

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

Read at the Annual Visitation of the Royal Observatory, 1943 June 5.

THE BOARD OF VISITORS

The President of the Royal Society. Sir Henry Dale.

The President of the Royal
Astronomical Society.

Prof. E.A. Milne.

To serve
until
June 30th

Nominated as Fellows of the
Royal Society.

Sir Ralph Fowler.	1943
Sir Charles Darwin.	1944
Prof. T.R. Merton.	1945
Sir James Jeans.	1946
Sir George Simpson.	1947
Prof. P.M.S. Blackett.	1948

Nominated as Fellows of the
Royal Astronomical Society.

Prof. E.A. Milne.	1943
Dr. R. Stoneley.	1944
Prof. W.M. Smart.	1945
Prof. W.M.H. Greaves.	1946
J.H. Reynolds Esq.	1947
Prof. H. Dingle.	1948

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 Sir John Edgell.

Secretary.

C. Jowsey Esq.

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Read at the Annual Visitation of the Royal Observatory, 1943 June 5.

The Report here presented refers to the period from 1942 May 1 to 1943 April 30 and exhibits the state of the Observatory on the last named day.

I. BUILDINGS, GROUNDS, MOVABLE PROPERTY AND LIBRARY.

No further damage from enemy action was sustained during the year. Temporary repairs effected since 1940 have been kept in good order. The lower framework and the running track of the Yapp dome have been repainted. A new door has been fitted at the top of the internal staircase giving access to the roof of the Octagon Room. The radiators in Flamsteed House and the Octagon Room have been repaired, and one has been replaced. All power and lighting circuits have been overhauled and tested. The West and North Libraries have been thoroughly cleaned and each book has been inspected and, where necessary, re-labelled.

All instruments which are not in use at the present time have been examined at regular intervals; the protection against rust by special oil and grease has been renewed where necessary. A demagnetising coil with rheostat for demagnetising watches has been designed and constructed in the Observatory workshop; it has been installed at the Chronometer Depot, where it has proved very effective in use.

The following instruments are on loan to the Royal Observatory:-

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.

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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 small transit instrument, of the broken type, with stand, by Bamberg, from the Royal Observatory, Edinburgh.

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

A Shortt free-pendulum clock, No. 61, a radio receiving set, a chronograph and a Brunsviga calculating machine, from Mr. H.R. Fry.

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 Imperial College of Science and Technology:-

6-inch Equatorial, Simms No. 2.

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.

Harrisons Time Machines Nos. 1, 2, 3 and 4 and the copy of No. 4 by Larcum Kendall, nominally on loan to the National Maritime Museum, were removed to and stored in a place of safety on the outbreak of war, with the exception of No. 3, which Lieut.-Comdr. Rupert T. Gould, R.N. (Ret.) had dismantled and was engaged in cleaning and reassembling.

Commander Gould conducted, in November, a thorough examination of their condition, with the permission and co-operation of the authorities with whom they are stored. He reports that No. 1 is slightly affected by rust in certain parts and will require overhauling after the war, although no replacements will be necessary. Nos. 2 and 4 and the Kendall copy were in excellent condition.

The objectives of the 26-inch, 28-inch and astrographic refractors, the 36-inch mirror and auxiliary mirrors of the Yapp reflector, the objectives of the Reversible Transit Circle, and its two collimators, the micrometer eye-end of the Reversible Transit Circle, the photoheliograph object glass No. 5 and a case containing some smaller instruments belonging to the Royal Observatory are for the present stored elsewhere in suitable accommodation.

Three telescopes on loan to the American Civilian Committee for the Defense of Homes have been loaned by the Ministry of War Transport. One, a 4½-inch telescope, was mounted at the Royal Observatory on August 5 and is being used for occultation observations. The other two will be of use for work while the large telescopes remain dismantled.

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

A quarter plate camera with a Zeiss anastigmat lens and an enlarging camera have been presented to the Royal Observatory by Miss Knobel.

II. ASTRONOMICAL OBSERVATIONS.

Airy Transit Circle. The damage caused by enemy action having been made good, observations were resumed as from 1942 May 26.

A new eye-piece slide with an adaptor to take a reversing eye-piece has been made and fitted to the north collimating telescope.

A very restricted programme is in operation, limited in scope by war-time conditions. Observations are made primarily of the Sun and of stars in the clock and azimuth lists; the Moon and other planets are observed when circumstances permit.

During the period 1942 May 26 to 1943 April 30, 1212 transits and 1100 zenith distances were observed, including

116 observations of the Sun			
40	"	"	Venus
5	"	"	Jupiter
3	"	"	Saturn
3	"	"	Uranus
3	"	"	Vesta
2	"	"	the Moon

The observations for collimation with this instrument have always been affected by defective vision, when viewing one collimator on the other through the pierced cube of the instrument. To counter this disadvantage as much as possible, an effort has been made to improve the observations by an alteration in method. The two wires in the north collimator have been replaced by a single wire. Better definition of the wires in each collimator in the observation of alignment of the two collimators is thus obtained. With the improved seeing, a reversing prism can now be used, the accuracy of the observations is thereby increased and the systematic differences between the results obtained by various observers are reduced.

Observations from 1931 to 1940. Observations during this period will be published later as the First Greenwich Catalogue for 1950. The ledgering of the observations to the end of 1938 has been completed. The ledgering of the observations made between 1939 January and 1940 September is in abeyance, as corrections for variation of latitude over that period are not yet available.

Clock and Azimuth Stars. The observations in right ascension of these stars have been investigated for the entire period 1931 January to 1940 September. As in preceding Greenwich Catalogues, the R.A.'s are based on a 12-hour system of observation. A comparison of results from both 12^h and 6^h groups has been made. The agreement is so close that the differences may be considered negligible.

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From the beginning of 1941 the stars for which apparent places are available are those in the FK3 fundamental catalogue and supplement. The apparent places are prepared by international co-operation and are published by the Nautical Almanac Office. A number of stars in the Greenwich clock and azimuth star lists have been excluded from this selection, because they are components of double star systems. The opportunity has therefore been taken to revise the lists of clock and azimuth stars for transit circle observations at Greenwich, so as to include only stars for which apparent places are available. A number of stars in the old lists have been omitted and others have been inserted, so as to give a better distribution in declination. The revised list of clock stars number 236, 17 more than before. In the azimuth list only four of the nine close circumpolars are now available. Six other stars have been removed and eight have been added.

The adopted right ascensions of the stars in the revised lists have been determined. Those of the stars in the old lists are based on the mean of the results given by the two catalogues 1922-30 and 1931-40, using Newcomb's precessions and adopting the proper motions of the FK3 catalogue. Those of the newly inserted stars are based on the observations at Greenwich, over the period 1915-1940.

Comparisons have been made between the right ascensions thus derived and the FK3. These give for $\Delta \alpha \cos \delta$ in the sense Greenwich - FK3:-

Clock Stars	$-.0045$	$+.0014$	$\sin \alpha$	$-.0043$	$\cos \alpha$	$-.0004$	$\sin 2\alpha$	$-.0020$	$\cos 2\alpha$
Azimuth "	$+.0153$	$+.0038$	"	$-.0015$	"	$-.0018$	"	$+.0038$	"

The probable errors of the Fourier coefficients are $\pm .0010$ and $\pm .0007$ respectively. Reasonable accordance is shown in the variations depending on right ascension, but the constant terms are discordant, indicating a variation with declination of the Greenwich right ascensions relative to the FK3 system.

The right ascensions in the FK3 catalogue of stars near the equator compared with those in high north declinations differ by as much as $.020 \cos \delta$, when compared with the Greenwich adopted right ascensions of clock and azimuth stars. These results correspond to the mean epoch of observation approximately 1930.

Reversible Transit Circle. The data furnished by the observations made with this instrument from 1938 to 1940 are considerable and varied. They have not yet been fully investigated but it is anticipated that they will provide most useful information, particularly with respect to instrumental errors. This will be helpful in planning post-war programmes, in order that the best use may be made of this instrument for obtaining star positions with the precision and with the freedom from systematic error that is required in fundamental positional astronomy.

Occultations. Only two occultations have been observed during the year, though, since the 4 $\frac{1}{2}$ -inch telescope was installed, a watch has been kept for all occultations for which predictions are given in the Nautical Almanac.

Cookson Zenith Telescope. The observations made with this instrument according to the new programme from 1936 July, when the instrument was remounted on a site adjacent to the Reversible Transit Circle, until 1940 September, when the instrument was partially dismantled and observations were suspended, are under discussion. New and improved group corrections have been derived and final values for the latitude-variation for this period will shortly be available.

Thompson Equatorial. During the year 247 plates have been measured. The parallaxes of 2 stars have been determined. The remaining plates form series which are as yet incomplete owing either to the material being insufficient or too unbalanced between morning and evening to give a reliable determination of stellar parallax.

Two papers, one on "Obscured Regions in the Greenwich Astrographic Zone" and the other on "Obscuration around the North Pole" have been communicated to the Royal Astronomical Society.

Photoheliograph. Photographs of the sun were obtained on 271 days. The number of photographs selected for preservation is 515 including 20 with double images for determination of the zero of position angle. The zero has also been determined regularly by a visual method. From reports received from H.M. Astronomer at the Cape and from the Director of the Kodaikanal Observatory, only one day is unrepresented in the combined series (Greenwich, Cape, Kodaikanal) for 1942. Measurements of the positions and areas of sunspots and faculae from the combined series of plates are complete up to 1939 June 21. Shipments from the Cape to Greenwich for plates after this date have been suspended. During the year, 245 Greenwich plates have been measured, covering the period 1940 September 7 to 1941 October 19.

The copy for press for 1939 is being prepared as far as possible pending the receipt of the Cape photographs after the war.

Computations of positions and areas of sunspots have been made from the Greenwich plates covering the period 1940 March 15 to 1941 June 26. The computed times of central meridian passages of large spots of area 500 millionths of the sun's hemisphere or greater have been telephoned to the Superintendent, Radio Research Station of the National Physical Laboratory, the Controller (Engineering) British Broadcasting Corporation, and to the Engineer-in-Chief, Cable and Wireless Limited. The Director, Solar Physics Observatory, Cambridge has also been notified of the presence of large active spots. A similar notification has been sent to the Superintendent, Eskdalemuir Observatory. On a further request from the British Broadcasting Corporation, the central meridian passage of any sunspot group reaching 200 millionths has been notified to the Controller (Engineering).

Sunspot frequency declined sharply between April and May 1942 but remained fairly steady afterwards. The mean "sunspot number" for the twelve months ending 1943 April is 21 as compared with 50 for the preceding twelve months. During the year ending 1943 April 30, eight spot groups reached or exceeded an area of 500 millionths of the Sun's visible hemisphere; three of these exceeded 1000 millionths at their maximum developments, the largest reaching 1400 millionths. The times of central meridian passage of these three largest groups were November 2.6, March 10.7 and April 21.3.

Daily sunspot numbers based on Wolf's method of counting have been supplied to Professor Brunner at Zurich for incorporation in the I.A.U. Solar Bulletin. Mean monthly values have been sent early each month to certain research centres in this country.

A series of six photographs at short intervals was taken just after the beginning of the partial solar eclipse on September 10, to enable the time of first contact to be determined. The results have been communicated to the Royal Astronomical Society.

The tube and stand of the 4-inch photoheliograph were repainted in June.

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Spectrohelioscope. The spectrohelioscope was used on 185 days, but on 38 days observations were limited to a few minutes because of poor skies. The observations made in $H\alpha$ were chiefly directed to the location of bright chromospheric eruptions. The larger spot groups were specially watched for any associated chromospheric activity. 140 measures of radial velocity were made of bright and dark flocculi on the disk and on a few prominences at the limb. In addition, 128 measures were made on bright flocculi primarily to determine their effective line-widths, but the measures also give an additional 128 values for radial velocity. Seventeen sets of photometer measures were made on normal or enhanced bright flocculi.

Eighteen bright eruptions were observed, but only one (on July 9) was of major importance. On four occasions fade-outs were reported whilst in progress by Cable and Wireless, Limited. In three of these cases, the sky at Greenwich was cloudy at the time; the fourth was synchronous with the bright eruption on July 9 which had just been located with the spectrohelioscope.

A paper dealing with the association of intense chromospheric eruption, and magnetic storms following about 24 hours later is in course of preparation.

Quarterly returns of bright eruptions observed at Greenwich are sent to certain research centres in this country as well as to Professor Brunner. Mr. M.A. Ellison, observing at Sherborne, and Mr. A.M. Newbegin, observing at Worthing, notify Greenwich of any major eruption observed by them. In addition, Mr. Ellison has sent his disk drawings of sunspots during the winter months.

The duplicate mirrors of the coelostat were re-aluminised during March.

III. TIME SERVICE.

Throughout the year, the practice has been continued of operating the time service from two stations, each of which forms a self contained unit fully equipped to maintain the service in the event of serious dislocation at the other. Further experience with this dual system, which was introduced as a war-time measure, has clearly demonstrated the desirability of providing for two stations as a permanent measure. The potentialities of the arrangement have been greatly increased by the provision, during the past few months, of a direct link between the two stations, a facility which has been made possible by the ready co-operation of the Post Office Telegraph Branch. The lines which enable each time service to transmit hourly signals to the Post Office, are automatically switched over to give intercommunication except for a period of three minutes at each hour, and apparatus has been installed to permit clock signals to be sent each way. Teleprinters have also been connected for the exchange of information. The direct link has already become invaluable and has led to the accumulation of useful data, which promises to be of considerable assistance in elucidating some of the uncertainties of comparisons by means of a radio link. In normal conditions it is also possible for both stations to contribute data from their best clocks to a common pool on which the actual transmission from each station can be based.

During the period covered by this report the time signals radiated from Rugby have normally been controlled by station B. Apart from the few occasions when, owing to technical faults, transmissions have not been possible from this station, it has also been the practice during the last three months to transmit one 18.00 hour signal per week from station A in order to ensure that the system and lines are in order. As mentioned last year, it has been possible to exercise a regular control of the transmission from station B by the utilisation of a return signal to detect

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changes in the lag of the land line. The provision of a similar loop circuit to station A presented great practical difficulties, but owing once again to the co-operation which has been established with both the Radio and Telegraph branches of the Post Office a return line was connected in March. Although not on the same basis as the return line to station B, it nevertheless provides information by means of which changes in the lag of the sending line may be detected and compensated. The arrangement by which the actual transmission was made from that station at which the standard clocks were more reliable has given way to the principle of giving preference for the 10.00 hour transmission to the station with the more stable transmitting clock and the better conditions on the sending line to the radio transmitters, as comparisons with the best standard clocks may be made by means of the inter-station line from either end. It is necessary for some of the 18.00 hour signals to be transmitted from the station acting as reserve in order to maintain a check on the sending line lag in case of failure of the signal from the station which has been given preference.

As a result of experience gained in 1940 when the 10.00 and 18.00 hour signals were transmitted by a group of short wave stations and primarily in order to meet the needs of survey workers abroad, short wave signals were introduced from July 1942, and have been radiated simultaneously with the long wave emissions from GBR. The particular stations and frequencies employed at any time are dependent on conditions and requirements, but in most cases both time service stations are within the skip distance and reception for monitoring purposes is unreliable. Final corrections to these signals have therefore been given to the nearest hundredth of a second.

The "six dots" time service to the BBC has normally been operated from station A, and the service of hourly signals to the Post Office, which also controls the talking clock, has been taken from both stations.

169 Transit observations were made at Station A on 142 nights and 157 at station B on 156 nights during the year.

As before, all observations have been combined for the determination of clock errors. The approximate personalities, determined as described in the last report, have been applied throughout. During the year it was found that the adopted scale value of the striding level used at station A was in error, the effect having been to increase the scatter of the observations. A careful redetermination of the scale value was made in December, and observations were adjusted from July 1.

At station A a new observing hut has been erected to accommodate the Bamberg transit instrument loaned by the Astronomer Royal for Scotland. It is proposed to equip this instrument with an electrically-driven micrometer but pressure of urgent work has delayed the completion of this scheme.

The usual regular check on the rhythmic time signals transmitted from Rugby at 10.00 and 18.00 hours has been maintained at both stations. Before the installation of the land line connection, the comparisons of the clocks obtained by means of the reception times of the 10.00 hour signals served as the link between the two stations. Both stations have recorded, whenever possible, the American and German time signals on both long and short waves, and station A has also maintained a check on the French signals at 08.00 hours. The published final corrections have been based on the reception times at the two stations, when both are available. A modification in signal transmission procedure has been introduced to increase the

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value of the signals for the purposes of frequency checking. Every endeavour is now made to keep the rate of the signals as near zero as data permit, i.e. to give successive signals at intervals of 24 hours with the greatest possible accuracy. In the event of subsequent data indicating that the signals exceed a certain specified error in absolute time, the return will not be made gradually, but in a jump, the signals then continuing with a zero rate as nearly as possible.

Identical long wave receivers, of standard Admiralty pattern, have been installed at both stations, and modified for the reception of time signals. A continuous dash, introduced between the morse preamble and the commencement of the rhythmic signals, has been instituted to facilitate setting all receivers to a standard output in order to minimise variations in receiver lag. At first this was hand operated, but it has now been incorporated in new equipment installed for the automatic transmission of the morse preamble. For the reception of short wave signals, station A employs a National HRO receiver or a Hallicrafter SX28 with an RME 69 as reserve. Station B has a similar HRO with a Hallicrafter SX17 as reserve. To facilitate the reception of short wave signals at station A, the Post Office Radio Department has erected two rhombic aerials and four dipole cage aerials with the necessary open wire lines and concentric cables leading to the Time Department buildings.

The free pendulum clocks Shortt 40 and Shortt 49 were erected in the new building at station A in November and Shortt 66 was transferred from the old clock room in December. The quartz controlled frequency clock Q3, previously installed at Greenwich, was overhauled at the National Physical Laboratory and re-erected in the new building in January.

The errors of the clock Shortt 4 at the Royal Observatory Edinburgh, and the clocks Shortt 13, Quartz 2 and Quartz 6 at the National Physical Laboratory, are determined by means of the 10.00 hour Rugby time signals and the results are communicated daily. This continued co-operation by the Astronomer Royal for Scotland and the Director of the National Physical Laboratory is of great assistance and is much appreciated. Commencing in August, similar comparisons with the quartz clocks designed and installed by the Post Office Radio Department have also been made available by the courtesy of the Engineer-in-Chief, Post Office Radio Branch, whose great personal interest in the work of the Time Department has resulted in a degree of co-operation which has played no small part in the considerable advances in accuracy which have been attained during the past year. Data obtained from direct intercomparisons between the Post Office clocks have been supplemented by information on relative rates.

A fundamental change in the operation of the Time Service, which has affected not only the preparation of final corrections but also prediction methods and reception technique, has been brought about by the fuller use of clocks of the quartz-controlled frequency type. Comparisons between clocks of the free pendulum type, of which there are ten available, and quartz clocks, of which there are at least six available, show the undoubted superiority of the latter. Pendulum clocks appear to be subject to a more or less continuous accidental change of rate, and the integration of these changes produces "wandering". Quartz controlled clocks on the other hand are subject to changes of rate which are definitely recognisable and may in extreme cases be large, but the epochs, and to a large extent the amounts of these, may be detected by intercomparisons between the quartz clocks themselves. In addition they may be subject to a continuous accidental daily change of rate, which would by integration produce wandering; such erratics, if they exist, are certainly much smaller than in the case of pendulum clocks.

In the transmission of time signals it is necessary, both for prediction and for the preparation of final corrections, to determine the errors of a clock by drawing a smooth curve through points on a chart representing its errors as indicated by transit observations. Any attempt to deduce the daily errors of a pendulum clock in this manner is bound to lead to a smoothing of the real wanderings of the clock owing to the scatter in the transit observations due to inherent and inevitable errors of observation. The complete disappearance of clocks of the free pendulum type from the group used in the determination of final corrections has been gradual, Shortts 4, 13 and 16 having each for periods of some months put up a very fine performance, but it at last became apparent that the inclusion of even the best of these was of no value in smoothing out such irregularities as may have been present in the quartz clocks themselves, or may have been introduced by the methods of intercomparison, since the pendulum clock might itself have introduced greater errors.

At present the quartz controlled clocks are mostly situated at institutions other than the two time service stations but, by using the comparisons based on the 10.00 hour Rugby signals, transit observations of the errors of the observatory clocks may be transferred so as to give determinations of quartz clock errors. In view of the undoubted superior performance of these clocks, a fairly drastic smoothing process can then be applied to the individual determinations of clock error, and reliable values for quartz clock errors thus obtained in which the accidental errors of transit observations have been to a large extent eliminated by meaning. Since the Observatory clocks can be compared daily with the quartz primary standards, again through the medium of the Rugby signals, their daily errors can be deduced. The procedure therefore has been to base the time service fundamentally on quartz clocks available at other institutions and to use the Observatory clocks as intermediary substandards for extrapolating the time as given by the quartz standards over 24 hours. For this extrapolation process, free pendulum clocks are singularly ill-suited. It is thus a matter of pressing urgency to replace the existing free pendulum clocks by quartz clocks at the time service stations, so that quartz primary standards can be used to control the service direct. As regards the use of the service for the provision of a fundamental standard of frequency, the present mean error in a 24 hour interval as defined by two successive signals at 10.00 hours U.T. is about ± 4 milliseconds. The use of quartz clocks directly controlling the service should materially reduce this figure. As regards the use of the service for navigational and surveying purposes the increasing utilisation of quartz oscillators will produce a precision which will be a great advance on the past, because these clocks are capable of efficiently maintaining the accuracy of the service during prolonged periods of cloudy weather to an extent that was impossible when reliance had to be placed on free pendulum clocks alone. It must be borne in mind, however, that the inferiority of existing pendulum clocks rests in their tendency to wander and this tendency may be partially due to variable lag in the mechanical devices used to take the time off the free pendulum. The present standard of accuracy calls for the elimination of existing pendulum clocks from the operation of the time service at the earliest possible moment, but only experiment can show whether the best free pendulums would be worthy of retention provided a photo electric method of taking the time directly off the free pendulum were employed.

Further improvements should come from the replacement of the present standard type of transit instrument by one of improved design, possibly of the photographic zenith instrument type. There is evidence that the standard type of transit is subject to certain systematic and quasi-systematic errors and its accidental errors certainly are much greater than those of a photographic instrument. Some preliminary investigations and enquiries have been made.

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The results from both stations have been correlated at station A and final corrections to the times of the Rugby time signals, the short wave signals, and to the foreign time signals, have been published as usual. The amount of computing work involved in this and cognate matters has shown a steady increase throughout the year, and the more elaborate methods of extrapolation and prediction which have been introduced now provide full-time occupation for one man at each station; as the stations must be capable of independent operation, much duplication is involved. The direct line link between the stations has increased the quantity of data to be dealt with, and it has been impossible to take full advantage of the facilities offered by the line because of the heavy pressure of urgent routine work. Preparation of the MSS. for "Greenwich Observations" from 1937 onwards is still in arrears.

General development work at station A has made satisfactory progress, especially during the latter half of the period under review. Unfortunately this progress has only been possible by cutting routine maintenance work below the level of safety; dislocations, impossible under normal conditions, have sometimes occurred, necessitating transfer of all services to the other station for a short period. A number of clocks have been cleaned and installed in the new building and the majority of the wiring has been completed. The photo-electric cell equipment for Shortt 4C is being redesigned and a new case for Shortt 3 has been obtained so that this may be similarly equipped. A jack panel to give greater flexibility of operation has been designed, constructed and installed in the new building. New valve relay units employing mains pentodes in an improved circuit have been tested and found free from some of the disadvantages associated with the previous equipment which employed battery triodes. It has also been found possible to design valve relays of a similar type to replace the majority of the few remaining mechanical relays where a double current output is required. In all these units great attention has been paid to the question of lag and variations of lag. A rapid and accurate method has been devised for the determination of the lag on the line between the two stations and the results obtained have shown an unexpected standard of consistency. The increase in the number of electronic units has led to the design of a standard form of mains-operated unit for stabilised high tension supplies. Six units have been completed and further units are under construction.

A valve unit to lengthen the seconds signals from Q3 has been designed, and a number of other urgent investigations are in hand, but still in an early stage. Considerable attention is also being given to the problem of lag in radio reception. The increasing tendency for the practical work of the department to become electronic rather than electro-mechanical has rendered acute the problem of lack of test equipment. A general purposes beat frequency oscillator and an additional universal meter have been obtained, but the delay in the delivery of other instruments and the difficulties of obtaining components, of which there is a negligible stock in hand, have been serious handicaps. Progress has also been hampered by the cramped surroundings, and experimental work has been carried out in the very limited accommodation available for housing and operating equipment on routine time service, with consequent constant danger to the latter; a small hut for experimental work will shortly be available. The absence of office accommodation is a further serious disadvantage and this matter is receiving attention.

The equipment for providing an emergency A.C. supply in the event of mains failure, originally ordered for Greenwich, has been installed at station A but is not yet complete. An A.C. supply is available at station B, secondary to the main supply.

The urgent need for precision quartz clocks should be alleviated to a limited extent by the delivery towards the latter part of 1943 of three clocks of the Post

Office group 4 type. These clocks are now under construction by the Post Office Radio Department and it is proposed to equip two of them, one for each time service station, with phonic motors carrying gearing to enable them to be used as rhythmic signal transmitters. The present transmitting clocks, which are of the slave clock type, suffer from many defects such as irregularity of contacts and wandering of phase and their replacement is a matter of urgency. All three oscillators will be of the highest possible stability and will therefore be equally valuable as standard clocks. The assistance of the Post Office in placing their experience and facilities at the disposal of the Observatory in this matter is greatly appreciated. It is apparent however that the provision of two quartz clocks at one station and one at the other is only a step towards the inevitable replacement of the pendulum clocks by groups of quartz standards. A number of groups of oscillators, three to a group, will be required, but only for certain groups will divider and amplifier stages with phonic motors be necessary. For other primary standards, continuous records of relative rates at the fundamental frequencies will suffice, since the integration of frequency comparisons is more accurate than chronographic comparisons of seconds impulses.

One of the weakest links at the moment, apart from the clocks, is in the matter of chronographic comparison. This urgent problem has received considerable attention and arrangements have been made with the Ministry of Supply for the early installation of two decimal counter chronometers which are entirely valve operated, and capable of an accuracy which should meet the needs of the time service for many years to come. It is not anticipated, however, that these devices will be applicable to radio comparisons, and for this purpose the possibility of obtaining two chronographs of high precision has been under consideration. Work is also in progress on the design of cathode ray equipment with photographic recording. It is apparent that in this matter an increase in accuracy will entail a big increase in work, but that is considered to be inevitable.

IV. CHRONOMETERS.

Throughout the year the work of the Chronometer Depot was carried on without interruption in the premises to which it was transferred in March 1941. The staff has been increased by the engagement of two Temporary Clerks III, an additional messenger, and a watch repairer.

Arising from the decision to have all chronometers and watches engraved with a pattern number, a Taylor, Taylor and Hobson Engraving Machine Model "C" was obtained for use at H.M. Chronometer Depot. Pending the engagement of a suitable operator the machine is not yet in regular use.

It was found that many watches were received back from service highly magnetised and that the demagnetising coil in use did not always completely clear them. A demagnetising coil with rheostat control, capable of reducing the field strength to zero, was designed and constructed in the Observatory workshop. The coil has proved very effective and satisfactory in use in the watch repair shop.

An assembly potence has been loaned to the watch repair shop by Messrs. S. Smith and Sons Ltd., Cheltenham for use as a jewellery potence.

The experiments to determine the effect of magnetic fields on the rates of chronometers and watches, mentioned in last year's report, have been completed. The results have been fully discussed and have been circulated to the Departments interested in this matter.

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The watch repair shop has continued to prove of great value in maintaining an adequate supply of watches of all classes. The high standard of rating has been maintained with an extremely small percentage of rejections. New types of movements have been examined and reported on with a view to their adoption for Admiralty service.

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. Other demands on the computational facilities of the Office have made it necessary to restrict the astronomical work to the minimum required for the continuance of the Almanacs: consequently there has been little change in their content or in their presentation.

The Nautical Almanac. The Almanac for 1944 was passed for press on January 6; it has not yet been published, although copies are now available and some have already been distributed to institutions on the exchange list. As for the edition for 1943, it has been printed partly by photo-lithography and partly from stereo plates. This mixture, resulting from the destruction of the standing type and plates for the first part of the Almanac, will be necessary also in the Almanac for 1945; the edition for 1945 is well advanced and it should be available early in 1944.

No changes have been made in the Almanac; its reduced size can now be regarded as standardised for the duration of the war. The continued omissions, especially of the fuller *Explanation*, will undoubtedly become more inconvenient, but they cannot be regarded as serious in present circumstances. The separate Supplement, required to complete the Almanac, has made no progress during the year.

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 1947 is complete and has been circulated to the other ephemeris offices, in accordance with the arrangements for interchange to avoid duplication. Most of the copy for 1948 is already at the printers.

No computation of the Moon's position beyond 1950 has been done during the year, and this work now assumes an urgency difficult to impress on the uninitiated.

Occultations and Eclipses. The occultation programme still occupies a considerable proportion of the work of the Office, although it has probably been at its minimum during the twelve months just elapsed; in that period no reduction elements (the computation was suspended after 1942) have been required, the prediction elements for the year 1945 for stars of magnitudes 6.5 to 7.5 have been supplied, for the first time, by the office of the *American Ephemeris*, and no observations have yet been received for reduction. It has not yet been possible to publish the comprehensive account of the revised occultation programme which had been intended for the *Astronomical Journal*; according to this revision, the Nautical Almanac Office will undertake the reduction of occultations observed after the end of 1942.

For 1945, elements of occultations for 2304 stars, not fainter than magnitude 7.5, were received from the Office of the *American Ephemeris*. These stars were put through the occultation machine and preliminary times recorded for 78 stations for the 1231 stars that were retained. A further 91 stars were excluded after computation, and there will thus be 1140 stars published in the elements of occultations for 1945. About 4000 prediction computations have been done during the year, for

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stations in the British Empire, allied and neutral countries; although relatively few predictions are being completed, machine times for other stations will be available for transmission if communication is restored before they are required. As for 1944, the predictions for Wellington and Dunedin are being computed and published in New Zealand by the New Zealand Astronomical Society; machine times and other data have been sent to Dr. Adams.

It is now clear that the present occultation machine is incapable of yielding the improved machine times, which it was hoped might make it possible to replace the computed predictions by duplicated machine times.

No special eclipse calculations have been undertaken.

Abridged Nautical Almanac and Air Almanac. There has been no change in the Abridged Nautical Almanac; the 1944 Almanac was published on February 4, rather later than planned, but it is expected that the edition for 1945 will be issued in October.

From 1943 the Air Almanac is issued in three four-monthly parts instead of quarterly. The last quarter of 1942 and all the three parts of 1943 have been published during the year as follows:-

1942 Fourth Quarter	May 26
1943 January - April	August 20
1943 May - August	November 7
1943 September - December	February 15

A revision of the *Air Almanac* has been introduced by arrangement with the Air Ministry, commencing with the first part of 1944; although the changes are small in principle they will result in greater simplicity in use at the small expense of a slightly larger page. The main improvement consists of standardising the interval of tabulation for all bodies at 10 minutes (the planets were previously given at hourly intervals only); this allows a redistribution of data on the two pages for each day, one of which can now be regarded as a "night" page and the other as a "day" page. Other smaller changes have been incorporated, the main one being the collection, on the inside back cover, of all the corrections to observed altitude.

Work has recently been recommenced on the *Astronomical Navigation Tables* which are being extended up to latitude 79°N.

Apparent Places of Fundamental Stars. The third volume, for 1943, was published on September 11 and reprinted in December. The greater part of the volume for 1944 has already been printed and the printed sheets are now being read; it is hoped that publication will take place in June.

Copy for the apparent places of the 32 additional circumpolar stars, normally computed by France, was received for 1944 from France through the intermediary of the United States. It had been hoped that it would be possible to obtain, through this channel, the apparent places, for 1945, of the 426 10-day stars normally provided by France; communication was broken before these could be despatched and they are now being computed by the Nautical Almanac Office, using Hollerith equipment. All the remaining computations for 1945 are complete and copy will be prepared as soon as the "Connaissance des Temps" stars are ready. It is hoped to publish the 1945 edition in May, 1944, this being regarded as the scheduled date for this publication.

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Other Publications. A reprinted edition of Interpolation and Allied Tables was issued during the year; the opportunity was taken to add two new pages briefly summarising the formulæ and method for the numerical solution of first- and second-order differential equations.

Proof Reading. The amount of proof reading has remained substantially the same as in the previous year; there have been 7,400 distinct readings representing 2,700 pages. The ratio, rather less than three readings to one page, reflects the duplication required when junior untrained staff are used for this specialised work.

Repayment Work. There has been no significant increase in the volume of demands for lighting-up times, black-out times etc.; nearly 200 lists have been supplied, in addition to about 50 lists of Moon's phases and about 25 of times of moonrise and moonset. Other astronomical information is supplied on the same basis of a small charge to cover cost of preparation and secretarial work.

Other Work. The additional work both for other Departments of the Admiralty and for other Service Ministries has continued to increase; the staff and the calculating machines have been utilised to their fullest capacity throughout the year.

Machines. A six-register National Accounting Machine, with a sexagesimal keyboard, has been added to the equipment of the Office during the year. Two Marchant XL calculating machines were obtained in lieu of an obsolescent Monroe electric calculating machine and a small portable Burroughs adding machine. No Hollerith equipment has been installed, and punched card work is being done by the British Tabulating Machine Company on a service basis.

VI. MAGNETIC OBSERVATIONS.

Regular magnetic observations have been made at Abinger throughout the year.

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 weekday. 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.

The variations of declination and of horizontal and vertical intensity have been recorded photographically both on slow-run and quick-run recorders. Wide-range low sensitivity records of the variations of declination and of horizontal intensity have been regularly obtained.

The base-line values of the la Cour magnetographs continue to be remarkably steady.

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 1942 December 31, and with provisional constants to the present time.

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The tabulation of results for 1941 and 1942 awaits chiefly the receipt of the list of International "quiet" and "disturbed" days, the preparation being otherwise in an advanced state.

The mean values of the magnetic elements at Abinger for the year 1942 are given below. The values for the years 1939, 1940 and 1941 are given for comparison.

	Declination West	Horizontal Intensity	Vertical Intensity	Inclination
1939	10° 51'.9	0.18528	0.43074	66° 43'.5
1940	10° 43'.0	0.18533	0.43099	66° 43'.9
1941	10° 33'.8	0.18539	0.43128	66° 44'.3
1942	10° 24'.8	0.18554	0.43146	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 7 magnetic disturbances reaching the dimensions of a "storm", none of which, however, reached the dimensions of "great storm". (A range of 30' in declination and 150γ in horizontal intensity is considered the lower limit for a "storm"; 60' or 300γ for a "great storm").

Magnetic charts showing the isomagnetic lines in declination, horizontal intensity, inclination and vertical intensity for the year 1942 have been completed, and have been published by the Admiralty. A harmonic analysis of the data has been undertaken along the lines of a similar analysis that was made of the data from the charts for the year 1922. It is desired to compare the residuals between the observed and computed values at the two epochs and to obtain information about the regions where the chart values have the greatest uncertainty. The computed values will also be used as a guide in the construction of isomagnetic charts in the polar areas where the observational data are scanty.

VII. METEOROLOGICAL OBSERVATIONS.

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.

The tabulation of meteorological results for 1942 is complete and the preparation of copy for press is well advanced.

The following details of the weather refer to the period of twelve months ending 1943 April 30.

The mean temperature was 51°.5 which is 1°.8 higher than the average of 100 years 1841-1940. The highest temperature in the shade was 88°.2, registered on August 28. Temperatures exceeding 80° were recorded on 12 days. The lowest temperature was 25°.0 on February 8. Temperatures of freezing point or below were recorded on 29 days only. The mean temperature for the winter months was abnormally high. With the exception of November the mean for each month was at least 2°.5 above the average for 100 years, for December it was 4°.0 above. The mean temperature for April was 5°.9 above the average for 100 years, and the highest average for April since 1865.

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The mean daily horizontal movement of the air was 248 miles, which is 9 miles below the average for 50 years 1867-1916. The greatest daily movement occurred on January 31 and was 661 miles. The least daily movement was 45 miles on February 20. The greatest pressure reached was 32.0 lbs. to the square foot on January 31.

The duration of *bright* sunshine recorded was 1437.4 hours, or 32.1 per cent. of the possible total. There were 56 entirely sunless days, 41 being in the five months November to March. There were 45 cloudless nights in the period, that is, nights on which a complete unbroken trace was obtained by the night-sky camera. The number of nights on which no trace of δ Ursæ Minoris appeared on the plates was 74 (against 108 last year), while on a further 44 nights the record was not more than 10 per cent. of the whole time of exposure.

The total rainfall during the period was 24.11 inches, that is 0.22 inches less than the average of 100 years 1841-1940. There were 158 days on which rainfall amounting to 0.005 inch or more was recorded.

The wettest month was January with 4.388 inches, also the wettest January in Greenwich records; the driest month was March, with 0.284 inch.

VIII. PRINTING AND DISTRIBUTION OF GREENWICH PUBLICATIONS.

No general distribution of Greenwich publications has been made during the year under review.

The MSS. for the years 1937 to 1942 are complete or in preparation but no steps are being taken at present to proceed with the printing of these volumes.

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.
Assistants	- R.T. Cullen, A. Hunter, Ph.D., P.J. Melotte, H.M. Smith, B.Sc., A.M.I.E.E., F. Inst.P., W.M. Witchell, B.Sc.
Junior Assistants (Higher Grade)	- H.W. Action, E.A. Chamberlain, F. Jeffries, E.G. Martin, H.W. Newton, G.W. Rickett, L.S.T. Symms.
Junior Assistants	- Miss J. Auckland, H.H.J. Barton, K.C. Blackwell, H.F. Finch, B.Sc., C.C. Harris, T.W.W. Hodgson (on active service), P.S. Laurie, B.R. Leaton (on active service), P.L. Rickerby, J.L. Rudd, A. Shortland, Miss M.B. Simm, R.H. Tucker (on active service), G.F. Wells.
Head of Repair Shop	- H. Warden.

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Secretary and Cashier - H.G. Barker.
 Clerical Officer - N.J. Miller (on active service).
 Clerical Assistant - Miss F.E.A. Jeffries.
 Established Typist - Miss C.M. Carr.
 Temporary Observing Assistants - V.Barocas, Ph.D., A.Inst.P., G.B. Wohlgemuth.
 Temporary Clerks - Miss O. Beardsley, Miss D.A. Bush,
 Miss C.E. Chapman, Miss B.G. Collett, D. Oliver,
 N.S.C. Rhodes, Miss C. Ryall, Miss M. Wilden.
 Temporary Typist - Mrs. B.H. Upfold.

(b) *Nautical Almanac Office Staff*

Chief Assistant as Superintendent - D.H. Sadler, M.A.
 Assistant - Miss F.M. McBain, M.A.
 Temporary Assistants Special - R.H. Corkan, M.Sc., P.H. Haines, M.A.
 Junior Assistants (Higher Grade) - A.E. Carter, A.J. Daniels, S.G. Daniels
 H.W.P. Richards, B.Sc., W.A. Scott, B.Sc.
 Junior Assistants - W.G. Grimwood, Miss V.H. Hitches,
 Miss G.E. Jackson, Miss J. Mounteney,
 Miss J.E. Pullen, Miss M.R. Rodgers,
 Miss M.C. Scadeng, E. Smith.
 Temporary Clerk, Grade II - Miss P.E. Franklin.
 Temporary Clerks, Grade III - G.E. Colman, Miss O.V. Kevelos,
 Miss M.J. Matthews, Miss K.M. Restorick.
 Part-time Clerk, Grade II - Mrs. J.M. Fox.
 Junior Assistant as Secretary - Miss D.J. Ifield.
 Clerk-Shorthand-Typist - Mrs. D.S. Oldland.

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. N.J. Miller, Clerical Officer, Mr. B.R. Leaton, Mr. T.W.W. Hodgson and Mr. R.H. Tucker, Junior Assistants of the Royal Observatory Staff and Mr. G.A. Harding, Junior Assistant of the Nautical Almanac Office Staff are serving in H.M. Forces.

Dr. D.S. Perfect, Scientific Officer, was temporarily loaned for duty in the Time Department from the Department of Scientific and Industrial Research, on October 1.

Mr. A.E. Carter was promoted to Junior Assistant, Higher Grade, on 1943 February 23.

Mr. P.H. Haines was appointed Temporary Assistant (Special) on 1942 December 28.

Mr. G.B. Wohlgemuth was appointed Temporary Observing Assistant on March 15.

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Miss J. Auckland, Miss G.E. Jackson, Miss J. Mounteney and Miss M.B. Simm, Clerical Assistants, have been promoted to Junior Assistants, Lower Grade.

Mr. R.H. Tucker, Junior Assistant, joined the R.A.F. on August 27.

Eight Temporary Clerks have been engaged during the year on account of increased work or to replace staff on active service or transferred on promotion.

The staff of workmen employed at the Observatory consists of a Foreman of Observatory, an Assistant Foreman, one joiner, six watch repairers and adjusters in the watch repairing department, a gate porter, three messengers, six labourers and two charwomen. There is also a caretaker-mechanic at Abinger, and a caretaker and two messengers at the Chronometer Depot. A skilled mechanic has been lent for duty at the Admiralty Research Laboratory, Teddington. Two members of the industrial staff, Mr. S.E. Bass and Mr. A.J. Johnson, are serving with H.M. Forces.

Visitors. The Civil Lord of the Admiralty (Captain R.H. Pilkington, M.C., M.P.) visited the Royal Observatory on August 21. He was accompanied by the Superintending Civil Engineer (Thames).

On May 25, Captain Dianders, an engineer officer of the Peruvian Army, visited the Observatory with a War Office official.

At the request of the Ministry of Information, the wife of the Soviet Ambassador to the Allied nations, Madame Bogolomova, accompanied by two officers of the U.S.S.R. Army, visited the Observatory on December 4.

Lieut. Geddes R.N.Z.N., from the Carter Observatory, N.Z., visited the Observatory on September 9.

Throughout the year parties of 12 Naval Officers from the Royal Naval College, Greenwich have been received weekly for a short visit. Other special parties of technical officers from the Royal Naval College have also been arranged by request, including those from the Naval Meteorological Section. Occasional parties of 12 W.R.N.S. cadet officers have also visited the Observatory at the request of the Superintendent W.R.N.S. O.T.C. Royal Naval College.

In all about 840 visitors, mostly from the Royal Naval College, have been received, either during or shortly after office hours.

At the request of the Director of Navigational Training (Air Ministry) and by agreement with the Hydrographer, twelve officers and two instructors of the new specialist navigation course visited the Nautical Almanac Office from March 23 to March 26. In addition to demonstrations of the preparation of the Almanacs and the *Astronomical Navigation Tables*, lectures were given and discussions held on various aspects of astronomical navigation. Several small changes will be made in the *Air Almanac* as a result of this visit, which proved extremely valuable to the Office in obtaining and appreciating the practical navigator's point of view.

H. SPENCER JONES
Astronomer Royal

Royal Observatory, Greenwich.
1943 May 24.