REPORT

OF THE

ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH.

Read at the Annual Visitation of the Royal Observatory, 1945 June 2.

THE BOARD OF VISITORS

The President of the Royal Society	Sir Henry Dale	
The President of the Royal Astronomical Society.	Prof. H. H. Plaskett	
		To serve until June 30th
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	Dr. G. M. B. Dobson	1949
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Read at the Annual Visitation of the Royal Observatory, 1945 June 2.

The Report here presented refers to the period from 1944 May 1 to 1945 April 30 and exhibits the state of the Observatory on the last named day.

I. BUILDINGS, GROUNDS, MOVABLE PROPERTY AND LIBRARY.

On July 15, a flying bomb exploded in Greenwich Park not far from the building of the 28-inch Refractor. Widespread damage, fortunately mainly of a superficial nature, was thereby caused to domes, doors, windows and frames, ceilings and fences. Much of the existing first-aid repair work in several parts of the Observatory was damaged. The dome covering of the 28-inch refractor was stripped to a considerable extent. The Thompson Dome suffered less severely in this way. None of the instruments was damaged. The Chief Civil Engineer of the Admiralty (Thames) and the Civil Engineer, Royal Victoria Yard, Deptford, visited the Observatory on July 17 in connection with this incident.

Minor damage from blast occurred on three or four other occasions.

Early in March, under the direction of the Civil Engineer, Royal Victoria Yard, Deptford, tubular steel scaffolding was erected inside the Octagon Room to support the panelling which had been strained and displaced by accumulative effects of blast. The scaffolding was arranged so as to preserve as far as possible the cornice and ceiling of the Octagon Room, should parts become dislodged.

The erection at the Chronometer Depot, Bradford-on-Avon of a prefabricated building to house the watch repair shop was, after some delay, completed at the end of December and the transfer of the work from the main building was completed by mid-January. The building has 54 feet of benches with good north lighting, bench space for lathes, cleaning machines and watch rate-recorders whilst benches along the south side of the building provide accommodation for rating and jobs additional to the normal repair work.

The old telephone cable from the Porter's Lodge to the Main Building was replaced by a new one in August.

On April 13 a bench mark was fixed on the leaded roof of the Octagon Room as a reference point in triangulation work being carried out by the Ordnance Survey.

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 spectroheliocope, 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.
A coil magnetometer designed by the late Dr. D. W. Dye, F.R.S., for measurement of vertical intensity, from the National Physical Laboratory.
Three potentiometers, with standard cells and resistances for measuring current supplied to the coil magnetometers, from the National Physical Laboratory.
A 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 and a chronograph 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.

Harrison's 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. (Retd.) has dismantled and is engaged, as opportunity permits, in the process of cleaning and re-assembling. Recent examination having revealed traces of rust in the movement of No.4 and the Larcum Kendall, they have both been sent to the Chronometer Depot, Bradford-on-Avon, for overhaul and cleaning in the watch repair shop.

A portion of the optical and other equipment which was removed early in the war from the Observatory to a place of greater safety has been brought back; the remainder is for the present stored elsewhere.

The annual examination of the Observatory Library has been made. 21 books are missing and cannot be traced at present. Of these 17 were reported missing last year.

II. ASTRONOMICAL OBSERVATIONS.

Airy Transit Circle. The restricted programme of observations has been maintained under difficult conditions. There was more than the average amount of cloud during the year and the observations were hampered by flying-bomb and rocket attacks. In all, 800 transits and 604 zenith distances of stars in the clock and azimuth lists were obtained. The observations also include

98	observations	of the	Sun
28	"	"	Venus
8	"	"	Saturn
2	"	"	Uranus

Further investigations of the diurnal changes in collimation, under the circumstances prevailing during the year and with the limited staff available, have not been possible.

A persistent feature over a long period of years in the observations for collimation has been a systematic difference in the setting of the wire system of the north collimator on that of the south collimator, according as the south collimator is viewed directly (with the instrument raised from its bearings) or through the pierced cube of the instrument. For the same observer the differences remained sensibly constant, but there were systematic differences between different observers though all observers obtained a smaller reading with the instrument up than with the instrument down. In 1943 the pair of wires in the north collimator was replaced by a single wire, to make the observation through the pierced cube less difficult; all observers then obtained a larger reading with the instrument up than with the instrument down, though the systematic differences between the observers remained substantially the same as before. After the apparatus, to enable the observation to be made with artificial instead of daylight illumination had been installed, as mentioned in last year's Report, the systematic differences between the observers disappeared and the readings with the instrument up and the instrument down were in close accordance. At the beginning of 1945, new mirrors were fitted to the apparatus; all observers now agree in obtaining somewhat smaller readings with the instrument up than with the instrument down.

First Greenwich Catalogue of Stars for 1950 (1931-40). Final places for equinox 1950 have now been derived for all stars in the zone +0° to +24° declination, and for those in the clock and azimuth lists.

Those yet to be derived are other bright fundamental stars, those for latitude and stars used with the Cookson Zenith Telescope for variation of latitude.

Other work is in progress to complete the zone catalogue. Precessions and secular variations have been computed, and proper motions for the stars not contained in the Albany General Catalogue are in hand.

As the proper motions are to be based on the system of the Albany General Catalogue a comparison of Greenwich and G.C. places was made, using the G.C. proper motion from the date of observation to the equinox 1950. The results were as follows:-

Boss G.C. - Greenwich
(+0° to +24°)

RA	RA $\Delta\alpha_\alpha$	Dec. $\Delta\delta_\alpha$	Dec.	RA $\Delta\alpha_\delta$	Dec. $\Delta\delta_\delta$
h	s	"		s	"
0	+.006	+.02	+0° to +1°	+.001	+.11
1	+ 7	.00	+1 2	+ 2	+.13
2	+ 11	.00	+2 3	+ 4	+.13
3	+ 17	+.03	+3 4	+ 6	+.09
4	+ 24	+.06	+4 5	+ 7	+.04
5	+ 29	+.09	+5 6	+ 7	+.01
6	+ 30	+.11	+6 7	+ 7	+.03
7	+ 27	+.11	+7 8	+ 6	+.04
8	+ 22	+.10	+8 9	+ 5	+.05
9	+ 20	+.08	+9 10	+ 4	+.04
10	+ 18	+.04	+10 11	+ 3	+.04
11	+ 15	-.01	+11 12	+ 3	+.03
12	+ 13	-.07	+12 13	+ 2	+.03
13	+ 16	-.14	+13 14	+ 1	+.04
14	+ 19	-.19	+14 15	0	+.05
15	+ 19	-.21	+15 16	- 2	+.08
16	+ 15	-.20	+16 17	- 4	+.10
17	+ 10	-.15	+17 18	- 6	+.12
18	+ 4	-.08	+18 19	- 7	+.13
19	+ 2	-.01	+19 20	- 8	+.16
20	+ 4	+.05	+20 21	- 7	+.18
21	+ 7	+.06	+21 22	- 7	+.18
22	+ 10	+.07	+22 23	- 8	+.17
23	+ 8	+.05	+23 24	- 009	+.19
24	+.006	+.02			

The above differences are read from smoothed curves where $\Delta\alpha_\alpha$ and $\Delta\delta_\alpha$ correspond to the beginning of each hour of RA, and $\Delta\alpha_\delta$ and $\Delta\delta_\delta$ to middle of each degree of declination respectively.

This comparison is of considerable weight, comprising in all nearly 4000 stars, the average number for each hour of RA and degree of declination being 165.

But the stars in this zone whose proper motions are required fall within the limits of magnitude 7.00 to 7.99; so a separate comparison, confined to these limits, was made.

This, with over 1250 stars common to both catalogues, was divided into two parts:-

(1) stars $7^{m}.00$ to $7^{m}.49$ inclusive

(2) " 7.50 " 7.99 "

based on 800 and 450 stars respectively.

In right ascension the two parts were reasonably accordant, but in declination a systematic difference of $0''.10$ was apparent.

As stars of $7^m.00$ to $7^m.49$ were in fair agreement with those brighter than 7th magnitude, a correction of $+0''.10$ to the Boss G.C. declinations was adopted for stars $7^m.50$ to $7^m.99$ to make the series homogeneous.

Results from these comparisons have been adopted for purposes of proper motion to stars of magnitude $7^m.00$ to $7^m.99$.

The catalogue positions of the stars in the belt of declination $+0°$ to $+21°$ have been communicated in advance of publication to Professor Brouwer, Director of the Yale University Observatory, for use as reference stars in the reduction of photographs obtained at Yale with the wide-angle lens camera. The reductions for the zones $+9°$ to $+20°$ are in progress at Yale and the discussion for the first twelve hours of R.A. indicates for the probable error of a Greenwich catalogue position at the epoch of the Yale plates (1940.0) a value between $''.145$ and $''.150$. The probable error of a catalogue position at the mean epoch of observation, derived at Greenwich from the accordance of the individual observations, was $''.14$, and is thus satisfactorily confirmed by the Yale results. It may be mentioned that the probable error of a position in the Yale catalogue for these zones will be $''.115$.

Reversible Transit Circle. Two papers have been published in the Monthly Notices of the Royal Astronomical Society. The first gave a summary of the preliminary results of the tests and observations made with instrument until they were suspended towards the end of 1940. The second gave an account of the determination of the division errors of the fixed circle, together with an analysis and discussion of the results.

Preparations are in hand to bring the instrument into commission at an early date, in order that observations may be resumed.

Photographic Zenith Tube. It was reported last year that details of design of a photographic zenith tube, to be constructed by Sir Howard Grubb, Parsons and Co., were under consideration. The instrument will be used for the double purpose of the determination of time and of the variation of latitude. During the year the design of the essential parts of the instrument has been under consideration; the main details have been settled and construction is now proceeding. It was felt that the design of the Washington instrument could be considerably improved and many radical changes have been made. The aim has been to ensure accurate geometrical location of the essential parts and to simplify the design as far as possible. Kinematical principles have been followed throughout.

Some of the changes may be mentioned. (1) The conical bearings in which the rotary portion was located has been replaced by a ball-race, in which the functioning surfaces on the rotary and its support are horizontal plane annuli. The friction and consequent strains are thus greatly reduced and, because of the large number of balls employed, weight relief becomes unnecessary. (2) The exact horizontal location of the rotary is irrelevant in principle, but in the Washington instrument it is required for the subsidiary purpose of enabling the orientation to be measured by means of two diametrically opposite microscopes. In the new instrument the orientation will be determined by autocollimation from a plane parallel vertical plate of glass attached to the rotary. It thus becomes possible to avoid constraining the rotary in the horizontal plane during rotation and to allow a slight play in the motion, though this is kept small enough to prevent undesirable bumping. (3) This horizontal play makes it possible to constrain the rotary to adopt a specific orientation by means of two diametrically opposite stops. (4) In the Washington instrument the rotation is performed mechanically by a special arrangement of gears. This arrangement is so designed that the angular velocity is initially small, builds up to a maximum, and dies away as the rotation approaches the required 180°. One undesirable feature is that the force is applied at only one point of the rotary. In the present design, the rotary is actuated by a pure torque applied by means of wires. The use of wires has the further advantage of simplicity over the complex gear system. The principle of a gradual build-up and dying away of the angular velocity is retained and is achieved by making use of the principle of dead-centre. (5) The plate-carriage has been radically re-designed and the conventional form of guiding ways has been discarded. The plate holder is supported from an annulus of greater diameter than the object glass. Symmetrical images, free from troublesome diffraction effects, will thereby be obtained. The annulus is carried on three balls, running between hardened flats and is located horizontally by two further balls at the extreme ends of its diameter. It is thus possible to ensure the desired accuracy of motion with relative freedom from friction and with great simplicity of manufacture. (6) The carriage is to be traversed, not directly by a screw, but by an intermediary wedge or sine-bar. By varying the angle of the sine-bar, the speed of travel can be varied to suit stars of different zenith distances. The functioning surfaces of this linkage can be made with extreme accuracy and by the use of this method it is hoped to reduce the effects of any screw-errors by a large factor. (7) The method previously employed to set the height of the mercury surface to a specific value corresponding to the best focus was to use a pointer on the end of a rod and adjust the mercury surface in height till it touched the pointer. One disadvantage of this system is that the rod has to be swung out of position when using the instrument. It is intended to replace this method by a purely optical method, which has been tried and shown to give more than adequate precision and requires no parts to be moved out of the way. Provision is made on the setting scale for varying the height to correspond with varying temperature so that the scale value of the instrument can be kept very nearly constant. (8) The shutter is made to cover the entire object glass instead of the photographic plate only. (9) Consideration has been given to the question of improving the method of emission of electrical signals from the moving carriage. Hitherto mechanically operated electrical contacts have been used. It is hoped that, by a suitable photoelectric method, the signals can be sent directly from the carriage without any intermediate mechanical linkage and the attendant uncertainties of the nature of back lash. Experiments on these lines are at present in progress in the Observatory.

Horizontal Transit Instrument. It has been realised for some time that, with the introduction of quartz controlled clocks as time standards at the Observatory, a limiting factor to the precision of the time-service provided by the Observatory would be imposed by the errors to which the determinations of time, with the conventional type of small transit instrument, are liable. The photographic zenith tube will reduce considerably the errors of the time determinations. The stars observed with this instrument are restricted to a narrow belt around the zenith. These stars are for the most part faint and their positions will require to be determined on the system of the FK3 fundamental catalogue by special meridian observations; these positions will be gradually smoothed out and their accuracy improved by the observations with the photographic zenith tube. The selection of the star programme will depend upon the precise latitude in which the instrument is located. With the removal of the Observatory to a new site under consideration, the selection of the star programme must be deferred until the new site is selected. Some while must therefore necessarily elapse before full advantage can be obtained of the high degree of accuracy in time determinations of which the photographic zenith tube is capable.

As mentioned in the previous report, consideration was being given to the possibility of improving the accuracy of time determinations with the small transit instrument. Attention was directed at the outset to reducing the uncertainty of the most troublesome and probably the largest source of error, namely the level of the instrument. A method was devised and some preliminary experiments were carried out to measure the level by purely optical means, instead of with the striding level. One important advantage of this method is that the level is determined for each star observed, with the telescope in the position in which the observation is made; the effect of pivot errors are thereby completely allowed for. This advantage is gained, however, at the expense of an appreciable increase in labour.

Arising from a more general consideration of the problem, a new type of transit instrument has been designed, the important feature of which is that the telescope system remains fixed (though adjustable), with its axis horizontal and in an east-west direction. The light from a star of any declination, near the position of meridian transit, is directed along the optic axis by a subsidiary optical system, which can be rotated about an east-west axis and can be set to the appropriate declination. The effect on time determination of its positional errors (whether due to maladjustment of the axis of rotation or to pivotal errors) is reduced to the second order. Level and azimuth errors of the telescopic system have the same effect on the observed time of transit as they do with the ordinary transit instrument; but since the telescopic system is not deliberately subjected to gross mechanical disturbances and suffers from no pivotal errors, these level and azimuth errors should be far more stable than in the reversible instrument. Small pier movements and temperature effects are the most likely source of residual disturbance. The collimation error is dealt with by duplication of the telescopic system and reversal of the subsidiary system, so that the essential advantage of the reversible instrument is not sacrificed. Observation is made at the mid-point of the duplex telescopic system from the two sides successively. The fixity of the telescopic system removes errors due to flexure, and thus permits the advantageous use of a focal length considerably greater than can profitably be used in the ordinary reversible instrument. The level is determined with reference to two mercury surfaces, one at each end of the instrument, by means of an autocollimation method.

In addition to the subsidiary optical system referred to above a variable-deviation system is used, by means of which the light in the telescopic portion of the instrument is kept always axial as the direction of the incident starlight rotates. In this way the tolerances of certain essential adjustments are greatly increased. Further, this variable-deviation system acts also as a micrometer and as the means by which signals are sent to the chronograph. An additional advantage of this axial method is that the fiducial line that bisects the star image is not required to move in order to follow the star's image or to be linked to the signalling system as at present. Thus no mechanical errors are introduced at this point, and an optical method is contemplated for defining the position of the variable-deviation system in such a way that in its performance as a micrometer or signal emitter the system will be effectively free from the effects of mechanical errors.

After an investigation of the theoretical aspects of the system had been made, it was decided that development on these lines was more promising than the original plan of trying to allow for inherent defects of the present reversible instrument. In order to try the system out in practice the construction of an experimental instrument is at present in progress.

Thompson Equatorial. 134 plates have been measured for the determination of parallax. The measurement of plates has now been concluded until the instrument can be brought back into use and further photographs obtained.

Photoheliograph. Photographs of the sun were obtained on 250 days. The number of photographs selected for preservation is 481 including 28 with double images for determination of the zero of position. The zero has also been determined regularly by a visual method. After a flying-bomb had fallen near the Observatory in July, it was found that the zero of position angle had changed by about $0^\circ.3$. From reports received from H.M. Astronomer at the Cape and from the Director of the Kodaikanal Observatory, one day is unrepresented in the combined series (Greenwich, Cape and Kodaikanal) for 1944. During the year, 377 Greenwich plates have been measured, covering the period 1943 February 20 to 1945 January 8.

The copy for press of the Daily Results has been prepared to the end of 1943 from the Greenwich plates forming the basis of the series. On the outbreak of hostilities, H.M. Astronomer at the Cape was instructed to retain the Cape Plates, because of the risk of loss in transit. The Cape plates required to fill the gaps in the Greenwich series for the years 1939 and 1940 have been packed ready for shipment when conditions permitted. H.M. Astronomer has now been requested to forward these plates as soon as possible.

Computations of positions and areas of sunspots have been completed from the Greenwich plates covering the period 1942 October 22 to 1944 December 28.

Sunspots of area exceeding 200 millionths of the Sun's hemisphere are reported with their times of central meridian passage to the Signals Division, Admiralty. Sunspots of area exceeding 500 millionths and their times of central meridian passage are reported to Radio Security; to the Superintendent, Radio Research Station, Slough; to the Controller (Engineering), British Broadcasting Corporation; and to the Engineer-in-Chief, Cable and Wireless, Ltd. For a limited trial period, the times of central meridian passage of all spots are being reported to the B.B.C. Reports of any major solar flares are also sent to these various centres.

Mean provisional daily sunspot numbers for each month, derived from the Greenwich record, are sent to:- the Radio Research Station, Slough; Radio Security; Signals Division, Admiralty; the Captain Superintendent, Admiralty Signal Establishment Extension (Witley), and the Australian Scientific Research Liaison Office, London.

Daily sunspot numbers, based on Wolf's method of counting, have been sent to Professor Brunner at Zurich, for incorporation in the I.A.U. Solar Bulletins.

Sunspot frequency indicates that the sun passed through the minimum shortly before the middle of 1944. Sunspots in high latitudes (20° - 35°) are becoming increasingly frequent. The mean sunspot number for the twelve months covered by this Report is 16, as compared with 10 in the preceding twelve months. The largest spot group, just exceeding 1000 millionths, crossed the sun's disk between December 8 and 20 in south latitude 22°. A "great" magnetic storm was recorded at Abinger on December 16. Another group of similar size passed the central meridian on May 1, but was not followed by any appreciable magnetic disturbance.

An analysis is being made of "Sudden commencements" in the Greenwich magnetic records for six 11-year solar cycles, from 1879 to 1944. Although magnetic storms frequently start with this characteristic movement of the recording magnets, many storms do not. Moreover, identical or similar movements occur which are followed by scarcely any disturbance at all. The complete "sudden commencement", with a main jerk, usually positive, in H and lasting on the average about 3 minutes, includes a small rapid preliminary jerk in the opposite direction. With rather different characteristics, the "crochet" movement contemporary with a solar flare has its main movement usually negative in H at Greenwich; relatively few "crochets" can be identified with certainty on the Greenwich traces.

The data of "sudden commencements", including the ranges in three elements, are being assembled in a card index that will contain about 700 records. Comparison will be made *inter alia* with the Greenwich sunspot data.

*Spectroheliosc*ope. This instrument was used on 160 days, but on 21 days observations were limited to a few minutes owing to poor observing conditions. From January 10 to February 4, the spectrohelioscope was out of use while the two collimating mirrors were being aluminized together with the duplicate coelostat mirrors.

Eight solar flares were observed in $H\alpha$ during the year. One of these on March 20 appeared as a small bright blob above the sun's limb, but just touching it. Although this may have been part of an eruptive prominence rather than the flare itself, it was the only patch of enhanced emission that could be found at the time when a fade-out, lasting 55 minutes, was reported as being in progress.

During the twelve months 378 measures were made of line-of-sight velocities of bright and dark flocculi. The 123 measures on bright flocculi also provide equivalent line-widths of $H\alpha$. Photometric measures were made on 21 patches of bright flocculi. Line-of-sight motions were measured in 41 prominences.

Professor Brunner has been sent quarterly lists of solar flares together with overall times of scanning the sun's disk for flares and other phenomena.

Ionospheric data are received monthly from the Superintendent, Radio Research Station, Slough. Cable and Wireless Limited continue sending quarterly lists of fade-outs. The British Broadcasting Corporation communicates records of ionospheric storms and fade-outs.

III. TIME SERVICE.

Throughout the year the time service has again been maintained from the two stations at the Abinger Magnetic Observatory and at the Royal Observatory, Edinburgh, which were designated A and B respectively in previous reports. Each station has been available for sending out the Rugby signals, the B.B.C. six-pips time signals, and the hourly signals to the Post Office, for the control of the speaking clocks and other services.

The Rugby time signal at 10^h G.M.T., which is used for the checking of precision frequency standards and for which the highest possible accuracy is therefore required, has normally been sent from Edinburgh, as the line conditions from Edinburgh to the Rugby Radio transmitting station are more stable than those from Abinger to Rugby. The Rugby time signal at 18^h G.M.T. was also normally sent from Edinburgh until the 11th February; since that date it has been sent from Abinger. The B.B.C. six-pips time signal has normally been sent from Abinger.

When the time service station was installed at Edinburgh, it was decided to transfer to Edinburgh certain general work of the Time Department. It was found most convenient to transfer computing work, such as predictions and the investigation and examination of results. This division of work was facilitated by the installation of a direct teleprinter line between the two stations. The time service station at Abinger has remained responsible for the main bulk of the Time Department work, including development work, the routine reception of radio time signals and the general computing and preparation of final corrections to the times of emission of signals.

Stellar observations for the determination of clock errors have been obtained at both stations during the year. At Abinger, observations were made with the small reversible transit instrument on 110 nights and at Edinburgh they were made with the reversible transit circle on 125. Observations were made at Abinger on a number of additional nights for the training of new observers, but have not been used because the personal equations of the observers have not been sufficiently well determined. The personal equations of the regular observers have been re-determined; as these are found to be in close agreement with previous determination, no changes in the adopted values have been made.

Progress in the installation of the new quartz clocks has been slow. As mentioned last year, contracts have been placed with the Post Office Radio Branch for the supply and installation of a total of eighteen primary standards, together with certain ancillary equipment. The two clocks at Abinger and the one at Edinburgh, already in use last year, are still the only clocks available. Some progress has been made at Abinger with the installation of further equipment, but no part of the new installation is sufficiently complete to enable any useful results to be obtained. Two groups of three standards each are in temporary operation on the mains, but the divider and beat counter equipment is incomplete, so that no useful data are available for time service operational work. Another group of three oscillators, but without crystals, has been received. Other work in connection with the quartz clock installation at Abinger has been pushed ahead in the hope that the Post Office equipment would have been delivered. The battery installation at Abinger has been completed by the Electrical Engineering Department, H.M. Dockyard, Chatham, and the equipment originally prepared for Edinburgh, and now to be installed at Greenwich, is ready for erection and wiring up. Because of the delay in the supply of instrument racks from the Post Office, the Admiral Superintendent, Chatham was asked to assist, and he has agreed to have twelve racks constructed to Post Office specification in the workshops at the Dockyard. These racks are required for mounting general time service equipment at Abinger and Greenwich.

The three Observatory standards, A1 at Edinburgh and B1 and B2 at Abinger, are still mains operated, since it is not practicable to transfer them to the new battery equipment. The crystals from B1 and B2 will later be transferred to one of the new groups now being installed, but this transfer cannot be made until some of the other new standards have been completed and brought into use. The best performance has been given by A1, which stopped, however, in July, September, December and January: it has shown a certain non-uniformity of frequency drift, due probably in part to these stoppages. Mains interruptions have been frequent at Abinger, especially during the period of flying-bomb and rocket attacks. B1 has stopped on 44 occasions and B2, which is apparently more susceptible to momentary flickering of the mains supply voltage, on 60 occasions. On the scanty evidence available, B1 appeared to give the better performance, but early in January the frequency drift of this standard became rapidly worse, and the crystal and holder were returned to the Post Office Radio Branch Laboratories for examination. It subsequently transpired that the crystal holder had developed a leak. The trouble was rectified, and the crystal is now undergoing a period of fairly rapid ageing. When time signals are recorded against it, they are transferred on to B2 by means of a comparison taken at the time of reception of the signal.

Throughout the past year, therefore, the three Observatory standards could not be used as primary standards and it has again been necessary to base the time service on quartz standards in establishments outside the observatory. The three primary standards at the Post Office Radio Branch Laboratories at Dollis Hill have continued to give a good performance, especially IVC. The assistance of the

Engineer-in-Chief, Radio Branch, in making the results of these standards available to the Time Department, is much appreciated. The daily comparisons at the National Physical Laboratory between the Rugby 10^h signals and the quartz clock Q2 have been communicated by the courtesy of the Director of the National Physical Laboratory. The value of these comparisons has been much increased by the considerable improvement which has been effected at the Laboratory in the methods of reception and measurement of the signals. The N.P.L. standard, Q2, appears to be subject to slight changes of rate, which occur at intervals of from a few days to several weeks. For this reason it is less suitable for use as a long-term standard than the Post Office clocks, though it has been of great service in bridging discontinuities caused by the stoppage of other standards.

For the transmission of the 10^h rhythmic signals from Rugby, preference has been given to the signals emanating from Edinburgh, because the conditions for transmission of the signals by land-line between Edinburgh and Rugby have been more stable than those between Abinger and Rugby. The Edinburgh signals are sent over a comparatively short line to the Edinburgh Repeater Station, then over a normal traffic V.F. system to Birmingham, and thence to Rugby. From Birmingham a return signal was sent to the Observatory over the return channel of the same V.F. system, and a regular check on the lag of this return signal enabled changes in the transmission time over the send circuit to be detected and allowed for. More recently, a spare V.F. channel became available between Edinburgh and Birmingham; this enabled a channel to be allocated exclusively for time signal purposes instead of switching a normal traffic channel. A high standard of maintenance could be ensured and the results have shown the value of this. The signals from Abinger are sent over a long land-line from an electronic relay to the terminal station of the V.F. channels in London. They are then sent to Rugby over a unidirectional carrier circuit. A return signal is received from Rugby over a separate circuit; when a change occurs in the total time of travel of the outgoing and return signals, it is not known how much of the change occurs on the send line. Because of the loss in accuracy occasioned by an unpredictable variation in the time of transit over the land-lines, a number of possible schemes for ensuring greater accuracy have been considered during the past two years. The method eventually adopted was to send out, prior to the actual time-signals, a long tuning note followed by a short series of dots: these signals are radiated by the Rugby transmitter, recorded at the transmitting station and the transmitting clock then adjusted to allow for the measured lag. The special signals from Edinburgh are sent out at 09.30^h and radiated from Rugby when (as is usually the case) the transmitter is free. The corresponding signals from Abinger are sent out at 09.45^h i.e. some ten minutes before the normal 10^h signal. The use of the decimal counter chronometer enables the signals to be measured and the transmitting clock to be adjusted for the derived lag in this interval. The results from Abinger are not altogether satisfactory, as it is found that the transmission over the land-lines from Abinger introduces irregularities in the spacing of the individual signals; when the radiated signals (originating from Abinger or Edinburgh) are compared with the signals direct from the contacts of the Abinger transmitting clock, it is found that the erratics are less when the signals are sent from the phonic motor of A1 at Edinburgh than when they are sent from the phonic motor of B2 at Abinger. The irregularities are therefore produced on the land-line between Abinger and Rugby. This matter is being investigated with the co-operation of the Post Office Telegraph Branch.

The present procedure, in which dependence has to be placed on the Post Office clocks, is to use the transit observations to determine the general run of these clocks; the accuracy of the reception of the time signals at Dollis Hill is insufficient to enable day-to-day figures to be used. The prediction line is then transferred to A1, which has been adopted as a secondary standard because it has proved to be the most reliable of the Observatory clocks. A1 is used to control the

10^h signals. The predictions on A1 are transferred to B2, so that B2 can be set to time to provide an alternative signal from Abinger, in the event of signals from Edinburgh failing for any reason to reach the Rugby station: B2 also controls the 18^h signals.

The 10^h and 18^h GBR time signals from Rugby have been regularly recorded throughout the year at both Abinger and Edinburgh, with the exception that the recording of the 18^h signal at Edinburgh was discontinued from 14th February. The short-wave signals, radiated simultaneously with the long-wave GBR signals, have been monitored as previously, mainly at Abinger. Since Abinger is within the skip-distance of most of these transmissions, it was expected that their reception would be uncertain. The final corrections to the times of emission are therefore given only to the nearest hundredth of a second. The uncertainty of the reception has proved, however, to be much smaller than had been expected.

Both stations have maintained a check on the German signals from stations DFY and DFC, except for the period June 22 to October 17, when these signals were not recorded at Abinger. In March, French time signals were resumed, from station TMA2 at 8^h and from XWX at 20^h: these signals have been received when possible at Abinger, but reception is not good. A special effort has been made to obtain good comparisons with the American short-wave time signals. Records have been obtained at Abinger of the NSS time signals, controlled by the U.S. Naval Observatory on 713 occasions and of the WWV signals from the National Bureau of Standards on 1,200 occasions. The regularity of the signal dots of the WWV transmissions has permitted the use of the selection technique used for the British short-wave signals. The decimal counter chronometer is started by the radio signals and stopped by the seconds contacts of B1. The consistent readings obtained with the clearest signals are taken as correct. Larger but not consistent readings are assumed to be caused by an atmospheric operating the counter before the actual signal; smaller readings may be obtained with poor signals. The method has proved to give a high standard of accuracy. The NSS signals are not observed in this way, because it is not known whether they are controlled from a phonic motor. The variations between individual readings may be due to irregular spacing of the signals: in that case the best result is given by the mean of a number of individual readings, obviously discordant readings being rejected.

From the beginning of 1944 the U.S. Naval Observatory has published corrections to the times of reception of the British short-wave signals GIH at 18^h. The adopted time at Washington can therefore be compared with the adopted time at Greenwich through the intermediary either of GIH signals or of the NSS signals, when the two signals are observed at both stations. 35 days were selected on which both the 16^h NSS signal and the 18^h GIH signals had been recorded at Washington and at Abinger and for which the corrections to the times of the two signals, as determined at both stations, were available. Applying a travel time of 20 milliseconds on the assumption that the signals travel with the speed of light along a great circle route, the amounts by which the Washington finally adopted time appeared slow on the Greenwich finally adopted time were derived, using the GIH and NSS signals separately. The mean difference between the comparisons by the two separate signals was practically zero (-0.4 ± 0.5 milliseconds). The probable error of a single difference (involving errors of reception of two signals at each station) was $\pm$ 3.1 milliseconds; if it is assumed that the errors of reception are equal at the two stations, the probable error of a single reception is $\pm$ 1.6 milliseconds. Since Abinger is within the skip distance of GIH, this result is encouraging. Furthermore, the small mean difference between the comparisons indicates that the travel lines of the two signals are equal, that the signals can not depart materially from the great circle route, and that the speeds of travel can not differ appreciably from the speed of light. When figures covering a substantially longer period are available, an accurate determination of the speed of travel will be possible.

There is further evidence that the short-wave signals can be received with a higher degree of accuracy than had been expected. The reception at Abinger of WWV time signals under the most varied conditions, by different observers, and by both day and night, show a remarkable degree of consistency in the comparisons between the WWV standards and the Observatory standards. It is not possible to make a strict comparison of Greenwich and Washington time by means of these signals, since Washington only checks the transmissions at 03.00 and 15.00 hours, but it may be noted that the comparisons between the Abinger clocks and the uncorrected WWV time signals shows a higher degree of consistency than those between the Abinger clocks and the NSS signals to which the final Washington corrections have been applied. The WWV type of time signal would appear to be very well suited for precision comparisons, especially where a counter chronometer is available.

Following a special request from Russia, efforts have been made to receive and measure the Russian time signals radiated from RSN and RPT. Reception conditions are not very favourable, but since May a total of 104 signals have been recorded at Abinger.

The service of six-pips signals has been extended during the year. In addition to the usual transmissions by the B.B.C., these signals have been sent over special lines to the Admiralty and to Fighter Command. They were also used for the synchronization of artillery barrages on the Western Front. Because of the various operational uses, it was important to ensure that no erroneous signal would go out. A continuous 24-hour watch each day was therefore maintained for a considerable portion of the year.

An alarm system has now been designed and constructed to guard against any failure of the six-dots transmitting clock. The operation of the alarm performs the dual function of ringing a warning bell, and cutting the signal lines. The alarm is set off if the transmitting clock gets out of control from the master clock, or if it is allowed to run down. It also operates if the magnetic corrector is left on inadvertently, or if the alarm unit itself fails, either owing to a mains interruption, or to a failure of the high tension supplies. The valves of the alarm unit are duplicated, and the correct operation of the alarm unit may be easily tested. A member of the staff sleeps at the station and is available to correct the trouble in the event of the alarm bell ringing during the night.

Various countries sent out time signals from transmitters operating on the long wave band, with low carrier frequencies. These signals have the advantage of reliable world wide reception, with relative freedom from fading and from varying path. The design of a suitable receiver for long-wave reception of time signals has therefore been one of the subjects of experimental investigation at the Observatory. It is essential to ensure that the lag introduced by the receiver shall be as constant as possible, and that the form of the build-up curve of the signal dots shall be kept as steep as possible. A fairly high degree of selectivity is essential, as the transmitting stations are very closely spaced in the frequency band; but high selectivity is associated with large delay in the receiver, and very careful design is called for. Variation in delay can be caused by variations in signal strength, so that it is essential to adopt some means of ensuring that the signal peak is adjusted to the same level for each signal. The actual field strength in the neighbourhood of the receiver cannot be relied upon to remain constant even over the five minutes of a signal period, so that continuous monitoring of the signal peaks is necessary. Modifications to various commercial or standard Admiralty receivers have been made but the results have not been entirely satisfactory. After considerable experimental work, a receiver comprising three sections has been designed and constructed. These are (1) a two-stage amplifier with negative feedback independent of frequency and positive feedback dependent on frequency. The positive feedback increases the selectivity, the negative feedback increases the stability of the circuit. The negative feedback always exceeds the positive, even at resonance, so that the stability is better than that of an amplifier without any feedback. (2) Two stage amplifier with negative feedback with gain control in the feedback circuit. This makes it possible to vary the gain at a point of relatively low impedance where wire-wound and fixed stabilised carbon resistors can be used instead of carbon track variable resistors, which had been found to cause considerable variations in amplification. (3) Cathode follower buffer stage.

Side-band splash was troublesome when the station DFY, whose frequency is close to that of GBR, was operating. It was therefore decided to use a directional aerial. An old frame aerial, erected on the roof, was tried with marked improvement. A balanced and screened frame aerial, which can be rotated from within the building, has been designed and construction is proceeding.

The receiver unit feeds two ancillary units. One is a monitoring unit, consisting of an audio monitor in which a source of 1,000 c.p.s. tone is applied to a built-in loudspeaker whenever a received signal is applied, and a peak voltmeter, with a rapid build up and slow decay time-constant of 30 seconds. This gives readings on a large scale meter corresponding to the output voltage from the receiver; because of the large delay time-constant, the indicating meter gives a sensibly constant reading, although the applied signal consists of dots of only one tenth of a second duration separated by intervals of nearly nine tenths of a second. The meter will, however, follow any changes of peak signal level due to field strength variation, during the five minutes signal period, and the gain may be adjusted to keep the output level constant. The second ancillary unit is a pulse producing unit, which selects a particular point on the build-up curve of the signal dots, and produces a very sharp pulse whenever this point is reached. This operative point may be selected by means of a switch, to be at 10%, 20%, 30%, 40% or 50% of the peak amplitude of the signal dots. The sharp impulses can then be fed to a decimal counter chronometer. For the production of these sharp impulses at pre-determined levels, trigger circuits, consisting of amplifiers with two stable states, were first tried, but the stability of the triggering point was not considered to be sufficiently stable over long periods of time. A circuit employing straight amplification and chopping with a biased diode is now being used, and has been found to be preferable. The complete receiver is being tested on G.B.R. signals. Reception of other signals will be by switched pre-tuned circuits, but although provision has been made for these, the results of the preliminary trials are awaited.

Provision has also been made for the decimal counter comparisons to be supplemented by film records of cathode ray tube signals. The received signal is applied to a rack-mounted double beam oscilloscope, one beam being used to record the time signals, and the pulses from the transmitting clock, and the other beam for timing pulses. A unit to produce the timing pulses has been constructed in the laboratory, and is based on a multivibrator circuit developed at the Radio Branch Laboratories of the Post Office. The output fed to the oscillograph consists of pulses every thousandth of a second, the fifth and tenth pulses being distinguished by larger amplitudes. The film records should be of great value in determining the performance of the receiver and in investigating the changes in the build-up of the signal dots throughout the time signal series. They can also be used during the preliminary test period for comparing the received signal with the time of the impulses passed on the decimal counters at various percentage settings of the pulse producing unit. A further unit is under consideration, which will produce a square-wave modulated test signal to be fed into the receiver in order to check up the build-up characteristics of the receiver. When tests are completed, it is proposed to build further receivers of the same pattern in order that duplicate receivers may be available at the two time service stations.

An improved type of electronic send relay has been designed and five units have been constructed. They give a faster build-up of the line signal and limit the amplitude so as to conform to normal Post Office practice. The temporary trigger units which were made for the decimal counter chronometers have been rebuilt in an improved form. Routine tests have been devised for the counters and for their ancillary equipment in order to ensure constancy in operation. Both counters have required a fair amount of skilled attention and some spare scale-of-ten units have been ordered to facilitate quick repair in case of failure.

The illumination of the field of the small transit instrument has been improved. In the previous method, a diffusing disk was mounted in front of the centre of the object glass at an angle of 45° to its axis, and illuminated by a low-power lamp, mounted outside the telescope tube. The disk, about one inch in diameter, reduced the effective aperture and white fringes, at the edges of the micrometer wires, made bisection of a star image difficult. A small disk, 2mm in diameter, is now placed on the optic axis in a plane which is conjugate to the focal plane with respect to the surface of the object glass acting as a concave mirror. The disk is illuminated from outside the tube and a very uniform illumination over the whole field is obtained. A blue filter has been incorporated in the illuminating system, giving a field illumination approximating to daylight. The intensity of the light is controlled by an iris stop, which enables the intensity to be varied without the change of colour that results when a lamp runs at a reduced voltage.

Two years ago, it was reported that photoelectric equipment was being fitted to a Shortt master clock. This work was shelved for a time for more urgent work, but some progress has been made. After a careful series of experiments to determine the optimum slit widths for the primary and secondary slits, the tolerance of focus, a means of focusing with suitable accuracy, the requisite degree of stability of the light source, and other details, an experimental optical system was constructed and has been tried out. One of the most serious difficulties has been the insufficiently rigid mounting of the clock, and it is hoped to try the system out with a clock mounted on a more stable support. It also became quite apparent that further refinement in the method of taking the time from the pendulum was of little value unless some improved method of impulsing the pendulum could be developed. Preliminary experiments have been carried out on a method of electrostatic impulsing, but little can be said except that it is possible to maintain the arc by this means. Further work on this subject is required, but for the present it is not of vital importance and is only receiving attention when more important work permits. The electronic unit for the impulsing has been completed, and also a pulse unit for operating from the photoelectric cell timing device.

IV. CHRONOMETERS.

The rating and supply of chronometers and watches to H.M. Ships and Naval Aircraft has continued to increase throughout the year. The work has been dealt with promptly and all records have been kept up to date.

The number of Admiralty chronometers and watches on charge to the Royal Observatory is 12,469 and they are disposed at Bradford-on-Avon, Taunton, Whitehall and Edinburgh. Of this total 361 chronometers (Patt. H.S.1), 410 chronometer watches (Patt. H.S.2 and H.S.6), 1,110 deck watches (Patt. H.S.3), 666 beacon watches (Patt. H.S.4), 591 pocket watches (Patt. H.S.5), 252 stop watches (Patt. H.S.7) and 2,188 wrist watches (Patt. H.S.8) are rating or reserved ready for issue. Three chronometers are in use at the Royal Observatory. The remainder, consisting of 118 Patt. H.S.1, 1,358 Patt. H.S.2 and H.S.6, 3,826 Patt. H.S.3, 447 Patt. H.S.4, 377 Patt. H.S.5, 231 Patt. H.S.7 and 534 Patt. H.S.8 are held in store awaiting adjustment, rating or repair.

The stock of watches 6B/60 held on behalf of the Air Ministry totals 223, of which 102 are rating and 121 are in reserve.

In addition to the above there are 189 chronometers and watches deposited for various reasons.

During the year ended 1945 April 30 a total of 23,378 chronometers and watches was received and 21,023 issued. The number sent for repair was 3,291 including 161 for the Air Ministry. The transactions recorded shew an increase of 60 per cent over the previous year, due to the handling of wrist watches and stop watches for use in Naval Aircraft, although transactions connected with the strapping of the wrist watches and involving their despatch and subsequent return to the Depot have not been included in the above totals. The issues and receipts during the year have been about three times greater than in the peak period during the last war.

Routine transfers of chronometers and watches to ships of Allied Navies fitting out in this country continued throughout the year. Instruments supplied to Commonwealth Governments and other Departments were:-

Australian Government	76 chronometers
Air Ministry	1,000 deck and pocket watches
	300 wrist watches
Ministry of War Transport	63 chronometers, 17 watches
Canadian National Steamships	65 chronometers
French Service Hydrographique	10 chronometers, 50 watches

The watch repair shop during the year has been responsible for the repair and adjustment of 2,537 instruments, including 135 chronometers and 448 chronometer watches. Additional watch repairers are needed to meet the increased calls on the watch repair shop, but great difficulty is being experienced in obtaining suitably qualified repairers. One watch repairer was released on account of ill-health and another proved unsuited to the high-grade work and was subsequently released.

Some 20,000 chronometers and watches have been engraved with pattern numbers and serial numbers, as necessary. The rating of wrist watches and stop watches, which is less exacting than that of the usual Hydrographic chronometers and watches, has been undertaken by women under supervision of the technical staff. Seven thousand wrist chronograph watches (Patt. H.S.9) are now being prepared for service, the work entailed consisting of the removal of dials for luminising, re-assembly, engraving, fitting of stainless steel bracelets and subsequent rating.

As the result of the appeal for chronometers, mentioned in the last Report, an additional 34 chronometers were received at Bradford-on-Avon for examination with a view to acceptance by the Admiralty for purchase or on loan. At the end of 1944, the demand for chronometers having eased, it was found possible to commence the return of loaned instruments to the owners. Up to date 32 such instruments have been returned to their owners in good going order.

The stock of watchmaker's tools and equipment purchased and held in reserve at another Establishment against a possible emergency has been recovered and brought into use in the workshop.

A second watch rate-recorder was obtained from the Western Electric Company and brought into use in January 1945. Another watch cleaning machine was purchased to replace the machine obtained in 1938, which is practically worn out.

In June 1944 minor adjustments were made to the standard clock at Portsmouth Chronometer Depot. The clock at Plymouth Depot was cleaned in August and in January 1945 the Graham regulator in use at Liverpool Depot was brought to Bradford-on-Avon for overhaul and subsequently re-installed at Liverpool.

A time recording unit was constructed in the watch repair shop for incorporation in the occultation Machine at the Nautical Almanac Office. This unit, which replaces the linear scale previously used, was made up from a condemned chronometer movement, particular attention being given to the avoidance of backlash and sloppiness in the gearing. Provisional results shew that increased accuracy and ease of observation have been attained.

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 through the year. It has again been 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.

For several years the Office has been fully engaged with building up an organisation and training additional staff to take on the computing work of the Admiralty Computing Service; during this time it has also largely provided the actual computing. With the recent new staff and with the increasing experience of the "trainees", it has been possible during the last few months gradually to lighten the additional load carried by the Office. Although it is neither possible nor desirable for the Admiralty Computing Service to be completely separated from the rest of the Office, it is hoped that it will shortly be sufficiently self-supporting to allow proper attention to be paid to the accumulated arrears in the astronomical work. As will be seen below, there are numerous directions in which development can no longer be postponed.

All the publications of the Office have been delayed by the pressure on the printing industry, which causes unduly long intervals between the preparation of copy and publication.

The Nautical Almanac. The Almanac for 1946 was published on March 19; this was the first edition for several years which has been printed from stereotyped plates in a uniform style, and it marks the end of the effects of the destruction, in 1940, of the type and plates for the first half of several Almanacs. It is hoped that by still further advancing the despatch of copy and by a reduction of the printing delays, the edition for 1947 will be available by the end of 1945.

No changes have been made in the contents or presentation of the Almanac. A first step towards a general improvement has been made by addressing a circular letter to users for suggestions for alterations and additions; the response has so far been rather disappointing, but one or two valuable suggestions have been made and will subsequently be incorporated.

The first part of the *Nautical Almanac*, which contains the fundamental ephemerides of the Sun, Moon and planets, has been completed for 1949; lightly bound printed sheets have been distributed to the Almanac Offices and other authorities in accordance with international interchange agreements. During the year there have also been produced and circulated duplicated copies of the fundamental values of the Besselian Day Numbers (for reduction of star positions) to one decimal more than printed in the Almanac. Almost the whole of the copy for the first part of the 1950 edition has been sent to the printer.

In conjunction with the preliminary consideration of improvements to the Nautical Almanac, some work has been done on the contents of the separate Supplement which it is hoped will be ready in time for issue with the 1948 Almanac.

The calculation of the Moon's longitude and latitude for every 12 hours in the ten years 1951 - 1960 has now been completed, and the final values checked and passed. A smoothing technique has been applied, under strict control, at various stages of the computation and it is thought that a significant improvement in the representation of Brown's *Tables* will result thereby. Hollerith equipment has been used in the relevant stages of the conversion of these values to right ascension and declination. Similarly, these machines were used in the conversion from heliocentric to geocentric positions of Mercury and Venus for every day in the period 1951 - 1960.

Occultations and Eclipses. The occultation programme has been increased during the year due to the successive liberation of many areas, enabling predictions to be transmitted to the Observatories concerned. Predictions were done for twelve such stations for the years 1945 and 1946 involving about 4065 computations.

Besselian elements for 2533 stars of magnitude 7.5 or brighter occulted during 1947 were received from the office of the *American Ephemeris*. These stars were examined by means of the occultation machine and preliminary times and position angles recorded for 78 stations for 1272 stars, the others having been discarded as not observable under suitable conditions. After computation the number of stars retained as suitable was further reduced to 1169, which will be the number published in the *Nautical Almanac* for 1947. The number of predictions done for the year 1947 is about 6820.

Predictions for Wellington and Dunedin will again be published with the other British Empire stations in the *Nautical Almanac* from 1947.

The receipt of partially reduced observations is somewhat erratic. For the year 1943, 290 observations have been received of which 96 had been completely reduced and the others have been completed in the Office. Further observations for 1943 are expected to be received soon. 210 partially reduced observations have been received for 1944 but the completion of these reductions has been deferred in order to allow the computation of 1945 and 1946 predictions for liberated stations.

By agreement with Professor Brouwer it has been arranged that the annual compilation and discussion of observations of occultations should be carried out by the Office as from the year 1943. The organisation of the work, the collection, reduction and publication of the observations has been deferred during the year, but can no longer be delayed.

No special eclipse computations have been undertaken, but a tentative request has lately been received for predictions of the ionospheric and corpuscular eclipses on 1945 July 9 and it is probable that these will be provided.

Abridged Nautical Almanac and Air Almanac. Although the last pages of the *Abridged Nautical Almanac* for 1946 were passed for printing in October, it has not yet been published, but publication is expected very shortly.

All the copy for the 1947 *Abridged Nautical Almanac* has been in the hands of the printer for several weeks and a determined effort will be made to ensure that this edition appears before the end of 1945.

No changes have been introduced in either the 1946 or 1947 editions. Drafts of a revised form of the *Abridged Nautical Almanac* have been prepared for several years, but it has not been practicable to introduce the long overdue changes. It is hoped to make specific proposals and to revise the Almanac before the 1948 edition.

Since the last report, four parts of the *Air Almanac* have appeared, namely

1945 January to April

1945 May to August

1945 September to December

1946 January to April

The date of publication is becoming progressively earlier and these publications are now appearing about eight months prior to the first date to which they refer.

Apparent Places of Fundamental Stars. The volume for 1945, the fifth of the series, was published on June 14. The whole of the volume for 1946 has been passed for press, and it is anticipated that publication will take place during June.

The *American Ephemeris* office supplied copy for the apparent places of the 32 additional circumpolar stars, normally computed by France; the apparent places of the 426 10-day stars, also normally supplied by France, have been computed by Hollerith machines for the Nautical Almanac Office. The apparent places of all these stars for 1947 have been promised by France, and are expected within the next few weeks. All the rest of the copy is ready, and the 1947 issue should be published in April 1946.

Other Publications. Volume Q of the *Astronomical Navigation Tables* was issued in January. This volume is mainly intended to cover latitudes N. 70° - N. 79° although it may be used in southern latitudes for declinations from 0° to 29°.

Tables for the Depression and Azimuth of the Sun for Latitudes N. 45° - N. 60° were issued on 8th March. These tables, which are printed by photolithography from typescript, give the depression of the Sun with arguments, latitude and local mean time for all times when the depression is between 6° and 18°. Previous to the final publication of these tables, four-monthly parts had been issued to meet special requirements.

General Navigational Work. In addition to the preparation of the *Air Almanac* and the *Astronomical Navigation Tables*, and the solution of the various problems associated with these publications, the Office has been continuing to do a considerable amount of miscellaneous computing work for the Air Ministry in connection with astronomical navigation.

In particular a set of standard curves has been calculated for use with a template for polar navigation, and a specimen set of "time-altitude-azimuth" scales constructed to test a new method for the reduction of the observed altitude of stars.

The R.A.F. second specialist navigation course, consisting of thirteen officers accompanied by two members of the staff from the Empire Air Navigation School, Shawbury, visited the Office from 2nd May to 5th May, to see the work of preparation of the *Air Almanac* and *Astronomical Navigation Tables* and to discuss matters connected with astronomical navigation. Professor W. M. Smart visited the Office at the same time and was able to join in the discussions. The Astronomer Royal gave a talk on the determination of time on the 4th May. This contact with the users of the air publications is most stimulating to the Office and provides a much closer appreciation of the problems to be overcome than could otherwise be obtained. A similar visit by the third course is due early in May 1945.

It is hoped that the Office will maintain its extended interest in astronomical navigation after the war, and continue to act for both Admiralty and Air Ministry in this sphere. A comprehensive library of navigational tables and text books is being collected.

Ryde Night Illumination Diagrams. The Office has continued to compute illumination levels and prepare diagrams to cover latitudes from S.10° to N.72°. The diagram which for 1944 had as its central latitude N.52° has been replaced by two diagrams for latitudes N.50° and N.55°, making the total number of diagrams prepared, for each four-monthly period, eleven.

During the year, diagrams have been issued for the first eight months of 1945 and those for the rest of the year are all in proof. The computation for the first four months of 1946 have been completed and diagrams prepared ready for reproduction.

Master diagrams have also been prepared for reproduction in India. These are specially drawn to obviate the necessity for interpolation for longitude. At first they were required for three latitudes but later the range to be covered was increased, and five latitudes have been provided from May 1945 onwards. These master diagrams, accompanied by rough colour tracings and explanations have been despatched up to April 1946.

Proof Reading. The amount of proof-reading has decreased since the previous year; there have been 6,200 distinct readings, representing 2,100 pages. The ratio of three readings to one page indicates that on the average all first proofs have been read in duplicate. This is still necessary owing to the enforced use of less highly trained staff on this specialised work.

Repayment Work. The demand for lighting-up times remains at about the same level as last year, but with the reversion to dim-out and then the lifting of black-out, the demand for black-out times has practically vanished.

Lists of Moon's phases and of times of moonrise and moonset have been supplied as before, and other information is also supplied on the normal basis of a small charge intended to cover the cost of preparation and secretarial work.

Admiralty Computing Service. The Admiralty Computing Service, the formation of which by Director of Scientific Research was announced in the Annual Report for 1944, has now been in existence for two years. Its object is to co-ordinate mathematical and computing activities within the Research Departments of the Admiralty, and to centralise computations whenever possible.

Since its inception, the Admiralty Computing Service has grown considerably, and with this growth organisational changes have been made. Some dozen members of the Technical and Scientific Pools are now employed at the Office as the nucleus of the Service. These are organised into three sections which are distinct from the Nautical Almanac Office proper, though remaining under the general direction of the Superintendent. At the same time, close liaison is kept between the two groups and a flexible arrangement for the mutual interchange of staff is in operation. The greater experience of the Office is thus available to the Admiralty Computing Service and the Office is able to ensure that the high standards demanded of it are, as far as possible, maintained. The Office has also undertaken the training of additional staff as they have been appointed.

The flow of investigations to the Admiralty Computing Service has been continuous and increasing. The demand for this type of work was considerable at the outset and it is clear that it will increase as the Research Departments become more aware of the nature of the service provided. Over a hundred separate investigations have now been undertaken, some 60 per cent of which have been completed, the others being either on hand or considered as long term projects of relatively low priority. Nearly 80 reports have been issued by Admiralty Computing Service, most of which have been prepared by the Office.

The projects undertaken have increased not only in numbers but also in scope and the range of problems has been very wide. Though it is still true to say that most of the work has consisted of the provision of numerical results from a given mathematical formulation of the problem, it can no longer be said that this has been the sole concern of the Computing Service. An appreciation of the physical background of any given problem has always been necessary in order to complete the computation intelligently. More recently, however, this appreciation has extended to the suggestion of modifications in the mathematical formulation and even to the provision of the complete mathematical theory underlying a problem. It has become clear from these investigations that one of the chief advantages of a central computing organisation occurs when research workers are unaware that an apparently difficult mathematical problem may prove tractable when computation is undertaken.

Other Work. The only additional work undertaken by the Office, other than that arising directly or indirectly through Admiralty Computing Service, has been that of interpolation to a smaller interval of the argument of previously prepared bomb ballistic tables for the Ministry of Aircraft Production, and certain theoretical calculations on sky brightness for the Ministry of Supply.

Machines. No new machines have been added to the Office equipment, though they are now very urgently needed. The arrangement by which the Office uses the machines of the British Tabulating Machine Co. on a service basis has been continued.

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. Observations of horizontal intensity with a unifilar magnetometer and of inclination with an inductor have been taken frequently, however, 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, but no re-measurement had been made during the past twelve months.

The variations of declination and of horizontal and vertical intensity have been recorded photographically both on slow-run and quick-run recorders.

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 1944 December 31, and with provisional constants to the present time.

The tabulation of results for 1944 awaits the receipt of the final 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 1944 are given below. The values for the years 1941, 1942, and 1943 are given for comparison.

	Decl. W.	Horizontal Intensity	Vertical Intensity	Inclination
1941	10° 33′.8	0.18539	0.43128	66° 44′.3
1942	10° 24′.8	0.18554	0.43146	66° 43′.9
1943	10° 16′.2	0.18556	0.43172	66° 44′.5
1944	10° 7′.8	0.18566	0.43189	66° 44′.3

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 8 magnetic disturbances reaching the dimensions of a "storm"; one of these (that on December 16) 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").

The harmonic analysis of the data interpolated from the Admiralty magnetic charts for the epoch 1942 has been extended to take into account the ellipsoidal figure of the earth. The changes in the harmonic coefficients from their values for a spherical earth are small. The computed position of the south magnetic dip pole is in close agreement with the observed position, but the computed position of the north magnetic dip pole is about 6° north of the position determined by Amundsen in 1903. The computed position is not appreciably changed when account is taken of the ellipsoidal figure of the earth. The discordance may be due to a large regional anomaly in the vicinity of the north magnetic pole. It is hoped that magnetic observations to be made in the series of flights over the north geographical and magnetic poles by the expedition from the Empire Air Navigation School may give some information on this question.

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.

Observations of temperature, wind direction and strength, rainfall and a general weather note are sent daily to Instructor-Commander, Naval Meteorological Section, Royal Naval College, Greenwich, when the class is under instruction there.

The tabulation of meteorological results for 1944 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 1945 April 30.

The mean temperature was 50°.5 which is 0°.8 higher than the average for 100 years 1841-1940. The highest temperature in the shade was 89°.3, registered on May 29. Temperatures exceeding 80° were recorded on 18 days, of which 12 were in August and one (80°.3) in April (1945). The last mentioned occurred on April 16, which is the earliest date in April on which the temperature has been observed to reach 80° at Greenwich. Although the standard thermometers are not now exposed on the open revolving stand it may be mentioned that the number of days in August on which the temperature registered on this stand exceeded 80° was no less than 17, - the greatest number for August ever recorded at the Observatory.

The lowest temperature was 15°.1 which occurred on January 29. Temperatures of 32°.0 or below were recorded on 42 days, of which 22 were in January. The first four months of 1945 were each remarkable for anomalous mean temperature. The deviations from the respective averages for 100 years were; January -5°.6; February +6°.0; March +4°.9; April +4°.4. The mean temperature for February was the highest for that month ever recorded at Greenwich.

The mean daily horizontal movement of the air was 268 miles, which is 11 miles above the average for 50 years 1867-1916. The greatest daily movement occurred on January 18 and was 640 miles; the least daily movement was 59 miles, on February 15. The greatest pressure reached was 27.0 lbs. to the square foot, which was registered on February 2.

The total duration of *bright* sunshine recorded was 1400.2 hours or 31.3 per cent of the possible total. There were 70 entirely sunless days, 57 being in the five months November to March. There were 41 cloudless nights in the period, that is, nights on which a complete unbroken trace of δ Ursæ Minoris was obtained by the night-sky camera. The number of nights on which no trace of this star appeared on the plate was 88, while on a further 39 nights the record was not more than ten per cent of the amount possible.

The total rainfall during the twelve months under review was 22.69 inches, that is 1.64 inches less than the average of 100 years 1841-1940. There were 165 days on which rainfall amounting to .005 inch or more was recorded. The wettest month was November, with 3.645 inches; the driest month was May with 0.614 inch.

VIII. PRINTING AND DISTRIBUTION OF GREENWICH PUBLICATIONS.

No steps are being taken at present to proceed with the printing of the annual volumes of Greenwich Observations. The MSS. for the years 1937 to 1944 are complete or in various stages of preparation.

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. Acton, H. H. J. Barton, E. A. Chamberlain, H. F. Finch, B.Sc. F. Jeffries, E. G. Martin, H. W. Newton, G. W. Rickett, L. S. T. Symms.
Junior Assistants	- K. C. Blackwell, C. C. Harris, P. S. Laurie, B. R. Leaton (on active service), Miss J. Mounteney, P. L. Rickerby, J. L. Rudd, A. Shortland, R. H. Tucker (on active service), G. F. Wells.
Head of Repair Shop	- H. Warden.
Secretary and Cashier	- H. G. Barker.
Departmental Clerical Officer	- J. J. McLoughlin.
Clerical Assistant	- Miss F. E. A. Jeffries.
Temporary Observing Assistants	- V. Barocas, Ph.D., A.Inst.P., J. D. Pope, G. B. Wohlgemuth, R. M. J. Withers.
Temporary Clerks Grade II	- Miss D. A. Bush, Miss B. G. Collett, Mrs. M. B. Goodfellow, Miss C. Ryall.
Temporary Clerks Grade III	- Miss C. E. Chapman, Miss K. M. Hempstead, Miss P. B. Hill, D. Oliver, S. R. Plester, Miss J. G. Slade, Miss J. White.
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.
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, G. A. Harding (on active service), Miss J. E. Pullen, Miss M. R. Rodgers, Mrs. V. H. Rogers, Miss M. C. Scadeng, E. Smith.
Temporary Clerks Grade II	- Miss M. J. Matthews, Miss Y. P. Mundon, Miss O. J. Ollis, Miss K. M. Restorick.

Temporary Clerks Grade III	- Miss E. A. Hazell, Miss Y. I. Reddy, Miss I. M. Restorick, M. J. Roch, L. A. Straw, Miss B. M. Tutt.
Junior Assistant as Secretary	- Miss D. J. Ifield.
Clerk-Shorthand-Typist	- Miss J. E. Perry.

Admiralty Computing Staff.

Temporary Experimental Officers	- L. Fox, M.A., D.Phil., E. T. Goodwin, M.A., Ph.D. P. H. Haines, M.A., Mrs. A. M. Macey, B.Sc. H. H. Robertson, B.Sc., Miss J. Staton, B.A., R. G. Taylor, B.Sc., S. R. Tibbs, M.Sc., Ph.D. E. M. Wilson, B.Sc.
Temporary Experimental Assistant III	- Miss K. Blunt, W. J. Ferguson, B.Sc., F. W. J. Olver, B.Sc., Miss O. E. Vanes.

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. B. R. Leaton 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, has been on loan from the Department of Scientific and Industrial Research for duty in the Time Department throughout the year.

Mr. J. D. Pope and Mr. R. M. J. Withers were appointed to the Royal Observatory as Assistants (Temporary) during the year. Miss M. B. Simm was married and retained in a temporary capacity. Miss J. Mounteney was transferred from the Nautical Almanac Office to the Royal Observatory.

During the year difficulties were encountered with the recruitment and organisation of Admiralty Computing Service Staff in those temporary grades corresponding to the Nautical Almanac Office staff; it was accordingly agreed to transfer all such staff to the Scientific and Technical Pools (of the Admiralty) and to recruit further staff through these pools. Mr. Haines, Mrs. Macey, Mr. Robertson, Miss Staton, Mr. Taylor, Mr. Wilson, Miss Blunt and Mr. Ferguson were duly transferred under this decision.

Miss V. H. Hitches and Miss A. M. Hathaway were married during the course of the year and retained in their existing grades in a temporary capacity.

Dr. E. T. Goodwin and Dr. S. R. Tibbs have been appointed as Temporary Experimental Officers and Mr. W. J. Ferguson, Mr. F. W. J. Olver and Miss O. E. Vanes have been appointed, as Temporary Experimental Assistants III, to the Admiralty Computing Service during the year.

The staff of workmen employed in all branches consists of a Foreman and an Assistant Foreman of Observatory, seven watch adjusters and repairers, four machine operators, one joiner, five messengers, four labourers, three cleaners, three caretakers, a laboratory boy and a part time gardener, a total of 31 in all. A skilled mechanic is still lent for duty at the Admiralty Research Laboratory, Teddington. Mr. S. E. Bass and Mr. A. J. Johnson, members of the industrial staff, are on active service abroad.

X. GENERAL.

During the year, the Dean, the Commander and some members of the professorial staff of the Royal Naval College, Greenwich have visited the Observatory. A party of 12 Naval Officers from the Royal Naval College have been received at fortnightly intervals; in addition there have been special groups from the Naval Meteorological Section, of Danish and Chinese Naval Officers, and WRNS (O.T.C.).

At the request of the Flag Officer Liaison with the Commander United States Naval Forces in Europe (Rear Admiral Sir Geoffrey Blake), 5 parties of United States Naval Officers have been received. On April 16, Major-General Badulin, Head of the Soviet Delegation to the Conference on European Inland Transport, visited the Observatory. With him were Professor Hondelink, Chairman of the Inter-Allied Technical Advisory Committee on Inland Transport, and the Joint Secretary, Mr. A. A. Evans of the Ministry of War Transport. Captain Richmond of the U.S.C.G. (at one time at the Naval Observatory, Washington) accompanied by Captain A. S. Mackay, R.D., one of the Elder Brethren of Trinity House, joined this party of visitors.

In all 552 visitors were admitted, of whom 459 came from the Royal Naval College, Greenwich.

At the request of the Ministry of Information, Mr. Cecil Beaton has made a photographic survey of the work of the various departments of the Royal Observatory.

At the beginning of the war, steps were taken to install a skeleton time service at the Abinger Magnetic Station which would provide a service adequate for normal navigational and domestic needs in the event of serious dislocation at Greenwich. A hut was built for a small transit instrument. Two additional free pendulum clocks, Shortt 66 and 67, the latter being equipped for sending rhythmic time signals, were obtained and installed, together with the clock Shortt 61, which was loaned by Mr. H. R. Fry. In the autumn of 1940, the continuous air raids on London made night observations at Greenwich impossible. The entire time service was accordingly transferred to Abinger. As all the time lines from Abinger passed through London and Abinger itself was in a part of the country suffering from air attack, a second time service station became essential. With the co-operation of the Astronomer Royal for Scotland this was set up at the Royal Observatory, Edinburgh, where the transit circle was available for time determinations. Two free pendulum clocks, together with other equipment, were transferred from Greenwich to Edinburgh, and staff from Greenwich was sent to assist in the installation. This was just completed in time to take over control of all signals when the service from Abinger was temporarily put out of action as the result of the destruction of the Central Telegraph Office and the complete severance of all the time signal lines from Abinger. In the intervening period the staff of the Edinburgh Observatory has been engaged almost exclusively on time service work, assisted by one member of the Greenwich staff. The assistance and co-operation of the Astronomer Royal for Scotland and of his staff have proved of the greatest value and have materially helped in enabling a considerable improvement in the accuracy of the time service to be achieved under difficult wartime conditions. With the end of the war in Europe, the time service equipment at Edinburgh will be brought back to Greenwich, as soon as some necessary structural alterations required for its accommodation can be completed.

Abinger will remain for the present the main time service station of the Royal Observatory. There is no space on the restricted site at Greenwich for the time service installation at Abinger. When a new site has been obtained for the Royal Observatory, the portion of the time service at Abinger will be transferred to the new site. Observations both at the new site and at Greenwich will then require to be continued for a sufficient period to enable the longitude of the new site to be determined with accuracy.

Steps are being taken to resume some of the work at Greenwich which was interrupted at the end of 1940. The reversible transit circle is being brought back into use in the near future. The interruption of meridian observations at Greenwich and the destruction of the Poulkova Observatory have entailed a serious loss to fundamental astronomy.

The covering of the dome of the 28-inch refractor has been seriously damaged by blast. Complete re-covering would be essential before the telescope could be brought back into use. The covering of the dome of the 26-inch refractor, though less seriously damaged, is in very bad condition and it is doubtful whether the use of the instrument, with the dome in its present condition, is advisable. The expense of renewing these two domes can be avoided if an early decision can be reached on the proposals for moving the Observatory to a new site. Meanwhile, with the continued interruption to the programme of stellar parallax observations, it is planned to undertake at Greenwich the measurement of the plates of one of the southern zones of declination, photographed with the wide-angle lens camera at the Cape Observatory, for the determination of star positions.

H. SPENCER JONES

Astronomer Royal

Royal Observatory, Greenwich.

1945 May 15.