

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

Read at the Annual Visitation of the Royal Observatory, 1941 June 7.

THE BOARD OF VISITORS

The President of the Royal Society. Sir Henry Dale.

The President of the Royal
Astronomical Society. Prof. S. Chapman.

		To serve until June 30th
Nominated as Fellows of the Royal Society.	Sir Edward Appleton.	1941
	Prof. G. P. Thomson.	1942
	Prof. R. H. Fowler.	1943
	Dr. C. G. Darwin.	1944
	Prof. T. R. Merton.	1945
	Sir James Jeans.	1946
Nominated as Fellows of the Royal Astronomical Society.	Rev. T. E. R. Phillips.	1941
	J. Evershed Esq.	1942
	Prof. E. A. Milne.	1943
	Dr. R. Stoneley.	1944
	Prof. W. M. Smart.	1945
	Prof. W. M. H. Greaves.	1946
Savilian Professor of Astronomy at Oxford.	Prof. H. H. Plaskett.	
Plumian Professor of Astronomy at Cambridge.	Prof. Sir Arthur Eddington.	
Hydrographer of the Navy.	Vice-Admiral J. A. Edgell.	
Secretary.	W. E. Llewellyn Esq.	

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Read at the Annual Visitation of the Royal Observatory, 1941 June 7.

The Report here presented refers to the period from 1940 May 1 to 1941 April 30 and exhibits the state of the Observatory on the last-named day.

I. Buildings, Grounds, Movable Property and Library:-

The buildings have received damage on several occasions by enemy action. The north wing of the Main Building and the south portico of the Altazimuth building have both received direct hits from bombs; the damage, though considerable is not serious. The main gates and supporting pillars have been destroyed by a direct hit, when most of the covered way in the courtyard was also destroyed. There has been extensive damage to windows, window frames and ceilings throughout the Observatory. The coverings of the altazimuth and transit pavilion domes have been destroyed and those of the 28-inch refractor and 26-inch refractor domes have been riddled with holes by fragments. The Cooke small transit instrument was broken in half when thrown from its mounting in the altazimuth dome, though the object glass was undamaged. The Cookson telescope received minor damage when the exposing shutter above the instrument was detached by blast and dropped on the telescope. The large lenses, mirrors, and some other valuable parts of the principal instruments have been sent away from Greenwich for safety. No structural repairs to damaged buildings have been made, but temporary repairs have been carried out.

A new personal equation machine has been constructed in the Observatory Workshop and fitted to the South Collimator on the Altazimuth Dome.

The brick pier for mounting the Cooke Small Transit Instrument, mentioned in the report last year, has been erected. This is surrounded by wood panelling, to which an electrical control panel has been fixed; this serves all the wiring circuits for the Instrument, Personal Equation machine and Chronograph.

The power and lighting circuits have been rewired in the Dome and a main switch arranged at the south entrance.

Patterns have been made for casting the metal base and parts for the variometer now in use at the Magnetic Station, Abinger.

New Castings have been fitted as toe plates to the strider level and a new bubble fitted for use with the Small Transit Instruments.

Two of three two-pen chronographs have been constructed in the Workshops. These chronographs are fitted with synchronous induction motors, for conveying the tape at a uniform speed. The third chronograph is now under construction, together with a portable double spring gramophone motor as an alternative for conveying the tape on either machine.

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A new relay control panel for the clock circuits and chronograph has been completed for use at one of the emergency time stations.

The following painting was done during the year:-

External painting of all the domes in the Observatory grounds, Stevenson's screens, thermometer stands, and the metal work of the Cookson shutter.

All the teak doors of the buildings in the Christie Enclosure have been re-varnished.

A new section together with new fire doors have been fitted to the independent boiler for central heating of the Wren building.

The new drilling machine was received in August.

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

The Cookson floating zenith telescope, from the Cambridge Observatory, for a fifth period of seven years from July, 1939.

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 spectroscope slit 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.

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

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:-

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.

To the Imperial College of Science and Technology.

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

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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.

To the Assistant Superintendent of Demagnetisation -

Small Transit instrument with stand and striding level; Theodolite, complete with striding level.

A case containing some smaller instruments belonging to the Royal Observatory is for the present stored at the University Observatory, Cambridge.

The annual examination of the Observatory Library has been made. Seventeen books are missing and cannot be traced at present. Of these, nine were reported missing last year. Eight books which were reported last year as missing have since been recovered.

The renovation and rebinding, by the Binding Department of H.M. Stationery Office, of about 190 valuable and rare books belonging to the Observatory Library has now been completed.

II. Astronomical Observations:-

Transit Circle. The Sun, Moon and Planets were regularly observed, together with accompanying clock and azimuth stars, until September 12, when observations were suspended, bringing to an end the long series of fundamental observations made at Greenwich with this instrument.

Apart from small breaks for necessary alterations and adjustments, the instrument has been in continuous use since 1851. More than 650,000 observations have been made with it, forming the most important contribution from a single instrument to fundamental positional astronomy.

During the period May 1 to September 12, 590 transit observations and 583 observations of zenith distance were obtained. These included 41 observations of the Sun, 29 of the Moon, 12 of Venus, 5 of Neptune and 3 of Ceres.

Annual results for the Sun, Moon and Planets for the years 1937 to 1940 are in course of preparation.

The large amount of time given to investigations with the reversible transit circle since its installation in 1936 has led to delay in the preparation of the star catalogue based on the observations from 1931 to 1938. Advantage is being taken of the suspension of observations to proceed with the preparation of this catalogue, with a much reduced staff.

Reversible Transit Circle. The observations for providing the foundations of a system of right ascensions were continued until September 11. During this period 1466 transits were observed as follows:-

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Clock Stars	..	..	717	observations
Zenith "	..	..	159	"
Azimuth "	..	..	559	"
Miscellaneous	..	..	31	"

In addition, 531 observations of collimation error and 533 observations of level error were made. A total of 9363 transits has been obtained in somewhat less than three years.

The experiment of jacketing the piers with felt, referred to in the previous report, has succeeded in materially reducing the rapid fluctuations of level error, caused by changes of air temperature and of direction of wind. By a more complete insulation against such changes, it is probable that the changes of level can be still further reduced.

The observations for determining the errors of the divisions of the fixed circle have been completed. Using the six ordinary microscopes, they cover an arc of 120 degrees at intervals of 5 minutes. The errors show certain definite periodicities, on which are superposed errors of an accidental nature. The analysis of the errors will be made later, but it is clear that the accidental errors are not negligible in comparison with the periodic errors. The method used for dividing the circle was an adaption of that employed for theodolites; for a large astronomical circle the use of an automatic dividing engine, with which the errors are mainly of a periodic nature, seems preferable. The extreme range in the division errors is satisfactorily small, being only three quarters of a second of arc.

On the completion of the determination of the division errors investigations were begun on the irregularities of the pivots. Frequent tests with a mikrotast gauge during the final stages of the figuring of the pivots at Greenwich had shown that the irregularities were small, but the mikrotast gauge does not give a quantitative determination of the errors. The measurement of the pivot errors necessitated dismantling the motor drive and installing the various components of the pivot telescope in the axis of the instrument. As observations of transits were then impossible, the observations of pivot errors were alternated with periods devoted to observations of transits. When the instrumental work was suspended in September, sufficient observations had been obtained to indicate that the errors due to the irregularities of the pivots are extremely small.

The object-glass and micrometer eye-end have been dismantled, and, together with the two collimator objectives, sent away from Greenwich for safety. The telescope has been taken out of its bearings and is supported on the reversing carriage. The pivots, bearings and other metal parts have been well greased and protected against damp and dust.

Cookson Zenith Telescope. During the year 108 plates were taken for latitude variation and 2 for the determination of scale. The measurement of the plates is proceeding.

Thompson Equatorial. During the year 82 parallax plates have been measured giving 4 determinations of stellar parallaxes. The results for 28 stars were published in *Monthly Notices* No.1 1941.

Owing to heavy parallax measuring and the completion of the colour-temperature discussion, a large number of proper-motion plates remained unmeasured. This accumulation has now been taken in hand, 703 plates having been measured during the year. The checking of the copy for press of parallax determinations for a future volume has been commenced and is being continued as opportunity permits. The results for bright stars have been forwarded to Prof. Schlesinger for incorporation in the new edition of the Bright Star Catalogue.

Yapp Reflector. Two papers on the "Effect of Absolute Magnitude on Star Colours" and "Space Reddening in the Galaxy" have been published in *Monthly Notices* during the year, thus concluding the discussion of results obtained from the colour temperature work. All parts of the reflector likely to suffer from rust have been treated with rust proofing oil. Both the Thompson and the Yapp Equatorials have been regularly inspected so as to detect any deterioration promptly.

Observations of Eros. The following results have been received since the date of the last report and a comparison made of the observed positions of the planet with the ephemeris.

La Plata:- Ex-meridian plates	246	Positions on 14 nights			
Meridian plates	49	"	"	34	"
San Fernando	12	"	"	10	"
Hyderabad	27	"	"	7	"

The results received from Hyderabad are a part only of the observations obtained, being 21 out of the 212 plates taken. The remainder were promised by the end of the year 1940, but owing to the prevailing conditions have not been received.

The discussion of the whole of the photographic material received is approaching completion. The material used totals 1392 plates from 18 northern observatories and 1455 plates from 6 southern observatories, the observations extending over seven months from the beginning of October, 1930 to the beginning of May, 1931. A system of weighting in right ascension and declination, based on comprehensive inter-comparisons between the results given by different instruments, has been adopted and corrections to reduce all the observations to one system have been derived.

The value of the solar parallax derived from the observations in right ascension is

$$8''.7875 \pm 0''.0009$$

and from observations in declination is

$$8''.7907 \pm 0''.0011$$

The values of the solar parallax given by photographic and visual instruments, the latter being employed photographically using yellow filters and yellow sensitive plates, are in close agreement. The value from long-focus instruments, depending on secondary reference stars, is in agreement with the value from short-focus instruments, depending upon primary reference stars. Possible systematic effects arising from differential atmospheric dispersion have been investigated and no conclusive evidence of such effects was found.

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The final value of the solar parallax from the complete programme may be taken as

$$8''.790 \pm 0''.001$$

The value used in the national ephemerides is $8''.80$.

The coefficient of the lunar inequality has been investigated from both right ascension and declination observations. A limit to the precision that can be attained is imposed by small inhomogeneities in the reference star system. Nevertheless, the determination has a greater weight than any previous determination. The provisional value of the coefficient is

$$6''.4393 \pm 0''.0018$$

The derived value of the ratio of the mass of the Earth to the mass of the Moon, using the above value of the solar parallax, is

$$81.277 \pm 0.021$$

Photoheliograph. Photographs of the Sun were obtained on 260 days. The number of photographs selected for preservation is 497, including 22 with double images for the determination of the zeros of position angle. The zero has also been determined regularly by visual observations.

From reports received from H.M. Astronomer at the Cape and from the Director of the Kodaikanal Observatory, it is known that no day is unrepresented in the combined series of photographs from May 1 to December 31. Complete reports for the last four months have not yet been received. Owing to the war, no photographs have been transmitted from the Cape. The last to be received were those up to 1939 June 21.

The measurement of the series has been made from 1939 January 4 to November 15, excluding 26 Cape photographs after June 21 which eventually will fill the gaps in the Greenwich series. Computations of spot positions and areas have been made from 1938 December 13 to 1939 September 18.

The copy for press of the *Greenwich Photoheliograph Results* for 1938 is nearing completion.

The decline of activity from the high maximum of 1937-38 continues, the frequency of sunspots, as assessed by "sunspot numbers", being about 25 per cent less than in the preceding 12 months or about one-half that of the maximum year, 1937.

In spite of the lessening activity, there was no general scarcity of spots during the year, and some 21 groups reached or exceeded 500 millionths of the sun's hemisphere (a general lower limit for the naked eye visibility of a sunspot in the central region of the disk.). Three of the above groups reached or just exceeded 1000 millionths, namely those with central meridian passage on July 7.6, August 20.9 and October 13.0.

The computed times of central meridian passages of spots with areas of 500 millionths or greater have been notified, as soon as each spot appeared, to the Superintendent, Radio Research Station of the National Physical Laboratory: the Controller (Engineering) British Broadcasting Corporation, and the Engineer-in-Chief, Cable and Wireless Limited.

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Six of the twenty-one large groups of sunspots were associated with magnetic storms within 4 days of their times of central meridian passage. With respect to most of the groups - a succession of six occurred in August and another of five groups in June - there was a general absence of chromospheric eruptions of intensity as high as 3 or even 2, on the international scale. Probably the most active spot of the year (whose activity was largely deduced from the number of radio fade-outs when the spot was near the sun's central meridian) was associated with the intense magnetic storm of 1941 March 1. Eleven other magnetic storms were not associated with any unusual solar activity, as far as could be ascertained from the rather limited observations available.

Daily sunspot numbers, based on Wolf's method of counting, have been supplied, after several weeks had elapsed from the current date, to Professor Brunner for eventual incorporation in the *Bulletin for Character Figures of Solar Phenomena*, published under the auspices of the International Astronomical Union. Owing to the temporary suspension of that publication, preliminary mean values for each month, based on Greenwich data alone, have been supplied to several research centres in this country.

Spectrohelioscope. Observations with this instrument were curtailed, owing to the daylight air raids on London and to a subnormal amount of sunshine during the early months of 1941. The spectrohelioscope was accordingly used in brief surveys of the sun's image seen in H α light to locate eruptive phenomena. These surveys indicated a general absence of chromospheric activity around a number of the sunspot groups seen during the year. Observations were made on 137 days; on 46 days the surveys were limited to a few minutes owing to unfavourable conditions. 164 measures of radial velocity were made, chiefly on bright and dark flocculi associated with sunspots.

Twenty-three bright eruptions, only one or two of them being of major importance, were recorded during the year, as compared with 63 in the previous twelve months. The sudden decrease in this manifestation of chromospheric activity is also indicated by the marked decrease in the number of radio fade-outs over the same period.

As mentioned in last year's report, the Engineer-in-Chief, Cable and Wireless Limited, had arranged for definite fade-outs (ionospheric irruptions) to be notified to Greenwich while in progress. During the year, 10 such phenomena were immediately reported. In two cases, a bright solar eruption was located in consequence; in two other cases the eruption had already been picked up at Greenwich, and in six cases observation of the sun was impossible on account of cloud.

On February 28, use was made of the report of the occurrence of three fade-outs on February 27 and 28 to issue a warning of a possible magnetic storm impending. No spectroscopic observations of the Sun were possible until March 3 when a major bright eruption was observed. A direct photograph of the sun taken on February 28 through cloud, showed faintly a rather large and complex spot near the sun's central meridian. It seemed very probable that the incidence of three fade-outs after a long period of infrequent ionospheric disturbance of this type indicated intense chromospheric activity associated with this spot, which was then favourably placed for an ejected stream of solar particles to reach the earth. Eighteen hours after the most marked of the three fade-outs, a "great" magnetic storm began on March 1 and reached its peak intensity some twelve hours later.

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The two original mirrors of the coelostat of the spectrohelioscope were re-aluminized in August.

III. Time Service:-

The conditions prevailing during the past year have necessitated a number of changes in the arrangements for the Time Service. The setting-up of a duplicate time-service, referred to in last year's report, was completed. The determination of time and the distribution of time signals from Greenwich was continued until September. The continuous all-night air raids then made night observations impossible and the service was accordingly transferred to the emergency station A. For some weeks time observations were made at this station whilst time signals continued to be sent out from Greenwich. The transmissions from Greenwich were finally terminated towards the end of November and all signals have since been sent out from the emergency stations. The small reversible transit B remained in use at Greenwich until observations ceased; from October 19, it replaced instrument D at the emergency station.

As equipment was not available at the emergency station for the determination of relative personal equations of observers, and as it was necessary to introduce certain new observers at this station, observers were employed in pairs, both making observations, until sufficient material for the determination of relative personal equations was available. A provisional longitude of the emergency station, based on observations made during the period of overlap, when observations were being made both at this station and at Greenwich, has been applied to subsequent observations to reduce them to the meridian of Greenwich.

A second emergency station B has been equipped to ensure maintenance of the time service in the event of damage to station A or to Post Office lines used in the distribution of signals. The Shortt mean time clock No.16 and sidereal clock No.11, together with Rugby diminished seconds transmitter, have been transferred from Greenwich and mounted at this station. Time observations are made with a reversible transit instrument and radio receivers have been transferred from Greenwich for the reception of time signals. The station B has been available for the emission of signals since the end of December and has taken over the Rugby rhythmic time signal service during a number of periods when, for one cause or another, it was not possible to transmit them from station A. The two stations are now being run in close collaboration and arrangements are being made for time signals to be radiated from that station at which conditions are most stable at the time. Every precaution has been taken to minimise the discontinuities when the change from one station to the other is made, and a continuous check on the signals is maintained at both stations.

Time determinations were made with the small transit instrument at Greenwich on 63 nights from 1940 May 1 to September 4. In addition 29 determinations with the reversible transit circle were included in the derivation of the final clock curves. After September 4 time determinations were secured at the emergency station A on 74 nights and from December 11 at station B on 26 nights. The observations at the two stations are combined for the derivation of the final clock curves.

The errors of the Shortt clocks at the Royal Observatory, Edinburgh and at the National Physical Laboratory are still determined by means of the Rugby time signals, and the results are communicated daily. A mean clock, employing all the available data, is used in establishing final corrections to the times of reception of radio time signals.

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The National HRO short wave receiver, referred to in the last report, has been received and has been in regular use. Its performance has proved to be highly satisfactory. A Sky rider SX17 receiver was also purchased and installed as a reserve and a further similar receiver is being purchased. These short wave receivers have made it possible to secure more regular reception of American time signals. The records of the Nauen long wave time signals have also been supplemented by regular reception of the corresponding short wave transmissions from DFC and DGZ. The long wave American time signals from NSS and the long wave signals from Bordeaux are also received. The time signals are recorded at both emergency stations.

It is not known whether the Bureau de l'Heure continues to function and corrections to continental time signals have not been received. It is therefore not possible to give the monthly means of the differences from Greenwich shown by foreign time signals.

Two new chronographs have been completed in the workshop, one of which is in use at station A and the other at station B. A third chronograph is approaching completion. Since September it has not been possible to arrange for the release of the Greenwich time-ball, nor to maintain the check on the Westminster clock. The well known Shepherd clock near the main gate of the Observatory, which for many years has been controlled by the mean time system, has sustained damage. Both the Time-ball and the Shepherd clock have been popular features among members of the public visiting Greenwich Park, but otherwise they have ceased to be of importance.

General research and development work has naturally been indefinitely postponed. The quartz clock together with its standby electrical equipment have been stored until more favourable conditions permit various modifications to be made. The proposals for the installation of a number of quartz clock units and ancillary equipment have of necessity been held over. As soon as the situation permits, however, it will be necessary to embark on a bold policy in order to make up for the present period of stagnation, since the standard of the service at present possible falls short of the high precision required for the adequate control of precision frequency standards.

IV. Chronometers:-

In the report for last year it was mentioned that the entire chronometer and watch testing and repair work had been moved from Greenwich to premises in Bristol at the beginning of the war. The heavy raids on Bristol made it desirable to move this work to a safer area. Premises were therefore obtained elsewhere in January and after the necessary alterations to adapt them to the requirements of this work had been made, the watch repair staff with their equipment were transferred from Bristol on February 24. The majority of the watches and chronometers were transferred the following day. The rating and issuing of chronometers and watches were continued at Bristol until March 3, on which date the office staff and equipment, together with the remaining instruments, were moved. There was no interruption to the normal work of issuing and receiving chronometers and watches during the period of transfer. Immediately after the completion of the transfer an audit of instruments was carried out and all were accounted for. As an additional safeguard reserve stocks of chronometers and watches have been widely dispersed.

During June, 1940 the refrigerator for testing watches at low temperatures, purchase of which was mentioned in the last report, was delivered at Bristol, where it has given satisfactory service at temperatures down to 10°F. It has since been moved and re-erected at the new premises.

The Gibbs Watch-rate recorder, used in the repair shop, developed trouble and it was found that a new quartz crystal was required. The necessary repairs have been efficiently carried out by the Furzehill Laboratories. This instrument is of considerable assistance in making preliminary adjustments for rate to watches after assembly, and also for the detection of faulty escapements or trains.

A $3\frac{1}{2}$ -inch Lorch lathe has been generously presented by Mr. R. W. Nicol for use in the watch repair shop. This will be of great use in work of a heavier nature than the present Lorch lathe can accommodate.

The high standard of results obtained from watches repaired and adjusted in the repair shop has been maintained. Many centre-seconds chronometer watches, previously unsuitable for use on account of minute hand discrepancies, received special examination, and repairs or replacements have been made with highly successful results. The experience thus gained has proved very useful in dealing with this type of watch generally. Other specialized work, which necessitated the expenditure of much time, included experiments in connection with the behaviour of watches at low temperatures, when treated with different oils.

V. Nautical Almanac Office:-

The routine calculation and proof-reading involved in the preparation and printing of the publications for which the Office is responsible have been continued throughout the year. Modifications, both in content and presentation, have been necessary owing to the war; in particular the destruction by fire of the whole of the type and plates (and some original copy) for all publications, with the exception of the *Astronomical Navigation Tables*, has led to considerable delay in publication as well as in some cases to reproduction by photography instead of by printing from type. The destruction of special founts and matrices, which cannot be replaced, will mean lowering of the standard of typography for some little time to come.

The Nautical Almanac. In October, most of the *Nautical Almanac* for 1942 was in various stages of type or stereo-plate; it has not yet been published, but photographic reproduction from proofs is now in hand for all except a few pages, which will be ready early in May. Publication is expected during July. This date compares unfavourably with the corresponding date, for the 1941 edition, of February 28, but the delay is not cumulative and it is expected that the Almanac for 1943 will be issued before the end of the year.

Considerable changes in content have been made, mainly due to the war. The Occultation Reduction Elements for 1942 have been omitted; it was intended to include them in the Almanac for 1943 if conditions permitted, but it is now probable that arrangements will be made for publication elsewhere. The sections containing lists of Standard Times and Observatories have been omitted; these sections differ little from year to year and the requirements of users are met by a list of amendments to the data given in the Almanac for 1941. Both the omissions will be rectified as soon as the war situation permits. The auxiliary tables have been revised and the Explanation rewritten as part of a definite permanent policy towards restricting the Almanac to contain only such auxiliary tables and explanations as are necessary for the user to extract the ephemeral data in the form he requires. It is intended to issue a separate Supplement, of a permanent character, which will contain all the material now omitted together with such added information as can be included in the rather wider scope provided by a separate publication. It is probable that publication of the Supplement will have to be delayed for some time, but in the mean time the Almanac will be self-contained.

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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: that for 1945 is now complete and most of the information has been circulated to the other ephemeris offices in accordance with the arrangements for the interchange of astronomical computations to avoid duplication.

So far the difficulties of international exchange have not affected the *Nautical Almanac*, but arrangements have been made for the additional work that will be necessary in future to be shared with the Office of the American Ephemeris in Washington.

The series of independent checks, mentioned in last year's report, is still in course of preparation, though many checks have been done on certain advanced work which may or may not be received from abroad: these checks will, if necessary, form a framework for complete computation.

Occultations and Eclipses. The occultation programme for 1943 has been much modified; the number of stations for which predictions have been made has been drastically reduced and no reduction elements have so far been computed. Apart from the question of whether predictions for particular stations in Europe will or will not be used, distribution of the predictions in manuscript for publication elsewhere is now virtually impossible; the programme is thus being limited to predictions for those stations which are either published in the *Nautical Almanac* or can be distributed. The opportunity has also been taken to omit stations, the predictions for which have not resulted in more than one or two observed occultations in the two full years for which records are available.

For 1943, elements of occultations for 1710 stars not fainter than magnitude 6.5 were received from the Office of the American Ephemeris, and elements for 838 stars between magnitudes 6.5 and 7.5 were computed in the *Nautical Almanac* Office from material supplied by Washington. These 2548 stars were examined by the occultation machine and preliminary times recorded for 78 stations for the 1417 stars that were retained; prediction elements will be printed for all these 1417 stars. The number of predicted computations is greatly reduced, there being only 2859 as against an average of about 9000 in previous years.

During the year an intensive statistical and theoretical investigation has been undertaken with a view to improving the mechanical accuracy of the occultation machine and enabling systematic errors to be allowed for in the machine times. It is hoped that by this means it may subsequently be possible to circulate "corrected" machine times without the necessity for individual computation. This course will be followed for those stations for which predictions have not been computed for 1943, when communication is restored and if time is then too short for computation.

The survey of the numbers of observed occultations resulting from predictions for various stations, referred to in last year's report, has shown that the occultation programme has not resulted in the expected increase of observations suitable for incorporation in the analysis of the Moon's motion. In particular, it has been found that it would be easier for the Office to reduce all such observed occultations than to compute reduction elements, most of which are never used. Consideration is thus being given to the advisability of discontinuing the computation of the reduction elements, with the possibility of including additional information to assist reduction in the prediction elements.

No special eclipse calculations have been undertaken during the year.

Abridged Nautical Almanac and Air Almanac. The *Abridged Nautical Almanac* for 1942 was almost ready for printing in October when the stereo plates from which it was to be printed were destroyed. Photographically reproduced proofs were passed for press on February 6, and publication is expected at any time, in spite of repeated printing difficulties.

The only change in the Almanac is the inclusion of tables of sunrise, sunset, civil and nautical twilight, moonrise and moonset for latitudes 60° to 73° north: this is now a permanent addition to the Almanac. A supplement containing similar data for 1941 was issued in August.

The *Air Almanac*, which was being issued one or two weeks earlier each quarter, was affected more seriously than other publications by the destruction of the type; the delay of three to four months, which this caused, is being rapidly reduced with the co-operation of the printers. At present a schedule of 8 weeks for each quarterly issue of over 200 pages is being maintained. Three quarters only have been published during the year as follows:-

1940 Fourth Quarter		June 4
1941 First	"	September 11
1941 Second	"	February 4

The third quarter of 1941 was passed for binding on March 15 (its original scheduled date for publication was February 11); the fourth quarter has been passed for printing, while the first quarter of 1942 is in proof.

The *Astronomical Navigation Tables* are now almost complete. Computation was completed early in December, a few weeks before the scheduled date. The issue of the volumes naturally lags behind the computation, but 11 volumes have already been issued, one is in the hands of the binders and the penultimate volume will be passed for printing early in May. First proofs have been read for the fourteenth (and last) volume, and the reading of the stereo proofs commenced. The completion of this programme within a few weeks of the estimated time of $3\frac{1}{4}$ years is very satisfactory.

Apparent Places of Fundamental Stars. This annual volume, arising from resolutions of the International Astronomical Union, contains the mean and apparent places of all the 1535 stars in the *Dritter Fundamentalkatalog des Berliner Astronomischen Jahrbuchs*. Although collated and printed by Great Britain, the computations are normally all supplied from abroad on the principle of international exchange. All material for 1941 was received in good time and the initial volume for 1941 was published on May 25.

The portion of the computations undertaken by France (apparent places of 426 10-day and 32 circumpolar stars) has not yet been received for 1942 or subsequent years; when it became evident that the data would not be forthcoming for 1942, and probably for subsequent years, arrangements were made by which the Nautical Almanac Office undertook to compute the apparent places of the 426 10-day stars, while the Office of the American Ephemeris computed the 32 circumpolar stars. Because of the relative urgency of the 10-day stars, without which no copy could be sent to the printer, they were computed for 1942 by a differential process using the figures for

1941 as the basis; the additional uncertainty introduced by this process is very small. The volume for 1942 has been delayed by fire, and it will have to be printed partly by photography from proofs and partly from type; publication is expected in July or August.

The computation of the apparent places of the 426 10-day stars, together with 26 other stars not yet received, for 1943 and 1944, is now in hand. The work has been adapted to the punched card (Hollerith) principle, the basic machine used being the multiplying punch, which has previously been put to considerable use in astronomical computations in the Nautical Almanac Office and elsewhere. By this process a certain economy is effected by doing two years together and present indications appear to justify the decision to take advantage of this. All the preliminary work is now complete, and the punched cards have been handed to the service department of the British Tabulating Machine Co. for routine multiplication and tabulation. Final results are expected about the end of June and publication of the volume for 1943 is scheduled for May 1942.

Other Publications. In addition to the preparation of several smaller tables for the Admiralty and other Service Departments, copy has been prepared for a five-figure table of the natural trigonometrical functions for every 10". This table is now all in proof and most of the proof reading is completed; it should be passed for press very shortly.

Proof Reading. As in previous years, the proportion of time actually spent on proof reading to the available maximum is high - in the neighbourhood of 70 per cent. Although this ratio will tend to be decreased by the completion of the *Astronomical Navigation Tables*, it will in fact be increased on balance by the staff changes necessitated by the war. In the past year there have been 10,000 distinct readings representing about 3,500 separate pages of printed figures; this represents an average of three readings for each page and implies that all first proofs have been read in duplicate. The reason for this is the necessity for using junior staff for proof-reading, a course which has not previously been considered desirable and which is not completely satisfactory; it may in future be necessary to rely more on the junior staff for this work and much of the duplicate reading in the past year has been undertaken deliberately for training purposes.

Repayment Work. The increase in the number of demands for information on lighting-up times, black-out times etc., mentioned in last year's report, continues; nearly 200 lists of lighting-up and black-out times, covering more than 40 cities and towns, have been supplied during the year. The amount of secretarial work has been greatly increased by the number of changes made in Summer Time and the Lighting Regulations. Small charges to cover cost of preparation and secretarial work are made for this service.

Other Work. During the year the Office has undertaken a greatly increased amount of additional work for other departments of the Admiralty and other Service Ministries. In particular, the Office has been in the closest contact with the navigation departments of the Air Ministry; in addition to keeping the *Air Almanac* and the *Astronomical Navigation Tables* in line with the latest service requirements, calculations and tables have been prepared for various navigational instruments, and a certain amount of theoretical work has been done in connection with current research.

In other directions, the work undertaken has in many cases been purely computational, having no connection with astronomy or navigation; the Office is well equipped for all work involving scientific computation and there are indications that the specialist nature of this work is being more and more recognised by other Departments.

Machines. No additions have been made to the mechanical equipment during the year.

VI. 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 normally 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, but no opportunity for re-measurement has occurred since the last report.

The La Cour magnetographs, installed in 1937 and 1938, continue to give great satisfaction. In view of the steadiness of the value of the base-line on the La Cour magnetograms, continuous recording with the Watson quartz-fibre vertical intensity variometer was abandoned, from 1940 January 1, as an unnecessary duplication. The disused recording mechanism has been incorporated in a magnetograph capable of recording fully on a small scale any variations of declination and horizontal intensity that could occur at Abinger. The magnetograph was put into regular operation early in June 1940 and has proved decisive on occasions when large sudden changes of the earth's field made doubtful the interpretation of the normal traces.

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 1940 December 31, and with provisional constants to the present time.

The manuscript copy of the "Results of Magnetic and Meteorological Observations" for 1938 and 1939 is prepared for printing.

The tabulation of results for 1940 is almost complete, and awaits only the receipt of the final list of International "quiet" and "disturbed" days.

The mean values of the magnetic elements at Abinger for the year 1940 are given below. The values for the years 1937, 1938 and 1939 are given for comparison.

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			Decl. W.	Horizontal Intensity	Vertical Intensity	Inclination
1937	..	..	11° 10'.4	0.18522	0.43031	66° 42'.7
1938	..	..	11° 1'.4	0.18522	0.43050	66° 43'.2
1939	..	..	10° 51'.9	0.18528	0.43074	66° 43'.5
1940	..	..	10° 43'.0	0.18533	0.43099	66° 43'.9

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

During the past twelve months there have been 17 magnetic disturbances reaching the dimensions of a "storm" and, in addition, two 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 disturbance which took place on 1941 March 1, though short-lived, ranks high among the severe disturbances of the past 90 years. There was a range of more than 1700γ in the horizontal component of the earth's magnetic field at Abinger.

There is no diminution of the continuous disturbance of the earth's magnetic field at Abinger by artificial fields due to electric traction.

Mr. H. L. P. Jolly of the Ordnance Survey Department was at the Magnetic Station on March 11 and 12, engaged on testing and standardising two "magneto-theodolites".

Under a standing arrangement facilities for adjusting variometers at the station have been granted to makers from time to time during the year. The number of instruments so adjusted was 8 in all.

VII. Meteorological Observations:-

Routine meteorological observation which began on 1840 November 9, has now extended through one hundred years without interruption of the major plan. The standard barometer (Newman 64) and the Osler anemometer have been in operation throughout the whole period.

During the past twelve months 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. Measurement of the amount of solid matter polluting the air has been continued, using an Owens automatic filter. Measurement of the gaseous pollution of the air by sulphur dioxide was discontinued from the beginning of September.

The tabulation of meteorological results for 1940 is complete and the copy for press is nearly complete.

The following details of the weather refer to the period of twelve months ending 1941 April 30.

The mean temperature was $49^{\circ}.3$ which is $0^{\circ}.2$ lower than the average of 75 years 1841-1915. The highest temperature in the shade was $85^{\circ}.7$, registered on September 4. Temperatures exceeding 80° were recorded on 11 days. The lowest temperature was $18^{\circ}.4$, on January 16. Temperatures of freezing point or below were recorded on 59 days. The mean temperature for the month of January 1941 was $4^{\circ}.5$ below the average, and for April, $2^{\circ}.9$ below the average. Each month from December, inclusive, was colder than normal. The temperature in the Stevenson screen during these five months did not on any occasion reach 59° . Even on the "Airy" stand the maximum thermometer never passed $60^{\circ}.5$, - a circumstance of which there is no previous example in the Greenwich records for the past hundred years. (The standard thermometers have been enclosed in a Stevenson screen since 1938 January 1).

The mean daily horizontal movement of the air was 261 miles, which is 24 miles below the average for 50 years 1867-1916. The greatest daily movement was 649 miles, recorded on November 17; the least daily movement was 57 miles, on February 18. The greatest motion in one hour, 36 miles, was recorded on December 6, as also was the greatest pressure reached, 17.5 lbs. to the square foot.

The duration of *bright* sunshine recorded was 1454.0 hours, or 32.5 per cent of the possible total. There were 74 entirely sunless days, 35 being in the two months December and January. No day in September was entirely sunless. There were 40 entirely cloudless nights in the period, that is, nights on which a complete unbroken trace was obtained by the night-sky camera. The number of nights on which no trace of δ Ursæ Minoris appeared on the plates was 82, while on a further 39 nights the record was not more than 10 per cent of the whole time of exposure.

The total rainfall during the period was 26.33 inches, that is 2.09 inches greater than the average for 75 years 1841-1915. There were 148 days on which rainfall amounting to 0.005 inch or more was recorded.

The wettest month was November with 6.864 inches; the driest month, August with 0.145 inch. It is necessary to go back 122 years in the Greenwich records to find an August with a lower rainfall than that of August 1940.

VIII. Printing and Distribution of Greenwich Publications:-

1. A restricted distribution of the Volume of *Greenwich Observations* and its separate parts for 1936 has been made.
2. MS. for the Volumes for 1937, 1938, 1939 and 1940 are being prepared, but no steps are being taken at present to proceed with the printing of these volumes.
3. A restricted distribution of *Observations made with the Cookson Floating Zenith Telescope, 1927-1936* and *Determination of the Variation of Latitude* has been made.

IX. 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.

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Assistants	- R. T. Cullen, A. Hunter, Ph.D., P. J. Melotte, H. M. Smith, B.Sc., W. M. Witchell, B.Sc.
Junior Assistants (Higher Grade)	- H. W. Acton, E. A. Chamberlain, F. Jeffries, E. G. Martin, H. W. Newton, G. W. Rickett.
Junior Assistants	- H. H. J. Barton, K. C. Blackwell, H. F. Finch, B.Sc., C. C. Harris, T. W. W. Hodgson, Miss C. M. Lark, P. S. Laurie, B. R. Leaton (on active service), P. L. Rickerby, J. L. Rudd, A. Shortland, L. S. T. Symms, R. H. Tucker, G. F. Wells.
Clerical Assistants	- Miss J. Auckland, Miss E. B. Gray, Miss F. E. A. Jeffries.
Head of Repair Shop	- H. Warden.
Secretary and Cashier	- H. G. Barker.
Clerical Officer	- N. J. Miller.
Established Typist	- Miss M. F. Cackett.
Temporary Clerks	- D. Oliver, N. S. C. Rhodes, Mrs. M. E. Higby, Mrs. R. Shortland.
Temporary Typist	- Miss B. H. Wescott.

(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.
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 (on active service) Miss M. R. Rodgers, Miss M. C. Scadeng, E. Smith.
Clerical Assistants	- Miss E. N. Histed, Miss V. H. Hitches, Miss G. E. Jackson, Miss J. Mounteney, Miss V. F. Peasgood, Miss J. E. Pullen, Miss M. B. Simm, Miss R. E. West.
Junior Assistant as Secretary	- Miss D. J. Ifield.
Shorthand-Typist	- Miss S. E. D. Harries.

Several piece-workers are also employed.

REPORT OF THE ASTRONOMER ROYAL

The present arrangement of the Observatory staff is as follows:-

Transit Circle, Right Ascensions	} - Mr. Acton.
Transit Circle, Declinations	
Transit Circle, Ledgering and Miscellaneous Reductions	} - Mr. Cullen, Mr. Blackwell, Mr. Hodgson.
Cookson Zenith Telescope	
Time Department and Chronometers	- Mr. Acton
	- Mr. Smith, Mr. Rickett, Mr. Symms, Mr. Finch, Mr. Harris, Mr. Shortland, Mr. Rudd, Miss Lark, Mr. Tucker, Miss Gray, Mrs. Shortland.
Thompson and Yapp Equatorials	- Mr. Martin, Miss Auckland.
Astrographic Department	- Mr. Melotte, Mr. Jeffries, Miss Jeffries.
Photoheliograph and Spectrohelioscope	- Mr. Newton, Mr. Barton, Mr. Laurie, Mrs. Higby.
Magnetic and Meteorological Department	- Mr. Witchell, Mr. Chamberlain, Mr. Wells Mr. Rickerby, Mr. Oliver, Mr. Rhodes.
Watch and Chronometer Repairs	- Mr. Warden.
Secretariat	- Mr. Barker, Mr. Miller, Miss Cackett, Miss Wescott.

Dr. R. d'E. Atkinson and Dr. H. R. Hulme, Chief Assistants, and Dr. A. Hunter, Assistant, have been loaned for special work in other Departments of the Admiralty.

Mr. R. T. Cullen, Junior Assistant, Higher Grade, has been appointed Acting Assistant.

Mr. E. G. Martin, Junior Assistant, Lower Grade, has been appointed to the Higher Grade in an acting capacity.

On the completion of the Astronomical Navigation Tables, Mr. W. E. Candler, Temporary Assistant, was transferred to the Ministry of Aircraft Production. He had been in charge of work on these tables since their inception and it is mainly due to his careful organization that the work has been completed in advance of schedule; during his period of service he proved himself to be admirably suited to the work of the Office, which requires specialized knowledge as well as intense application to detail. His theoretical knowledge and computing ability were of great service in many special investigations.

The position of Chief Adjuster, vacant owing to the death of Mr. R. Kunzler, as reported last year, was filled in August, 1940 by the appointment of Mr. H. Warden as Head of the Watch Repair Shop. The Shop staff was augmented on September 30 by the engagement of a junior watch repairer, who will be trained to the high standard required in this class of work.

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Mr. B. R. Leaton, Junior Assistant of the Royal Observatory Staff and Mr. G. A. Harding, Junior Assistant of the Nautical Almanac Staff, joined H.M. Forces on 1940 August 5 and 1941 March 26 respectively.

Eleven Clerical Assistants have been transferred to the Admiralty for duty elsewhere during the present emergency.

The staff of workmen employed at the Observatory consists of a Foreman of Observatory, two joiners, four watch repairers in the watch repairing department, a gate porter, three messengers, five labourers and two charwomen. There is also a caretaker-mechanic at Abinger, a messenger at the Nautical Almanac Office, and a caretaker and a messenger at the Chronometer Depot. A skilled mechanic has been lent for duty at the Admiralty Research Laboratory, Teddington.

Mr. H. G. Scott Barrett, whose services have been lent to the Observatory by the Radcliffe Trustees, has rendered valuable help in the reduction of the Eros photographs. With the concurrence of the Trustees, he is now engaged on other important work for which he is eminently suited.

Towards the end of September, the Office, together with the Time Department the Meridian Department and certain other branches of work, were moved from Greenwich to the neighbourhood of the emergency time service station. Solar and meteorological observations have continued to be made at Greenwich.

Mr. L. Mountain, Joiner, in charge of the industrial staff remaining at Greenwich, has been awarded the Medal of the Order of the British Empire (Civil Division) for courage and devotion to duty on an occasion when the Observatory was damaged by high explosive bombs.

The renovation and rebinding of about 190 valuable and rare astronomical books belonging to the Observatory Library was undertaken by the Binding Department of H.M. Stationery Office, at the British Museum. The skill and care with which this work was carried out is much appreciated. These books, together with the early records of the Observatory and Minutes of the Board of Longitude, have been sent away from Greenwich for safety.

The total solar eclipse of 1940 October 1 was successfully observed at Calvinia, Cape Province, South Africa by a joint expedition from the Royal Observatory, Cape of Good Hope, and Radcliffe Observatory, Pretoria, using equipment that had been sent from Greenwich, belonging to the Joint Permanent Eclipse Committee, the Royal Observatory, Greenwich and the Solar Physics Observatory, Cambridge. Results of considerable value are expected from these observations, which are the more important in as much as most of the proposed expeditions for observing the eclipse had to be cancelled on account of war conditions, and because conditions for observation in Brazil at the time of the eclipse were uniformly unfavourable. The instrumental equipment is being retained in South Africa until after the conclusion of the war.

H. SPENCER JONES,
Astronomer Royal.

Royal Observatory, Greenwich.

1941, May 8.