satisfactorily not only with routine work but also with the special investigations that frequently arise. As at present constituted, a strong dividing line is drawn between the astronomical and navigational work of the Office, though there is common ground in the two pools for proof reading and the National machines ; each section is divided into smaller groups among which there is considerable co-operation. For the astronomical section, the groups are (i) Nautical Almanac, (ii) Occultations and Eclipses, and at present (iii) Volume of Apparent Places of Fundamental Stars ; in the navigational section there are only two groups—(i) Abridged Nautical Almanac and Air Almanac, and (ii) Astronomical Navigation Tables. While each group is self-contained in the respect that the head of the group is responsible for the supervision and accuracy of the routine work of that group, the whole of the work in the two sections is arranged and co-ordinated under the general supervision of the Superintendent.

*The Nautical Almanac.*—The *Nautical Almanac* for 1940 was published on March 10, as compared with the corresponding date April 20 in the case of the 1939 edition ; it had been hoped that the arrears in this publication might be overtaken at about 3 months each year, but it has this year proved impossible to maintain this accelerated rate owing, in some measure, to the rather exceptional demands on the Office, made by doubling the size of the *Air Almanac*. Certain sections of the Almanac are supplied from the other ephemeris offices, and consequently the date of publication is not entirely within the control of the Office.

No major changes have been made in the 1940 edition, though much of the eclipse material appearing in former editions has been collected and reprinted in the Explanation, together with illustrative examples of various eclipse computations. In view of the resolution of the International Astronomical Union, recommending the adoption of the FK3 catalogue for radio time-signals from 1940 onwards, an appendix has been included giving the definitive corrections necessary to convert the apparent places of stars in the *Almanac* (referred to Eichelberger) to the FK3.

The first part of the *Nautical Almanac*, containing the ephemerides of the Sun, Moon and planets, is set in type in advance of the remainder. The first part of the *Almanac* for 1943 is now complete and has been circulated to the other ephemeris offices in accordance with the arrangements for the interchange of computations to avoid duplication.

*Occultations and Eclipses.*—The occultation programme for 1941 has been continued without major change, and it has again been possible to complete the whole of the predictions and reduction elements before the end of April, although copy for all the individual stations has not yet been completed. A start has lately been made on the machining and prediction for the 1942 programme. During the year predictions for 44 stations for 1940 and for 11 stations for 1941 have been forwarded to the observatories and periodicals concerned.

For 1941, elements of occultations for 1,698 stars not fainter than magnitude 6·5 were received from the Office of the American Ephemeris, and elements for 813 stars between magnitudes 6·6 and 7·5 were computed in the Nautical Almanac Office from material supplied by Washington. These 2,511 stars were examined by the occultation machine and preliminary times recorded for 1,276 stars, which were retained for subsequent computation. During the latter process 107 stars were rejected as the resulting occultations would not be visible under the adopted conditions. Prediction and reduction elements for 1,165 stars and prediction elements for 4 planets will therefore be published in the *Nautical Almanac* for 1941. The total number of predictions made for the 58 stations has been 4,816, involving 8,563 separate computations; these figures compare with 3,856 predictions and 7,084 computations for 1940. Further, 283 extra computations were done for additional stations to ensure the inclusion in the prediction elements of all stars observable under suitable conditions anywhere on the Earth.

A special eclipse supplement to the *Nautical Almanac* for 1940 has been prepared and duplicated for free issue ; this supplement, which was prepared on the suggestion of Professor J. A. Carroll, is intended to supplement the information given in the *Almanac* and to provide data required in the design of instruments and in their final adjustment. This is thought to be the first time that such information has been made generally available, and it is intended to incorporate similar data in future almanacs, if the supplement is well received.

During the course of the year two papers giving the paths of the ionospheric and corpuscular eclipses of 1940 October 1 were communicated to the Royal Astronomical Society.

*Abridged Nautical Almanac and Air Almanac.*—The *Abridged Nautical Almanac* for 1940 was published on March 22 ; the date of publication is arranged to follow shortly after that of the standard edition, and so the rate at which the arrears in publication are overtaken is the same for the two publications. No changes have been made, but considerable investigatory work has been undertaken towards the possible form which an almanac incorporating the direct tabulation of the Greenwich hour angle could take ; this investigation is not yet complete.

The separate reprint for 1939 containing the tables of sunrise and sunset, moonrise and moonset, and other associated data was published on May 5 ; as this material is now available in the *Air Almanac* it is doubtful if the demand for this reprint will warrant its continuation.

The *Air Almanac* covering the second half of the year 1938 was published in June, after an effort had been made to change from quarterly to half-yearly publication.

As envisaged in last year's report the form of the *Almanac* was completely changed from January 1 onwards. The decision by the Air Ministry to double its size, in order to simplify the extraction of the essential data required by the airman, was made as a result of practical experience, by the Royal Air Force, of the first form, which was not considered sufficiently simple for the arduous conditions in which it was to be used ; this decision has made possible considerable improvements which amply compensate for the increased cost. Firstly, it has been possible to discard the loose-leaf form of the first edition, involving a permanent cover and ephemeral sheets issued at intervals, and to replace it by a much more convenient

self-contained quarterly volume, in which each perforated sheet of two pages, containing the data for one day, can be torn out after use. The most important practical advantage is, however, the reduction of the interval of tabulation which enables interpolation to be dispensed with entirely for the declination, and reduced to such an extent for the Greenwich hour angle that, with the special flap provided, only one opening of the book is (in general) necessary for the extraction of the fundamental quantities required. The new form has further made possible the inclusion of complete tables of sunrise, twilight and moonrise, etc., as well as all necessary auxiliary and special tables ; for the third quarter of 1939, a comprehensive list of standard times will also be included. The revised *Almanac* appears to have met with general approval, and is now well established.

The volume for the first quarter of 1939 was published on December 12, and for the second quarter on February 24 ; that for the third quarter is in the hands of the binder, while the whole of the fourth quarter is in type. Quarterly publication is essential for the avoidance of an unwieldy volume, and an effort is being made to produce each quarter successively earlier.

The *Astronomical Navigation Tables*, which are being prepared for the Air Ministry, are up to schedule as far as the computation is concerned ; the issue in March of the first of the twelve volumes was delayed owing to difficulties concerned with printing and binding, but now that these have been successfully overcome further volumes are anticipated at an accelerated rate. It is a pleasure to record the co-operation of the U.S. Hydrographic Office in supplying advance photostat copies of the similar publication H.O. 214, in exchange for the duplicates of certain stages of the fundamental computations.

*Apparent Places of Fundamental Stars.*—It was reported last year that complete agreement had been reached with the directors of the other four almanac offices concerning the major points connected with the issue of this annual volume, containing the apparent places of the 1,535 stars in the FK3 and its supplement ; during the year many minor points have been settled and specimen pages approved. At the present time, the great majority of the copy is in the Office, and printing will commence as soon as the printing contract is completed. For the first year at least the work involved in the final preparation of the copy for the printer is considerable, involving a certain amount of computation and much recopying, as well as the

actual pasting up into pages of the computations from four different sources. Publication of the volume for 1941, of approximately 600 pages, is anticipated about the middle of 1940.

*Other publications.*—As anticipated, the proof reading of the table of trigonometrical functions for every second of time had to be delayed owing to pressure of other work; the complete volume was, however, passed for press on March 14 and should soon be available.

The second volume of Planetary Co-ordinates for the equinox of 1950·0, covering the years 1940–1960 is now all in stereo proof, and very few pages remain to be read; publication is expected in about two months' time.

During the year agreement was reached with Professor Peters, with whose collaboration the 7- and 8-figure tables of trigonometrical functions for every second of arc were prepared, to a division of the copy, by which he received the 8-figure table and the Office retained the 7-figure table. Arrangements for the publication of the 8-figure table in Germany have now been made and the table should soon appear; no arrangements for the printing of the 7-figure table have as yet been made. In addition to the completion of the 8-figure copy certain checking of the end-figures on the proofs was carried out for Professor Peters.

*Proof Reading.*—A large proportion of the work of the Office consists in the preparation of copy for the printer and the reading of the proofs; this is especially the case at present when the ratio of printed matter to computational work is large. During the year an attempt has been made to standardise the proof reading methods; for this purpose, general and special instructions for nearly all the different printed pages have been drawn up, and it is hoped that this instruction book will soon be complete. In the past year there have been separate readings of approximately 7,500 pages of proofs; this figure includes those cases where duplicate reading of the first proofs is considered advisable, and also the reading of stereo proofs or printed sheets.

*Other Work.*—An investigation into the possibility of the application of the National machine to certain problems in ballistics has been carried out for the Ordnance Committee on a basis of repayment by the War Office; satisfactory methods of applying the machine were successfully developed.

A notable increase in repayment work for the supply of astronomical information to commercial firms has occurred during the year, and this now appears to be an established part of the work of the Office.

*Machines.*—The present equipment of the Office consists of Brunsviga, Marchant, Mercedes, Monroe and Muldivo calculating machines and of Burroughs and National accounting machines, which have been applied to scientific computing, while the Hollerith tabulating, sorting and multiplying equipment is used as occasion demands. No additions have been made during the year.

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.

A change in the adopted ratio of the international unit of current to the c.g.s. unit was made on 1938 January 1. The new value, 0·99988, is in accordance with the recommendation of the International Committee. A discontinuity in mean values of horizontal and vertical intensity is thereby introduced, amounting to $-1{\cdot}7\gamma$ and $-3{\cdot}9\gamma$ respectively.

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 1938 December 31, and with provisional constants to the present time.

The tabulation of results for 1938 is almost complete, and waits 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 1938 are given below. The values for the years 1935, 1936 and 1937 are given for comparison.

| | Decl. W. | Horizontal Intensity. | Vertical Intensity. | Inclination. |
|---|---|---|---|---|
| 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 |
| 1938 .. | 11° 1′·4 | 0·18522 | 0·43050 | 66° 43′·2 |

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 23 magnetic disturbances reaching the dimensions of a " storm," and, in addition, five disturbances classified as " great storm." (A range of 30′ in declination or 150γ in horizontal intensity is considered the lower limit for a " storm " ; 60′ or 300γ for a " great storm.")

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

A vertical intensity balance magnetometer, in use at Lerwick Observatory.

A portable coil-magnetometer of the Smith type for use on R.R.S. *Research.*

Two portable vertical intensity variometers for use by the Government of India.

The disturbance of the earth's magnetic field at Abinger by artificial fields due to electric traction has been increasingly serious as the extension of the area of electrification of the Southern Railway has proceeded. Disturbance is continuous throughout the working hours and ceases only during the interval 1h. to 5h. civil time. In amount it usually varies from 5γ to 10γ. It depends not only on the number and weight of the trains but also on meteorological conditions. Prolonged rain increases the disturbance to a marked degree.

The complexity of the total effect makes identification of the separate origins ordinarily impossible. The installation of the La Cour quick-run magnetograph has provided evidence, however, that significant effects occur coinciding with the movements of trains in the neighbourhood of Guildford as well as of Dorking.

In the early part of March an investigation of the extent of disturbance produced in the neighbourhood of Chichester by trains running on the South Coast railway was carried out under the advantage of a limited number of trains and a regular service. In the first instance a portable vertical intensity variometer of high sensitivity (kindly lent by the Director of the Geological Survey) was employed. It was found that rapid changes up to 30$\gamma$, of either sign, occurred at sites half a mile from the line. At a distance of six miles there were still total ranges of 5 .

Subsequently conditions at two sites were investigated in detail by means of a continuous record of vertical intensity and declination obtained from a magnetograph set up in a temporary hut. The effect at Itchenor—three miles from the nearest point on the line, with Chichester Channel intervening—was nearly of the same magnitude as at Abinger, though not continuous. The disturbance at Selsey, close to the sea shore and seven miles from the nearest point on the line, was still quite distinct, but from some aspects might be considered negligibly small, seldom amounting to 1$\gamma$ in vertical intensity. Effects produced by trains on the main lines to Portsmouth and Bognor Regis, as well as by trains on the line through Chichester, were detectable. Thanks are due to Major Levin for permission to set up the equipment in his garden, which enabled observations to be obtained at the maximum distance from electrified lines.

It is clear that accurate magnetic measurements of the undisturbed field of the earth cannot be performed in the neighbourhood of electrification of this sort at all, and the removal of the magnetic observatory from Abinger is becoming necessary.

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.

In connection with the change in the type of screen used for the standard thermometers, which took place on 1938 January 1, and which was described in the last Report, a site was subsequently found for the disused open screen on the north side of the Christie Enclosure, in a position not likely to be affected by radiation from neighbouring buildings. A maximum and a minimum thermometer mounted in this screen have been read daily, from 1938 May 1, so that ranges of temperature under " open screen " conditions might still be available.

The tabulation of meteorological results for 1938 is complete and the copy for press is well advanced.

The following details of the weather refer to the period of twelve months ending 1939 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 84°·0, registered on August 6. Temperatures exceeding 80° were recorded on 8 days. The lowest temperature was 20°·4, on December 20. Temperatures of freezing point or below were recorded on 29 days of which 11 were in December. The month of November was remarkable for a mean temperature 6°·3 above the 75 years' average and was the warmest November ever recorded at Greenwich.

The mean daily horizontal movement of the air was 301 miles, which is 16 miles above the average for 50 years 1867–1916. The greatest daily movement was 639 miles, recorded on October 4; the least daily movement was 141 miles, on October 25. The greatest motion in one hour, 35 miles, was recorded on November 23 and the greatest pressure reached, 33·2 lbs. to the square foot, was recorded on the same day.

The duration of *bright* sunshine recorded was 1296·5 hours, or 29·0 per cent. of the possible total. There were 64 entirely sunless days, 39 being in the three months November to January. No day in June or July was entirely sunless. There were 26 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 Ursae Minoris appeared on the plates was 84, while on a further 46 nights the record was not more than 10 per cent. of the whole time of exposure.

The total rainfall during the period was 25·02 inches, that is 0·78 inches greater than the average for 75 years 1841–1915. There were 179 days on which rainfall amounting to 0·005 inch or more was recorded.

The wettest month was January with 4·233 inches; the driest month, June with 0·414 inch.

The mean amount of solid matter in suspension in the air during the period covered by "Summer Time" increased from 0·48 milligrams per cubic metre in 1937 to 0·54 milligrams in 1938. The corresponding figures for the periods of normal time were 0·88 milligrams in 1937–38 and 0·84 milligrams in 1938–39. It appears that conditions have not improved during the last twelve months.

Exceptionally bad days were October 25, January 6 and February 3. During the afternoon of October 25 the amount reached 5·4 milligrams per cubic metre, that is, approximately nine pounds in the volume of air contained in a cube with one hundred yards edge.

With regard to gaseous pollution the average amount over the whole period May 1938 to April 1939 was found to be 0·046 parts of sulphur dioxide per million parts of air, which is a substantial improvement on the average for the previous period of twelve months. On the two worst days, *i.e.*, days ending at noon October 26 and February 4, the amounts, respectively, were 0·531 and 0·308 parts per million. The conditions on October 25 were very much worse than on any previous day since these records began.

IX.—Printing and Distribution of Greenwich Publications :—

The volume of *Greenwich Observations* and its separate parts for 1936 have been printed and will be issued immediately they are received from the binders.

The volume for 1937 is being prepared and manuscript is being sent to the printers as it becomes available.

A volume containing the latitude variation results for 1927 to 1936 and a discussion of the observations from 1911 to 1936 is in the press.

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, M.A., Ph.D., H. R. Hulme, M.A. Ph.D.

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, P. S. Laurie, B. R. Leaton, E. G. Martin, P. L. Rickerby, G. W. Rickett, J. Rudd, A. Shortland, L. S. T. Symms, G. F. Wells, J. G. Wickham.

Clerical Assistants.—Miss J. Auckland, 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 D. A. Nunn, Miss J. E. Payne, Miss D. F. G. Poole. One vacancy.

Principal Watch Adjuster.—R. Kunzler.

Assistant Watch Adjuster.—H. Warden.

Secretary and Cashier.—H. G. Barker.

Clerical Officer.—N. Miller.

Established Typist.—Miss M. Brickman.

Temporary Typist.—Miss M. F. Cackett.

(*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 M. B. Simm, Miss R. E. West.

Clerical Officer.—Miss H. A. Howard.
Shorthand-Typist.—Miss V. M. Hooper.
Several 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 Payne. |
| Transit Circle, Ledgering and Miscellaneous Reductions | Mr. Cullen, Mr. Blackwell, Mr. Rudd, Miss Nunn, Miss Poole. |
| 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, Miss Jeffries. |
| Photoheliograph and Spectroheliscope | Mr. Newton, Mr. Barton, Mr. Laurie, Mr. Wickham. |
| Magnetic and Meteorological .. | Mr. Witchell, Mr. Stevens, Mr. Wells, Mr. Rickerby, Mr. Leaton, Miss Foster. One vacancy. |
| Watch and Chronometer Repairs .. | Mr. Kunzler, Mr. Warden. |
| Secretariat and Library .. .. | Mr. Barker, Mr. Chamberlain, Mr. Miller, Miss Brickman, Miss Cackett. |

The post of Chief Assistant, rendered vacant by the appointment, in the previous year, of Mr. W. M. H. Greaves to the post of Astronomer Royal for Scotland, was filled on June 15 by Dr. H. R. Hulme, Fellow of Caius College, Cambridge, and formerly Lecturer at Liverpool University.

The staff of workmen employed at the Observatory consists of a foreman of observatory, two joiners, a mechanic, a watch repairer and 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.

Visitors to the Observatory during the year included Drs. J. Jackson and R. H. Stoy of the Cape Observatory, Dr. E. Hertsprung of Leiden Observatory, Drs. B. J. Bok and T. E. Sterne of Harvard College Observatory, Dr. B. W. Sitterley of Van Vleck Observatory and Mrs. C. Moore-Sitterley, Dr. J. S. Plaskett, Honorary Director of the Dominion Astrophysical Observatory at Victoria, British Columbia, Professor Batakliev of Sofia University and Madame Yoshida, wife of the Japanese Ambassador.

Professor F. C. Leonard of the University of S. California, Professor H. D. Curtis of the University Observatory, Michigan, Dr. P. W. Merrill of Mount Wilson Observatory, Mr. H. M. Jeffers of Lick Observatory, Dr. A. O. Leuschner of the Students' Observatory, California University, and Mr. W. E. Harper, Director of the Dominion Astrophysical Observatory at Victoria, B.C., visited the Royal Observatory on their way to or from the International Astronomical Union meeting in Stockholm in August.

Dr. G. V. Simonov, Assistant Astronomer of the Bosscha Sterrenwacht at Lembang, Java, was at the Royal Observatory from September 1 to April 17. He has been engaged principally on the study of double stars.

Dr. A. Beer of Mill Hill Observatory spent from October 10 to November 11 studying parallax work at the Royal Observatory.

Dr. H. O. Hartley, computer to the British Association Tables Committee, spent a week in the Nautical Almanac Office during June, learning the operation of the National machine.

Visits were paid to the Nautical Almanac Office by Dr. J. Robertson, director of the American Ephemeris, on August 24, and by Dr. Y. Hagihara, of the Tokyo Observatory, on July 22.

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 meeting of the International Astronomical Union at Stockholm was attended by the Astronomer Royal, Dr. Atkinson, Mr. Sadler, Mr. Witchell and Mr. Newton, the three first named forming part of the official British delegation. Subsequently Mr. Witchell visited the laboratory of Dr. La Cour in Copenhagen, Mr. Sadler visited the Astronomisches Rechen-Institut in Berlin to discuss matters arising from the forthcoming publication of the new volume of *Apparent Places of Fundamental Stars*, and Dr. Atkinson visited the Askania-Werke in Berlin and the observatories at Babelsberg and Potsdam in connection with the proposed purchase of a new small transit instrument.

The future of certain branches of work at the Royal Observatory has caused me much concern since my appointment as Astronomer Royal. The conditions for astronomical observations at Greenwich have steadily deteriorated during the last twenty years in consequence of the extensive building developments in a southerly direction, from which the prevailing winds come, and the growth of industrial plants, more particularly in the vicinity of the river. Both of these cause smoke, reduce atmospheric transparency and result in a non-uniformity of conditions in different directions. Modern developments in street lighting, such as mercury vapour lamps, high pressure gas, etc., and the extensive use of neon signs for advertising purposes have made the night sky at Greenwich so bright that long exposure photography is no longer possible.

The deterioration of observing conditions is noticed, in one form or another, by all the experienced observers. The definition obtained with the astrographic at the time when the Carte du Ciel work was done is not attainable now, and the exposures for a given magnitude are longer. The definition on the 26-inch refractor was so much improved by the alterations three years ago that a comparison here is impossible, but it is now rarely possible to give the so-called " normal " exposure of three minutes. The considerable increase of difficulty with the 28-inch has already been referred to. Transit circle observers of experience note that the seeing has deteriorated considerably.

The sunshine records are especially striking. The following figures give the annual differences of sunshine recorded at Greenwich and at Kew, averaged for five-yearly periods since 1911 :—

| Years. | Greenwich minus Kew. |
|---|---|
| 1911 to 1915 .. .. .. .. | + 62·1 hours |
| 1916 to 1920 .. .. .. .. | + 65·3 ,, |
| 1921 to 1925 .. .. .. .. | — 17·0 ,, |
| 1926 to 1930 .. .. .. .. | — 66·1 ,, |
| 1931 to 1935 .. .. .. .. | —133·2 ,, |
| 1936 to 1938 .. .. .. .. | —158·6 ,, |

The decrease in the amount of sunshine recorded at Greenwich in relation to the amount recorded at Kew is the result of loss of register at Greenwich when the sun is low, caused by atmospheric impurity.

Many programmes of observation depend for their success on uniform transparency of the sky in different directions. Such work, which used to be successfully undertaken at Greenwich, has been impossible for some years. The future of all photographic observations is threatened by the increasing brightness of the sky at night. The operation of numerous searchlights for anti-aircraft defence is a further addition to present difficulties.

In addition there are various forms of fouling ; the two most serious are the deposit of grit and the destruction of aluminised surfaces. With regard to the former, it is frequently advisable to interrupt a series of observations with the small transit instrument in order to clean the pivots ; the chief disadvantage is not so much the actual time lost as the fact that damage to the pivots may actually have occurred before anything is noticed. With the new reversible transit circle such impromptu cleaning is out of the question; the pivots are of course better protected, but examination shows that there is already appreciable scoring of both pivots and Y's. The outer surfaces of the objectives of the big refractors are still reasonably free from scratches, owing to the care taken when they are cleaned, but it cannot be questioned that there is a permanent risk of damage by grit. The difficulty of preserving aluminised mirrors has been most marked with the spectrohelioscope, where it is unusual for an outside mirror to last a year. These mirrors are uncovered only when the sun is shining, but they face upwards. The Yapp paraboloid cassegrain was still in fairly usable

condition after nearly three years ; it is never, of course, directed upwards, and actual solid matter does not, therefore, deposit on it to any great extent. The amount that does deposit on the main mirror, and the indications that in the case of the spectro-helioscope such deposits attack the film, have made it appear inadvisable to aluminise the 36-inch mirror at present. Since the new slit spectrograph is primarily an ultra-violet instrument this position is evidently very unfortunate, as aluminised surfaces are much to be preferred for work in the ultra-violet.

The difficulties of the present conditions affect all observations. The photographic observations and the visual observations of faint double stars are interfered with to the greatest extent. Meridian observations are less affected because they are now restricted to brighter stars, the fainter stars being observed photographically, but the observations of stars at low altitude are greatly hampered, and it is on these that the determination of the instrumental errors depend.

If the Royal Observatory is to continue to make important contributions to astronomy, as it has done for the past 264 years, and to provide an efficient time service of high accuracy, it is essential that it should be removed to a site where astronomical conditions are favourable. The present wasteful efforts to secure observations under increasingly bad conditions, and the restriction of programmes that are necessitated by such conditions, would thereby be avoided.

Much investigation has been made to decide in what area the best conditions are to be found. Good meteorological conditions, both by day and by night, with freedom from liability to mist and fog, are needed, whilst proximity to a large town, with the resulting smoke and glare, must be avoided. Records of sunshine and of horizontal visibility have been analysed. The Director of the Meteorological Office placed at my disposal the records of night cloudiness and of night visibility for the past eight years, at all stations where such observations are made.

Many enquiries have been made and a number of likely sites have been examined but no definite decision has yet been reached.

The continuous registration of the elements of the Earth's magnetic field has been carried on by the Royal Observatory since September, 1847, providing the longest continuous series of records anywhere available. The observations were made at Greenwich until 1924 when, in consequence of the development of electric traction in the vicinity of the Observatory, it became necessary to transfer this work

to another station. A site was selected near Abinger in Surrey. The observations were carried on satisfactorily there for several years, but the electrification of the Guildford line to the north-west of Abinger caused well-marked disturbances. The more recent electrification of the line to the east of Abinger, on which regular running of electric trains commenced in July last, has produced further disturbance. At times the disturbances have been very great, apparently as the result of leakages in the system. Under normal conditions they are worst during spells of wet weather and at times of heavy traffic. The general level of the disturbances is now such as to render all observations difficult and, when the disturbances are at their worst, the observations lose much of their value. The removal of the magnetic observations to another site has become a necessity. The observations made at Selsey in March have shown that the site selected should be at a distance of not less than eight miles, and preferably of at least ten miles from any electrified railway. As a safeguard against the probable extension of railway electrification in the future the essential condition for a new site is that it should be at least ten miles from any railway line. It is desirable that the magnetic observatory should remain in the south of England ; this practically limits the choice of a new site for the magnetic work to a few regions in Devonshire.

Proposals for the removal of the whole of the astronomical work from Greenwich and of the magnetic work from Abinger to new and more favourable sites are accordingly under consideration.

H. SPENCER JONES.

Royal Observatory, Greenwich.
1939 May 11.

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