THE INSTITUTION OF
POST OFFICE ELECTRICAL ENGINEERS

The Electrical Control of Time Services in the British Post Office.

BY

A. O. GIBBON, M.I.E.E.

A PAPER

Read before the London Centre of the Institution on December 9th, 1930.

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The Electrical Control of Time Services in the British Post Office.

There is little need to stress the importance of such a subject as the electrical control of Time Services to members of the Institution of Post Office Electrical Engineers. The development of the electric clock industry, which has been greatly assisted by the distribution of Greenwich Mean Time over the Post Office system of lines during a period of approximately sixty years, together with the time signals sent out by the British Broadcasting Corporation, have aroused a national consciousness in the importance of accurate time-keeping.

In any development of time distribution, the G.P.O. is bound to take an important part. In addition to the use made of the telegraph and telephone networks for conveying time signals to all parts of the country, there are approximately 18,000 mechanical or electrical clocks performing their daily task in Post Office buildings all over the Kingdom. The clocks are of all sorts and sizes, with faces ranging from three inches to six feet in diameter; most of them are on duty in telephone exchanges and in telegraph offices; but wherever their lot is cast, indoors or out-of-doors, in turret or in test room, the essential requirement is that the 18,000 must keep correct time.

In view of the complexity of the subject, combined with limits of time and space, the difficulty confronting the writer of a paper on Electrical Time Services is to know where to begin and where to leave off. Fortunately there have been several papers read on the subject, before this Institution, the Institution of Electrical Engineers, and other scientific and technical societies. So long ago as 1899, Mr. Frank Hope-Jones read a paper before the I.E.E. on " Electrical Time Services " and he has been in the forefront for many years, both as a scientific investigator and as an electrical engineer specializing in this subject. The late Mr. R. Myles Hook's paper on " Correct Time," read before the London Centre of this Institution in October, 1912, has been printed. The paper deals in detail with standard Post Office practice up to that date and, in two particulars at least, Myles Hook's description is still current practice, namely, in the methods adopted by the Post Office for the distribution of Greenwich Mean Time, and also for the periodical synchronizing of clocks with the parent clock at the Royal Observatory. As these two points are dealt with in detail in the paper referred to, there is no necessity to do more than direct attention to Myles Hook's contribution on the subject and also to refer, in passing, to Post Office Engineering Department Technical Instruction XI. dealing with "Clocks and Time Distribution."

A census taken in November, 1930, of the clocks in use for Post Office purposes shows that there are approximately 11,000 mechanical and 7,000 electrical clocks in service, *i.e.*, 61% of the total is made up of mechanical clocks and 39% electrical.

The general tendency is for electrical clock systems to be installed in increasing numbers for telephone exchange purposes, whilst mechanical clocks are being replaced by electrical clocks in a large number of cases where financial economies result. Each case of replacement is worked out on an annual charge basis.

There has been an enormous growth in the provision of electrical time services since 1912 and, in this development, the Post Office has taken an important part, not only in connection with the electrical control of clocks for purely time-keeping purposes, but also in the arrangement of master clock mechanism for telephone and telegraph timing work. The functions of the master clock, providing for time check purposes in automatic and manual telephone exchanges, and also in large telegraph offices, are dealt with in later sections of this paper.

There are several types of electrical master clocks of the impulse pattern available for commercial purposes which, although differing in detail, are all highly efficient in operation. It was decided some years ago that, in order to ensure uniformity in the electrical characteristics of master clocks and secondary dials, the Post Office Engineering Department should frame specifications for a time service which would provide not only for time-keeping, but would also give facilities for the timing of calls, supervision, and other services in telephone exchanges; a development in the functions of the master clock which has become increasingly important in recent years. The adoption of Post Office specifications has had several advantages, which may be summarized as follows:—

(*a*) Standardization of mechanism.
(*b*) Standardization of current consumption.
(*c*) Interchangeability of parts.
(*d*) Avoidance of royalty payments to manufacturers.
(*e*) Free competition and reasonable costs as regards supply.

It is true that in the early days, prior to the transfer of the control of clocks in Post Office premises from the Office of Works to the Post Office Engineering Department, and also in the days of the National Telephone Company, there was a certain freedom of choice in this respect. In some of the older Post Office buildings and pre-transfer N.T. Co. exchanges, etc., there are a number of clock installations which, although efficient, do not conform to the existing standard practice.

Electrical master clock.

The standard electrical master clock is known as Clock No. 36 and is shown in Fig. 1. It has a seconds-beating compensation pendulum made of Invar. The specification stipulates that the variation in the rate of time-keeping must not be greater than eight seconds per week. The clock is fitted with contacts which furnish impulses at intervals of one second, six seconds, and thirty seconds. The one second impulse is provided by the fitment at the top of the pendulum rod. This fitting alternately closes two contacts, one on each side, connected in parallel. The one second impulse is used for certain types of secondary dials with seconds hands, also for time check and other purposes at telephone exchanges. A count wheel and its associated contact springs are fitted on the left hand side of the pendulum in order to provide impulses at intervals of six seconds. These impulses are required for telephone equipment purposes at manual and automatic telephone exchanges. Details of these arrangements will be discussed in a later section of the paper. The six seconds count wheel revolves once per minute and is fitted with 30 teeth. Every third tooth is cut deeper than the normal, thus allowing a pawl to close a contact ten times in every revolution of the count wheel.

The half-minute impulses are used for time-keeping purposes and also for supervisory signals on automatic telephone switching equipment. The impulses are provided by

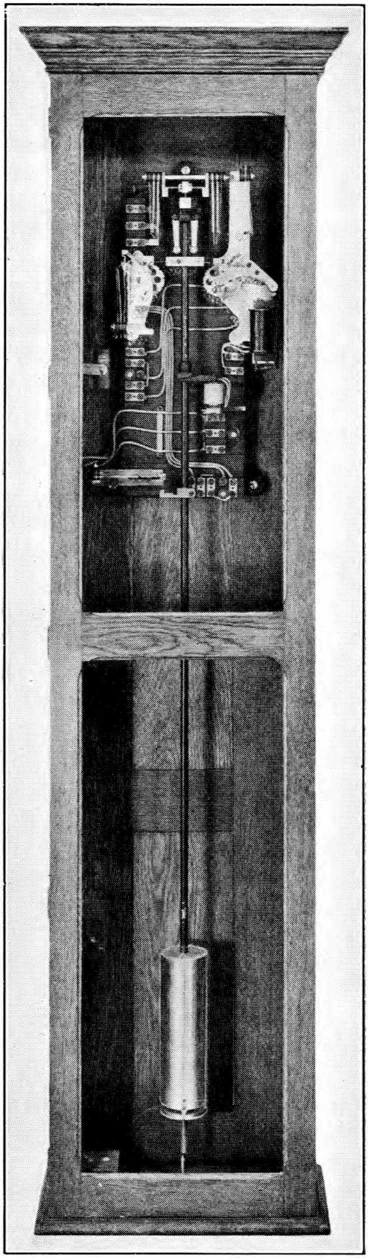


FIG. 1.

the action of a count wheel, which has 30 teeth cut on its edge. The wheel is turned by a pawl attached to the pendulum rod; the action of the pawl rotating the count wheel one tooth for each complete swing of the pendulum. The count wheel has two cuts diametrically opposite to each other, which permit the pawl to drop into the cuts and in this way engage a push rod once every half minute. The push rod is attached to a contact spring which, on being closed, makes a circuit for an electric impulse once every half minute.

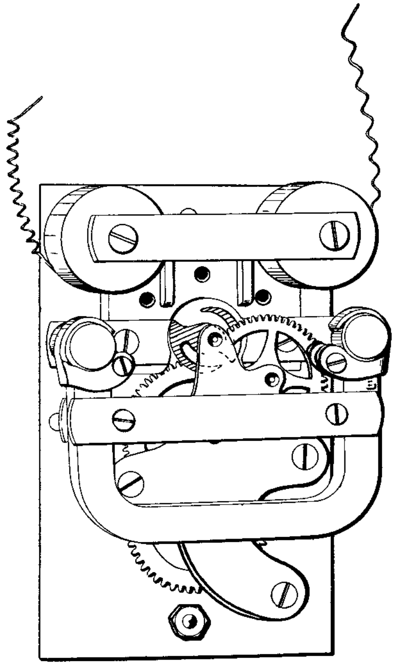
The regular swing of the pendulum is maintained by the application of a Hipp toggle contact and electromagnet. The latter has extended pole pieces which enclose the pendulum rod. Situated above the pole pieces, and attached to the rod of the pendulum, is an iron armature. The electromagnet is energized by currents from a 4-volt battery. When the arc of swing of the pendulum exceeds a certain minimum, a detent trails over a notched agate attached to the pendulum rod. If the arc of swing is reduced to the minimum, the detent engages in a notch and, on the return swing of the pendulum, acts as a toggle, raises a contact, and joins the driving battery momentarily through the coils of the electromagnet. The armature is attracted and this action gives an impulse to the pendulum. Driving impulses are not required more frequently than once every 15 complete swings of the pendulum. The half-minute count wheel is fitted with a synchronizer which provides for periodical synchronization with the Greenwich Mean Time clock.

The battery power is obtained by means of taps from the standard telephone or telegraph battery installation. To ensure that the clock is in a vertical position, a register is fitted at the lower extremity of the clock case and the V-shaped end of the pendulum rod must be directly over the register. A rating nut is fitted to the pendulum in order to facilitate adjustment.

The various contact springs in the master clock are so arranged that the external circuit is closed through a resistance before the battery spring breaks its contact. This precaution prevents sparking at the main contact.

Secondary dials.

The standard type of secondary dial associated with the master clock is shown in Fig. 2. The arrangement is, briefly, a combination of an electromagnet, (energized say every half minute from the master clock), associated with a permanent magnet and pole piece; with a movable soft iron



Post Office type of Secondary Dial.

Fig. 2.

keeper to increase or decrease the strength of the magnetic field due to the permanent magnet. · The poles of the electromagnet are placed behind those of the permanent magnet. Two Z-shaped soft iron armatures, fixed on the same spindle, lie, one between the poles of the permanent magnet, and the other between the poles of the electromagnet. When the energizing current passes through the electromagnet, the compound Z-shaped armature is caused to rotate a certain distance. A pinion is fitted to the arbor carrying the Z-shaped armature which, together with gear wheels, provides a 60-1 reduction for the purpose of turning the minute hand. A further reduction system of 12-1 is provided to drive the hour hand. If the voltage of the battery available is too high, resistance is inserted in the lead between the battery and the master clock to reduce the current to 250/300 mA, the value required to operate the secondary dials.

A typical lay-out of an electrical clock system, with associated timing devices for telephone purposes, is shown in Fig. 3. The illustration gives particulars of an interesting arrangement of master clock control in the City of London.

LONDON "METROPOLITAN" AND "NATIONAL" EXCHANGES.

Lay-out of Electric Clock and Time Impulse System.

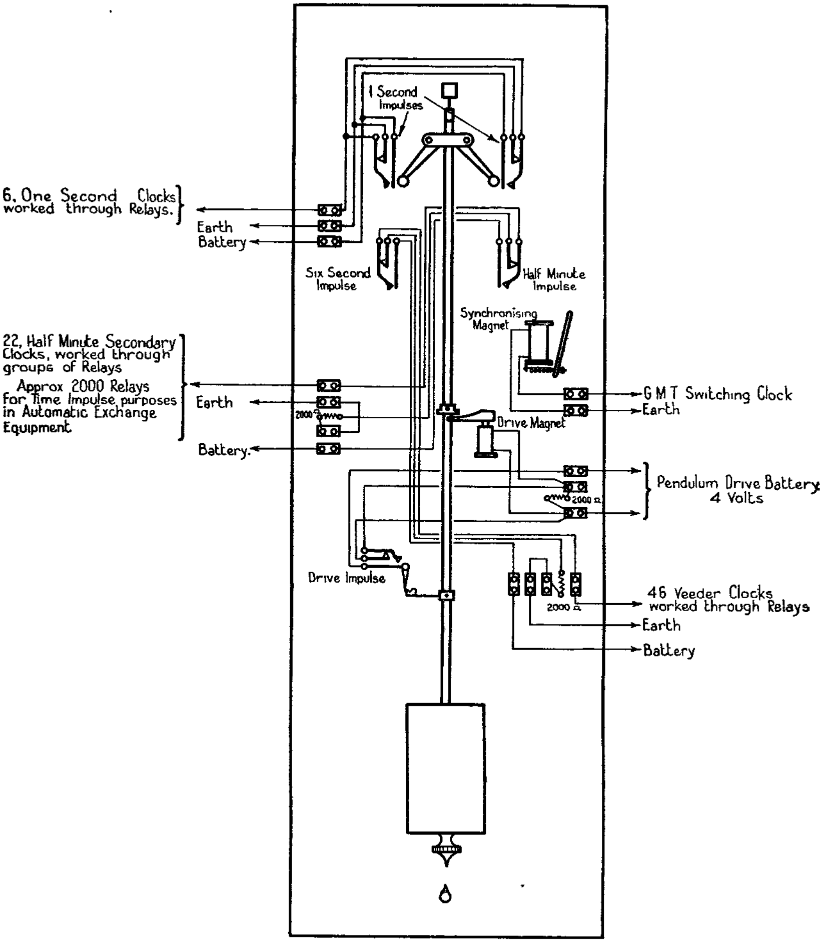


Fig. 3.

The Metropolitan and National exchanges are two of the latest automatic exchanges on the London "Director" system and are housed in one building in Wood Street. One master clock is used for the control of all secondary clocks, veeder clocks, and time impulse arrangements required for both exchanges.

In this instance there are:—

6 one-second secondary clocks
22 half-minute ,, ,,
46 six-seconds veeder ,,

and over 2000 time impulse relays associated with the automatic telephone equipment.

The wiring diagrams for the complete network are complicated and ingenious and Fig. 3 gives only a summary of the arrangements. It will be agreed that the master clock is carrying an important load.

The secondary dials are arranged in series, but where the installation is in a building containing several floors, it is necessary to arrange the clocks in groups with the aid of relays, one group as a rule being provided for each floor.

There are approximately 400 master clocks in service at the present time in the Post Office and experience of operation spread over a number of years indicates that the electrical system requires little attention after installation. In the fixing of master clocks care is taken to see that they are not fitted to walls subject to vibration, or placed in positions where wide variations of temperature may occur, such, for example, as may exist immediately over hot water radiators.

The standard master clock No. 36 is not fitted with a dial and, from some points of view, the title "clock" is a misnomer. It is, in effect, a mechanism for sending impulses of different time values; and a clock dial would be in the way of the spring contacts.

Timing arrangements for telephone exchange purposes.

This subject has developed to such an extent that a paper entirely devoted to Time Checks and other associated timing arrangements at manual and automatic telephone exchanges would appear to be fully justified. In the present review, attention can only be directed to the broad principles underlying the different timing arrangements, and the manner in which the master clock distributes impulses of different time values.

Time checks.

Time checks of the one-second Medlyn, Boddington, or McKichan types are installed at large telephone exchanges for the timing of trunk and toll calls. The check, which has no electrical connection with the telephone circuit, is brought into service by the operation of a lever-type locking key: it receives impulses every second from the master clock and, at the expiration of three minutes, a warning lamp glows. If an extension of the three minutes call is desired, the device is re-started by hand and the operations are repeated.

The arrangements are shown in diagrammatic form in Fig. 4. The seconds impulses from the master clock operate either up to 6 K relays joined in parallel, each K relay operating 30 time checks, or, in the case of large installations, a master relay of the L type actuates up to 36 K relays, each K relay in turn operating 30 time checks.

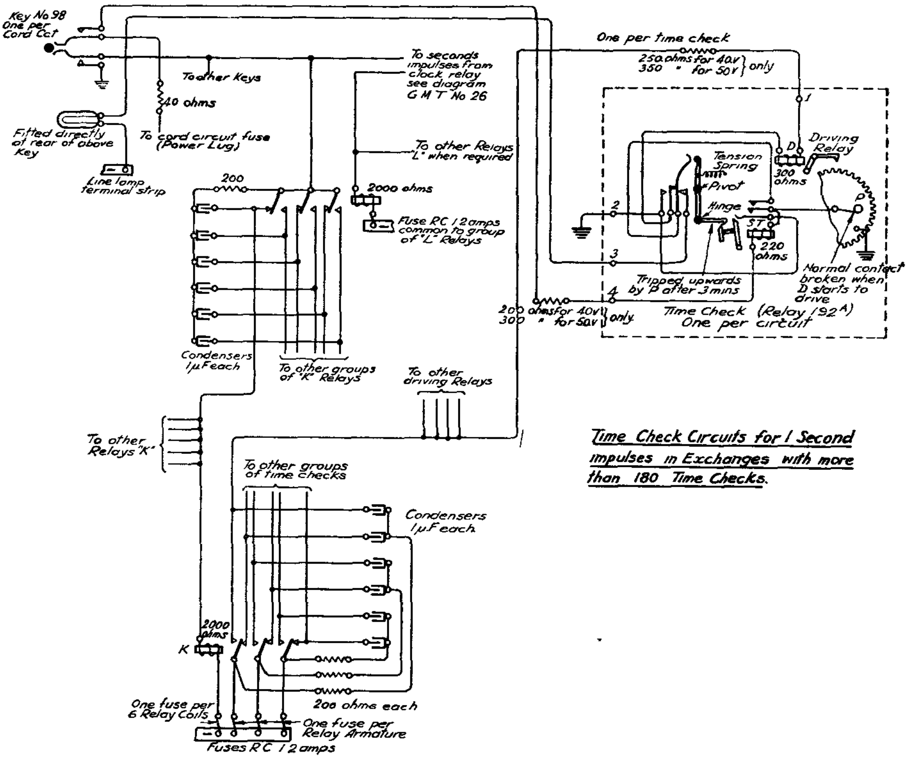


FIG. 4.

When more than 1080 time checks are installed, a second master relay of the L type is introduced.

As an indication of the magnitude of time check provision at large telephone exchanges, it is of interest to note that at the London Toll A exchange, which deals with all outward toll traffic, there are 1600 time checks in use.

It has been found that considerable wear occurs on the count wheel in the one-second time check and a modified McKichan type has been introduced which is actuated by an impulse every six seconds from the master clock. The impulses are distributed in a similar manner to the one-second impulses. The modified standard time check shown in Fig. 5 possesses several advantages. These may be summarized as follows:—

(1) It is a self-contained unit independent of auxiliary driving gear.
(2) Current is taken only whilst the device is in use.
(3) The time check occupies a small amount of space and can be fitted on mounting plates on standard apparatus racks.

The time check consists of two electromagnets mounted one above the other—one for driving the mechanism and the other for holding an engaging pawl. The switchboard equipment consists of a lamp to indicate the expiration of three minutes, and a standard lever key, which is a one-position key and locks when thrown. In order that the operator may enter at the end of the three-minute period, the warning signal glows 12 seconds earlier.

The method of operation is shown in Fig. 6. When the key is thrown, the current is supplied *via* the key contacts to the start relay ST and thence through the contact P to Earth on the driving wheel. The armature of relay ST is operated and locks ST, *via* its own contact, to Earth. Earth is also connected *via* contacts A to the driving relay D. The lamp circuit has been connected by B and disconnected by A on the operation of the relay ST. A battery impulse from the master clock is applied every six seconds to the driving magnet D, which steps the toothed wheel one tooth for each impulse.

After 28 six-seconds impulses (2 min. 48 seconds), the pin P on the toothed wheel reaches the pivoted armature and trips it mechanically, thus releasing the contacts A which

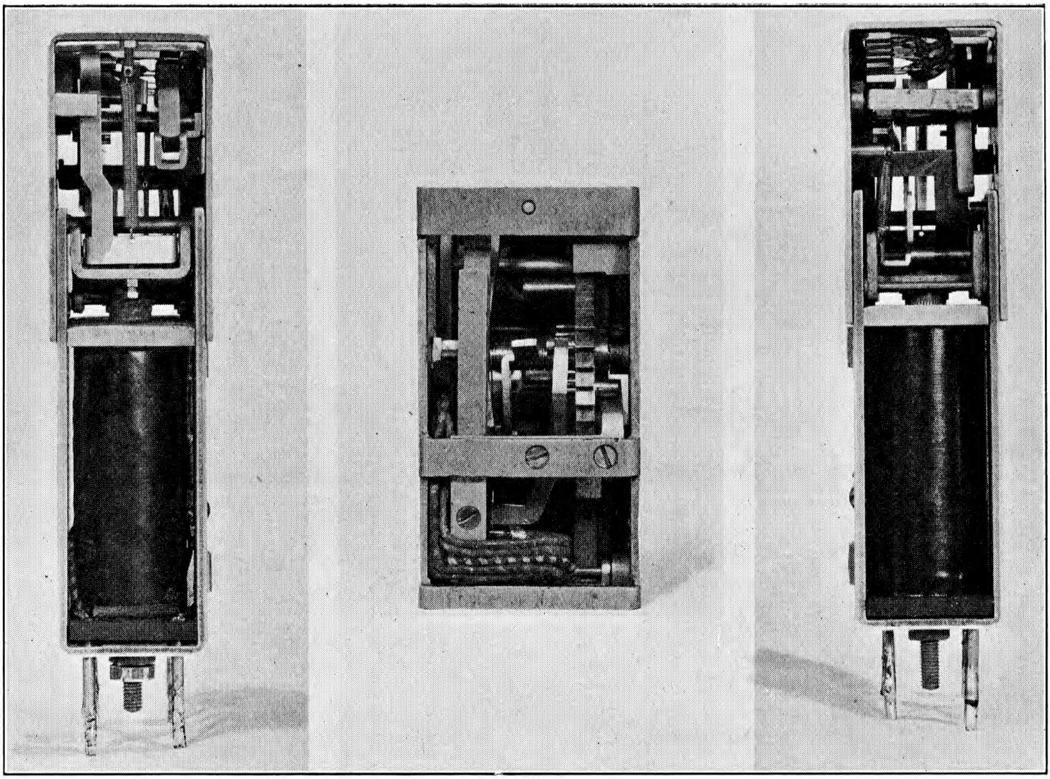


FIG. 5.

were operated initially by the relay ST. Contacts B of the relay ST, however, still remain operated. The toothed wheel returns to the normal position after the pivoted armature has been tripped. Earth is now connected *via* the contacts B and A of the relay ST to the lamp, which lights and continues glowing until the key is restored. The ST relay then releases and the time check is available for a fresh operation.

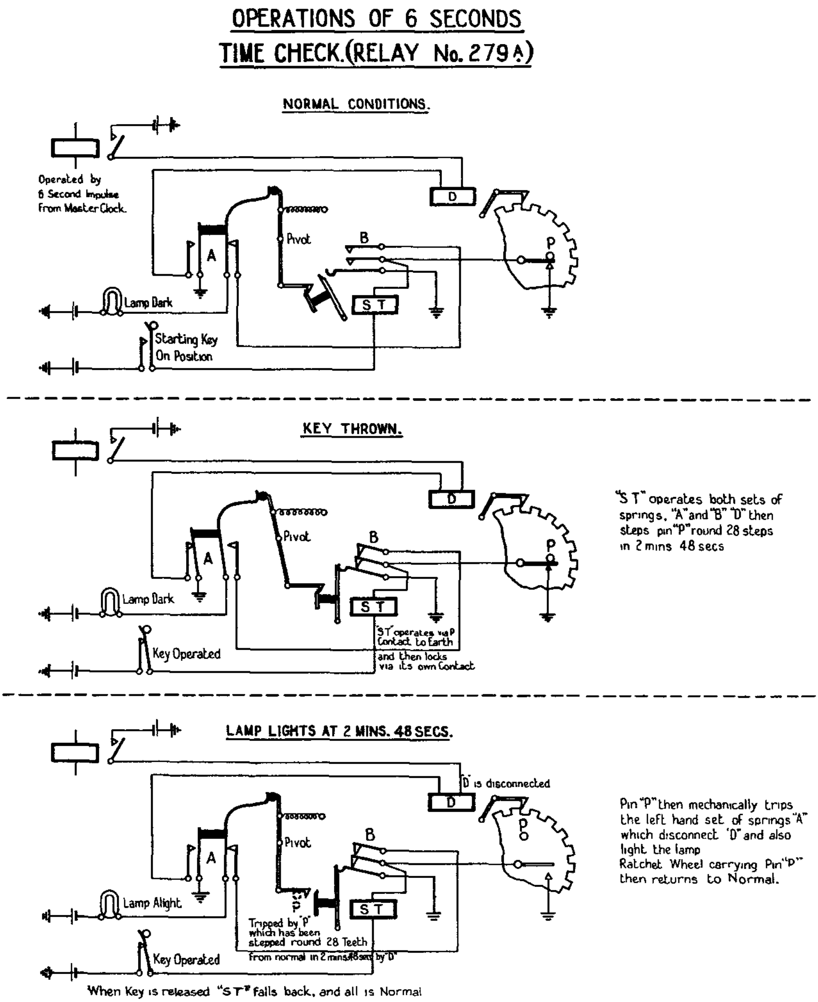


FIG. 6.

Master clock impulses used at automatic telephone exchanges.

Time pulses, one-fifth of a second in length, sent every half minute from the master clock, are used to operate alarm signals which disclose faulty or abnormal conditions on subscribers' lines or in automatic telephone equipment. There are several conditions requiring attention under this heading :—

(*a*) Each first and final selector in an automatic exchange equipment is fitted with a lamp, which glows under certain conditions. After a subscriber's call has passed on its journey to its subsequent selector, the lamp on the first selector ceases to glow, but, if for any reason, a faulty or abnormal condition is set up and the call does not proceed—such, for example, as when a subscriber lifts his receiver from the hook but does not dial, or when a short circuit exists on the line—the lamp continues to glow and, after a pre-determined interval, an alarm signal is given by apparatus controlled from the master clock. In the case of the final selector, the lamp glows and an alarm is given when, after a certain interval, a calling subscriber fails to replace his receiver after finishing a conversation.

(*b*) In director area automatic equipment there is a limited number of "A" digit selectors and directors, each of which should be in use only for the actual dialling and completion of the circuit to the called subscriber. In the interests of traffic efficiency, therefore, it is necessary that this equipment shall not be "held" beyond a normal period and, when abnormal conditions prevail, its release is forced automatically by impulses from the master clock.

(*c*) When an operator assigns a junction circuit, working into an automatic exchange but, for some reason, fails to complete the setting up of the connection, apparatus controlled by the master clock is brought into use to force the release of the "sender" equipment, of which there is only a limited number.

(*d*) A "time unit meter," brought into circuit by a "congestion" meter, is actuated by half-minute impulses controlled by the master clock. This meter gives an estimate of the amount of congestion of traffic in automatic exchange equipment.

(*e*) In order to facilitate the routine testing of automatic exchange equipment, automatic "routiners" are provided. It is necessary to fit these "routiners" with timing devices for checking the working of the apparatus and, for this purpose, impulses from the master clock are furnished through relays, at intervals of 2, 4, 8, 12, 60, 90, and 180 seconds.

The different timing operations at automatic exchanges referred to in this section are secured by a number of ingenious circuits. An attempt has been made in Fig. 7 to

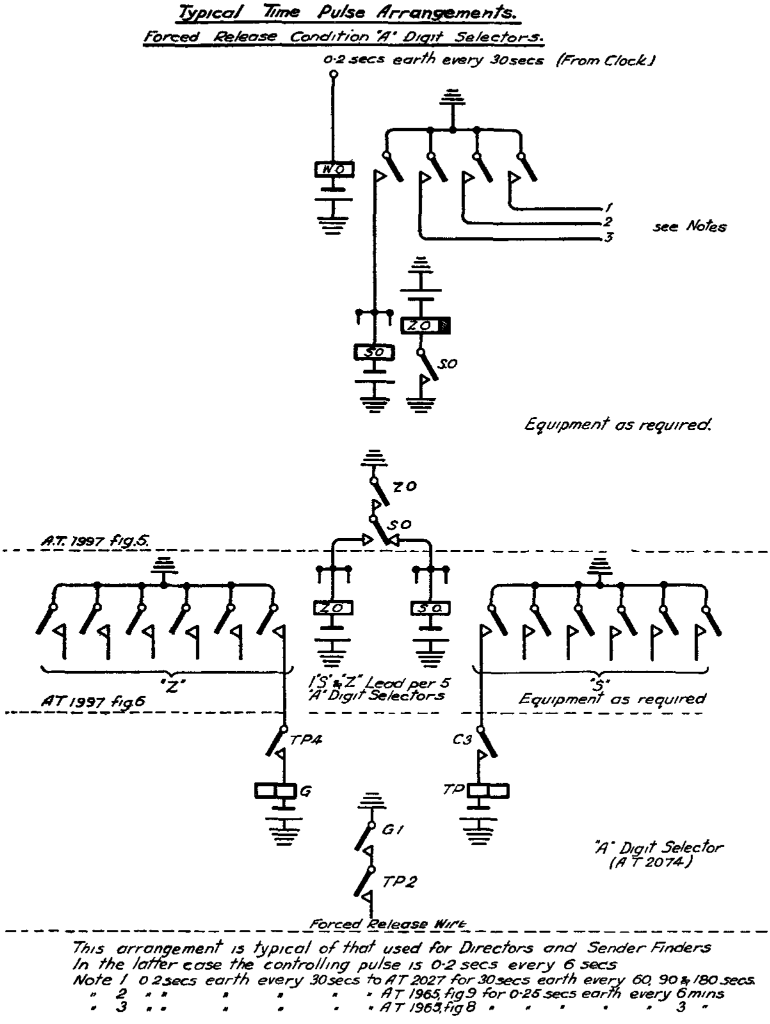


FIG. 7.

indicate in a simple manner the association of the master clock with one of these operations, namely, the time pulse arrangements associated with " A " digit selectors. The operating procedure is briefly as follows :—

An impulse from the master clock is communicated to the master relay WO, which operates, and its contact completes the circuit of the relief relay main SO, a contact of main SO operating the main ZO. The main ZO relay is slow releasing, *i.e.*, it has a lag of approximately 250 milli-seconds. With the main SO and the main ZO contacts operated, the section ZO relay functions and, provided that TP4 is operated, a circuit for a relay G in the " A " digit selector is completed.

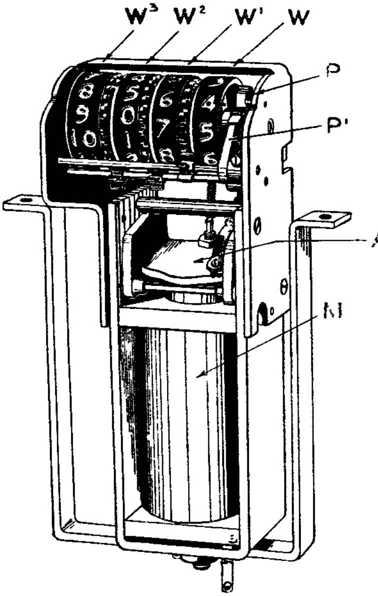
After a period of one-fifth of a second, the time pulse from the master clock is disconnected from the master relay WO, and the main relay SO is released. The main relay ZO will not release until a period of approximately one-fifth of a second, (the 250 milli-seconds lag previously referred to) and therefore the contact of relay main ZO will be in the operated position and the main SO contact will be released: thus the section relay SO will be operated and its contact will complete the circuit for a relay TP (Time Pulse) in the " A " digit selector. The contact C3 has already been operated independently when the " A " digit selector has been taken over by the calling subscriber, thus contacts TP2 and TP4 are operated.

When the next half-minute impulse is received by the master relay WO, the pulse is again repeated to the section relay ZO. and ZO contact completes a circuit previously prepared for relay G by the operation of TP4, *via* the section relay SO concerned. The closure of contact G1 completes the forced release circuit of the " A " digit selector.

The diagram shows a number of additional contacts serving other circuits requiring forced release conditions or alarm circuits, all operated from the master clock.

Veeder clocks.

A six-seconds impulse from the master clock operates distributing relays which are used for the control of veeder clocks. The clock is shown in Fig. 8 and comprises a timing arrangement similar in essentials to a telephone subscriber's meter. The clocks are mounted in a slot on the switchboard key shelf on auto-manual boards, trunk and toll suites, etc.



VEEDER CLOCK MECHANISM.

FIG. 8.

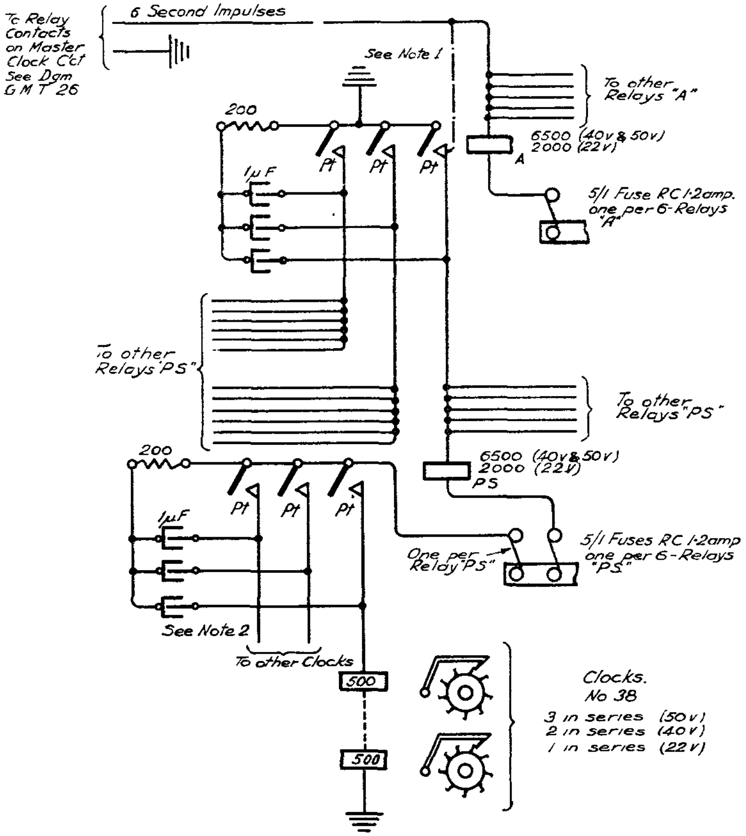
The time is indicated to the one-tenth part of a minute by plain numerals on a series of revolving drums.

The electromagnet operating the clock has a resistance of 500 ohms and requires a current of 30 mA. There are four count wheels associated with the clock. The passage of an impulse through the electromagnet attracts the armature, and a pawl P attached to the rear end of the armature advances the count wheel W one-tenth of its revolution for every impulse received. Another pawl P1 prevents any backward movement of the wheel W. The wheel W1 is advanced one numeral for each complete revolution of W; wheel W2 advances one numeral for every complete revolution of W1; and the final count wheel W3 advances one numeral for every *half* revolution of W2.

A wiring diagram of the veeder clock installation at telephone exchanges is shown in Fig. 9. The distribution of impulses to the veeder clocks shown in Fig. 9 follows in principle the arrangements already explained for time checks.

VEEDER CLOCKS.

Distribution Arrangements at Telephone Exchanges.



Note 1

	22v	40v	50v
Clocks per 6 Relays PS	18	36	54

In Exchanges where the ultimate number of clocks will not exceed the above figures. Relays "A" will be omitted and the "PS" Relays connected directly to the impulse lead as shown —·—·—·—·—

Note 2

A Pilot Clock No 38. (with compensating Resistance for 40v or 50v Exchanges) to be fitted adjacent to the time pulse distributing Relays, associated with the Master Clock

Fig. 9.

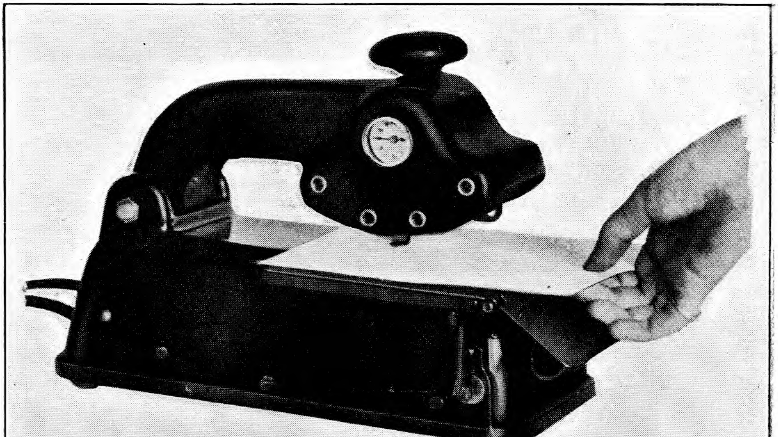
Modified veeder clocks.

A modified time check known as Clock No. 40 is being tried experimentally, for timing calls up to 12 minutes in duration by minutes and tenths of a minute. The clock is of the veeder type and the elapsed time is recorded by two drums, the right hand drum indicating tenths of a minute and the left hand drum intervals of one minute. The time check receives six-seconds impulses from the master clock and is started by the operator throwing a key at the side of the time check. Contacts are fitted in the device to operate an alarm lamp, which glows for 12 seconds before the expiration of each 3-minute period. This time check differs from the ordinary veeder clock in that it does not "tell the time," but is started by the operation of a key when a call matures and ticks off the elapsed time at intervals of six seconds. If the experiments with the new time check now in progress prove successful, it is anticipated that this device may replace the one-second and six-seconds time checks referred to earlier in this paper.

Electrical timing stamps for telegraph purposes.

Machines designed to stamp on telegram forms the time of receipt, are under trial at certain large telegraph offices.

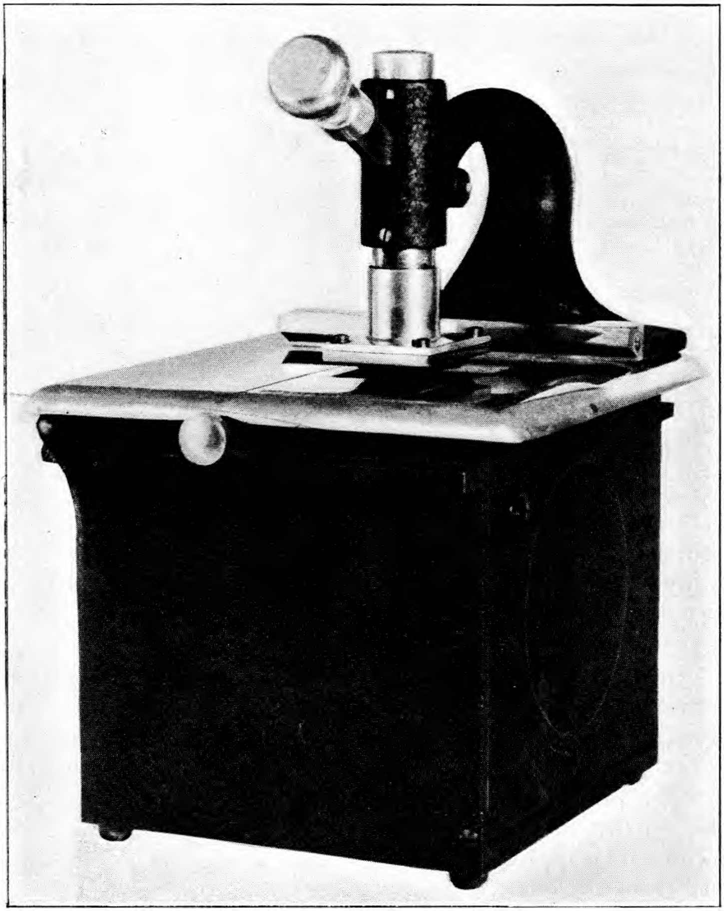
Two models having a master clock control are in use experimentally, namely, the "Stromberg" and the "Blick." Illustrations of these timing stamps are shown in Figs. 10



STROMBERG TIMING STAMP.

FIG. 10.

and 11, whilst the circuit arrangements for a group of Blick timing stamps recently installed at Leeds H.P.O. are shown in Fig. 12.



" Blick " Timing Stamp.

Fig. 11.

A train of wheels bearing hour and minute numerals, etc., on the rim, is rotated by half-minute impulses from the master clock. The timing stamp impresses on the telegram form the circuit designation, the hour and minutes, and " AM " or " PM."

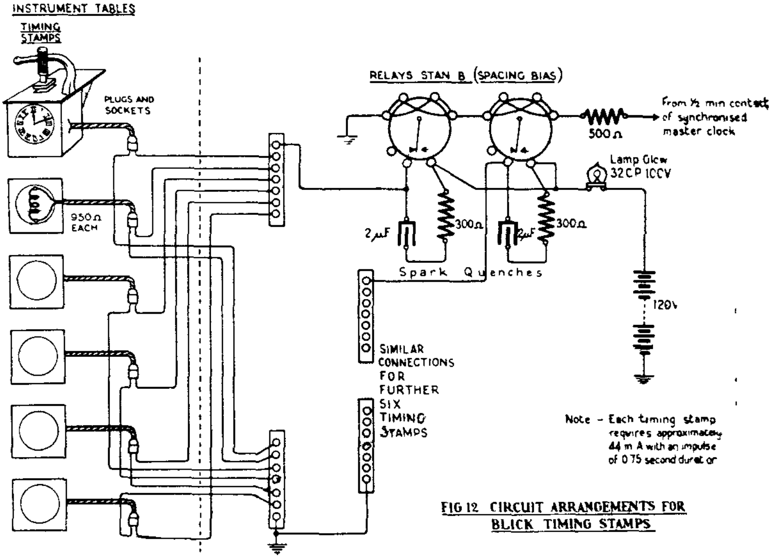


FIG. 12.

In the " Stromberg " machine, the train of wheels is carried in a " head " and when the message form is placed on the stamping platform, a power circuit is completed automatically, which causes the " head " to descend and impress the time on the message form.

In the " Blick " type, the telegram form is placed on a platform, beneath which is the train of wheels operated from the master clock. The impression is given by means of a rubber pad held by an arm, which is depressed manually.

The object of timing stamps is to minimize labour and consequently to increase the number of telegrams dealt with on busy telegraph circuits.

The Rugby International Time Signal.

It is true to say that the highest grade of time registration has been set up for the distribution of the International Time Signal from Rugby. The service has been in operation since December, 1927, so that it is possible to review the working of the installation after an experience of three years. Fig. 13 is a schedule prepared by the Astronomer Royal for the month of November, 1930, showing the small degree of error between the outgoing signals from Greenwich Observatory

INTERNATIONAL TIME SIGNALS FROM RUGBY RADIO STATION.

Schedule giving details of the degree of error in decimals of a second between the outgoing signals from Greenwich Observatory to Rugby, and the same signals emitted from Rugby Radio Transmitter and registered on a Wireless Receiver at Greenwich Observatory.

Date	10 hour (10 a.m.)	18 hour (6 p.m.)	Remarks.
1930.	Decimals of a second.	Decimals of a second.	
Nov. 1	0.00	+ 0.01	+ indicates that signal was received late.
2	.00	.00	— ,, ,, ,, ,, ,, early.
3	+ .01	.00	
4	.00	.00	
5	+ .01	.00	Monthly mean error +0.003 second.
6	− .01	+ .01	
7	.00	.00	
8	.00	+ .01	
9	.00	+ .02	
10	.00	+ .02	
11	.00	+ .01	
12	.00	.00	
13	.00	.00	
14	.00	+ .01	
15	.00	.00	
16	+ .01	.00	
17	.00	+ .01	
18	.00	.00	
19	+ .01	+ .01	
20	+ .01	+ .01	
21	+ .01	.00	
22	.00	.00	
23	.00	.00	
24	.00	.00	
25	.00	+ .01	
26	.00	.00	
27	.00	.00	
28	.00	.00	
29	.00	.00	
30	.00	.00	

FIG. 13.

to the Rugby Radio Station, based upon the calculated time of emission of the signals, compared with the same signals emitted from Rugby and registered by a radio receiver at the Observatory. From this schedule it will be seen that the monthly mean average error is +3 milli-seconds. Records have been kept daily in a similar form since the service was inaugurated and the error is of approximately of the same order throughout, viz., 3 milli-seconds.

This result may be regarded as highly satisfactory. I has been made possible by the full co-operation of scientist: and engineers and, in particular, by the provision of th highest grade of mechanism at the Observatory.

The transit circle on Zero Meridian at Greenwich Obser vatory is shown in Fig. 14 which also shows the telescop

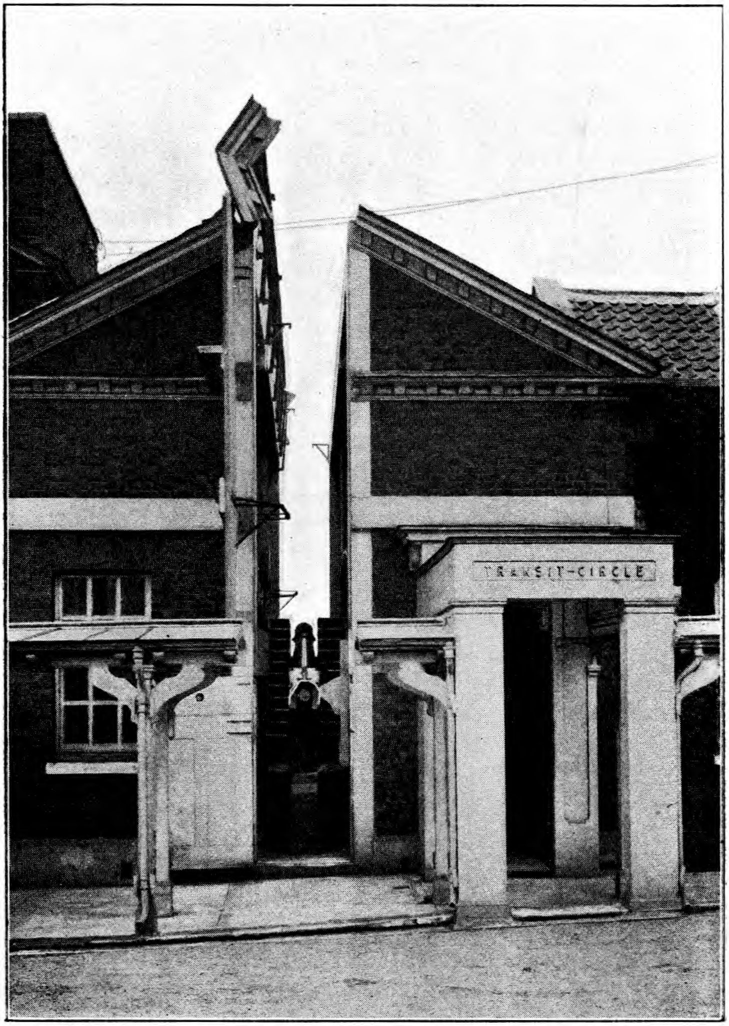


FIG. 14.

and collimators. Frequent observations of the clock stars are made through a telescope and from these observations the Standard Mean Time is derived.

The mechanism at the Observatory has been supplied by the Synchronome Company under the personal direction of Mr. Frank Hope-Jones. It consists of a " Free " pendulum, a slave clock, and a signal transmitter. A special chamber, free from vibration, and maintained at an even temperature, has been adapted at the Observatory for the accommodation of the apparatus : Fig. 15 gives a view of this chamber.

In order to avoid the loss of energy inherent in the behaviour of clock mechanism as generally designed, a Free pendulum, designed by Mr. W. H. Shortt on the Synchronome system and known as the " Shortt " clock, is used on the Rugby service. The Free pendulum is associated with the subsidiary clock called a " slave " ; rightly so named because the slave undertakes all the work and yet is so accurately controlled by the Free pendulum, that perfect synchronism between slave and Free is maintained. The slave clock is the standard synchronome master clock. The Free pendulum is made of Invar and is enclosed in an airtight case, the air pressure therein being reduced from normal atmospheric pressure to a suitable working point.

A comprehensive skeleton diagram of the mechanical and electrical arrangements, from the Free pendulum to the Rugby aerial, is shown in Fig. 16; and a first impression of such a complicated network makes one wonder how such scientific accuracy as has been so consistently recorded is possible of attainment.

The pendulum of the slave clock, in swinging to the right, rotates the count wheel and, after each revolution, the arm A engages the small trigger B. The trigger is opened and allows the impulse lever C to fall, thus giving a push to the pendulum by sliding down the inclined plane. At the end of the fall of lever C, the contact D is closed. The electrical circuit is from D, through the electromagnet and armature E, the battery, the electromagnet F of the Free pendulum, to the dial connections S of the slave clock. The current in passing through the electromagnet E attracts its armature and re-sets the lever C. The current also releases the trigger which holds the lever G of the Free pendulum, and so moves forward the finger of the slave dial

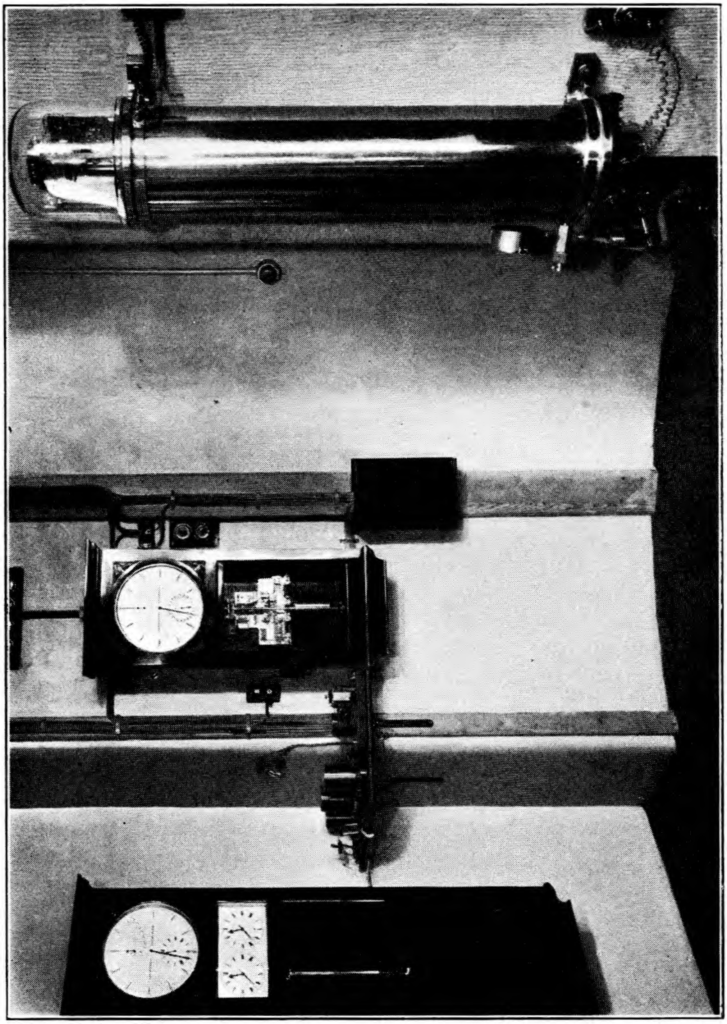


FIG. 15.

S one half minute. The cycle of operations of the Free pendulum corresponds with that of the slave clock.

The operation of resetting the lever H of the Free pendulum is as follows:—When contact is made at H, the current flows through the armature and coils K, and the battery, to the synchronizer L of the signal transmitter, also

INTERNATIONAL TIME SERVICE.

Wiring Diagram.

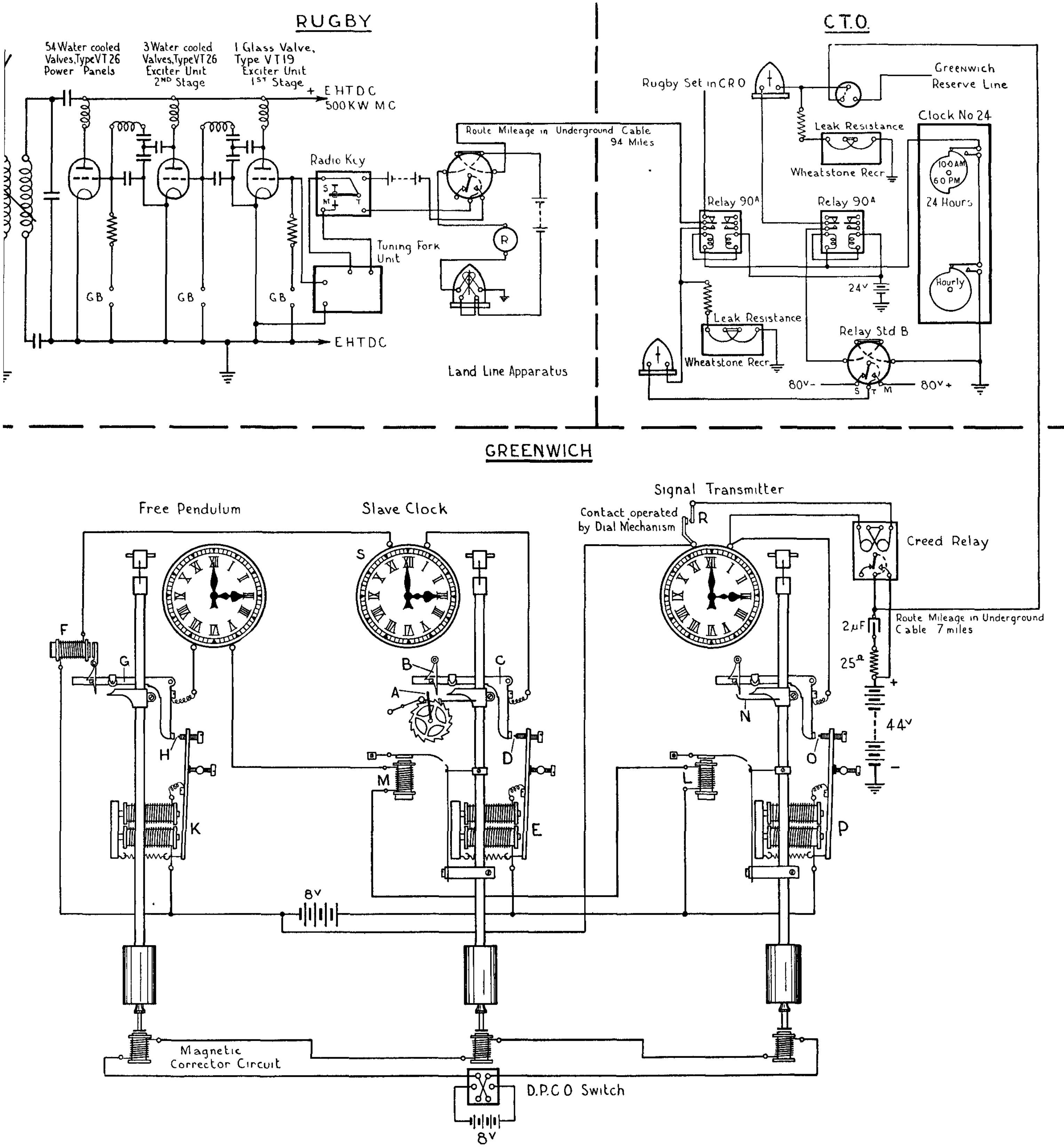


Fig. 16.

synchronizer M of the slave clock; completing the circuit through the dial mechanism of the free pendulum. Synchronizing in this manner is required in order to keep the three mechanisms in phase. The signal transmitter receives an impulse at every alternate swing of its pendulum, through the click N, which releases the trigger in a similar manner to that of the slave clock. The electrical circuit in the signal transmitter—after the impulse has been given—is through the impulse lever, the contact O, the armature and electromagnet P, and the battery, to the dial mechanism of the signal transmitter: also, if the contact arm R is closed, through the transmitting relay, from the local contacts of which the C.T.O. line is operated.

At the G.P.O. there is a special master clock fitted with two cams, the front cam revolving once every hour and the rear cam once in every 24 hours. Slots in the cams, close contacts at appointed times in the morning and evening of each day and operate two relays, which act as locking devices, joining the Greenwich Observatory line direct to the Rugby Radio Station. The time signal passes through a standard B relay and, on the local contacts of this relay, suitable voltages are applied to operate the land line apparatus of the Rugby radio transmitter. The normal arrangements for wireless transmission at the Rugby Radio Station are shown in skeleton form in Fig. 16.

The normal lag of the whole of the mechanical and electrical network has been very carefully measured and an allowance of 30 milli-seconds has been found to be sufficient to cover it. The lag, which has remained practically constant for three years, is compensated for by sending out the time signal from the Observatory 30 milli-seconds in advance of exact time.

An arrangement has been made at the Royal Observatory whereby each outgoing signal is recorded on a tape receiver and also, on the same receiver, a registration is made of the time of emission of the same signal at Rugby. In this way the data given on Fig. 13 has been built up.

The calculated allowance of 30 milli-seconds may vary from time to time within very small limits. There may, for example, be minute differences in the adjustment of relay contacts, or the setting of the master clock at the Observatory may not always be 100% accurate, or again, the tape recording arrangements at Greenwich, associated with both the outgoing and incoming signals, may be concerned with a very small portion of the error. It will probably be agreed that it is difficult to apportion the blame for any portion of a " lapse " of the order of 3 milli-seconds in such a complicated network!

The time signal is of the rhythmic type and consists of 306 beats 0.1 second in length in 300 seconds, or at the rate of 61 beats per minute. The commencing signal, and also that at the end of each minute, is sent in the form of a dash 0.4 second in length, exactly on the zero or O of GMT.

The signal is sent twice daily, at 09.55.00 GMT and 17.55.00 GMT. These times have been selected as the most suitable for reception in all parts of the world. A printed notice is issued monthly by the Admiralty giving particulars of the corrections required to the standard master clocks controlling the emission of wireless telegraphy time signals in different parts of the world. These corrections are made as the result of observations carried out on the transit circle at Greenwich. The notice for October, 1930, is reproduced in Fig. 17 and the details given provide a useful comparison between the performance of the different master clocks, and, incidentally, pay the highest of compliments to the work of the British station.

The B.B.C. Time Signal.

An important and universally popular feature of the B.B.C. programme is the regular broadcasting of Greenwich Mean Time by means of the " six pips " signal. Although the Post Office is not responsible for the signal, there is a partnership of interests in the matter, in that the Mean Time Clock at Greenwich Observatory used for B.B.C. purposes, is the same clock from which the hourly synchronizing signal is sent to the G.P.O. This clock is synchronized by the *Master* Mean Time Clock, a Free pendulum clock on the Synchronome system. The physical circuit between the Observatory and the studio at Savoy Hill is rented from the Post Office.

A skeleton diagram of the Mean Time Clock circuit at the Observatory, showing also the manner in which the B.B.C. time signals are transmitted, is given in Fig. 18. The three electrical contacts shown in diagrammatic form are operated from the escape wheel of a single

ADMIRALTY NOTICE TO MARINERS.

No. 1941.

WIRELESS TIME SIGNALS.

CORRECTIONS TO RUGBY, ANNAPOLIS, BORDEAUX AND NAUEN W/T TIME SIGNALS.

Former Notice.—No. 1814 of 1930.

Details.—The corrections to the above-mentioned W/T time signals for the month of October, 1930, as determined at the Royal Observatory, Greenwich, are as follows:—

	Rugby.		Annapolis.	Bordeaux.	Nauen.
Date.	10 hr. Signal.	18 hr. Signal.	17 hr. Signal.	20 hr. Rhythmic.	12 hr. Rhythmic.
1930.	seconds.	seconds.	seconds.	seconds.	seconds.
October 1	−0.06	−0.06	+0.09	+0.07	−0.05
2	− .04	− .05	+ .10	+ .08	− .02
3	− .06	− .06	+ .10	+ .02	− .03
4	− .02	− .02	+ .08	+ .02	− .06
5	− .01	− .01	+ .11	+ .02	
6	− .01	− .01	+0.06	+ .01	− .11
7	− .01	− .01	+1.08†		− .06
8	− .01	− .01	+0.13	+ .02	− .08
9	.00	.01	+ .07	+ .04	− .09
10	+ .01	+ .03	+ .12	+ .05	− .08
11	+ .04	+ .05			+ .04
12	+ .00	+ .05	+ .15	+ .09	
13	+ .06	+ .06	+ .12	+ .11	+ .08
14	+ .04	+ .03	+ .15	+ .11	+ .06
15	+ .03	+ .03	+ .10	+ .11	+ .02
16	.00	+ .01	+ 10	+ .08	− .05
17	.00	+ .02	+ .09	+ .05	− .05
18	.00	.00	+ .06	+ .09	− .05
19	+ .02	+ .01	+ .09	+ .08	
20	+ .01	+ .02	+ .13	+ .08	− .05
21	+ .02	+ .02	+ .13	+ .07	+ .04
22	+ .02	+ .02	+ .14		.00
23	+ .02	00	+ .18	+ .05	− .05
24	+ .01	.00	+ .15	+ .03	− .15
25	.00	.00		+ .01	+ .01
26	*	− .01	+ .10	+ .03	
27	− .02	− .02	+ .12	+ .01	.00
28	− .02	− .01	+ .13	+ .07	− .05
29	− .01	− .01	+ .08	+ .10	− .08
30	− .02	− .02	+ .12	+ .12	− .10
31	−0.02	−0.02	+0.13	+0.08	−0.10

Notes.—The sign + indicates that the signal was transmitted late.
* No transmission. (Constructional alterations to Rugby Aerial)
† Transmitting clock defective.

Authority.—Royal Observatory, Greenwich. (*H. 57/30.*)

By Command of their Lordships,

H. P. DOUGLAS,
Rear-Admiral and Hydrographer of the Navy.

Admiralty, London,
25th November, 1930.

FIG. 17.

DIAGRAM OF THE GREENWICH MEAN TIME CLOCK CIRCUIT FOR THE B.B.C. TIME SIGNALS. "SIX DOT SECONDS."

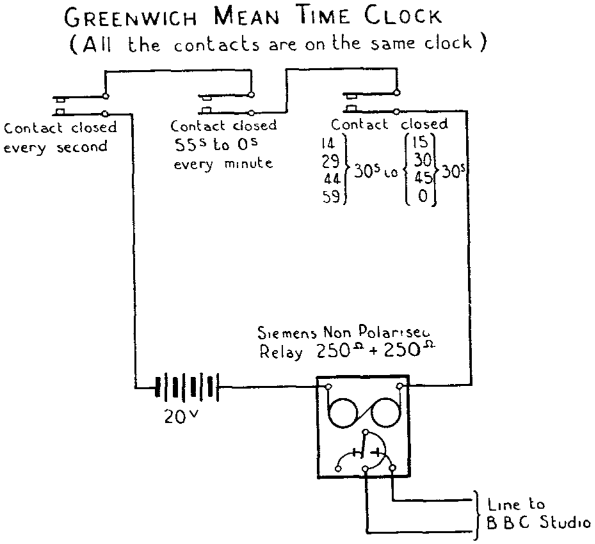


FIG. 18.

clock mechanism, and the signals are fully automatic. A Siemens relay is brought into circuit for one minute every fifteenth minute during the 24 hours, whilst a second contact closes from 55 seconds to 0, *i.e.*, 60, seconds, every minute during the 24 hours. A third contact is closed every second. By means of this arrangement, a succession of six beats can be transmitted from 55 seconds to 0 second, the beginning of successive beats being separated by intervals of one second, and the duration of each beat being approximately one-tenth of a second. The last or final beat denotes zero, that is to say, if the broadcast signal is emitted at the hour, the last beat of the series would denote the exact hour. The selection of suitable times for the broadcasting of the time signal is controlled at Savoy Hill. The musical note of the signal is obtained through the agency of a valve, oscillating at audio frequency, in the studio. The six beats from the clock at the Observatory are made to control the grid circuit of the oscillating valve, so causing the familiar six "pips."

It is interesting to refer to the origin of this particular form of broadcast signal. On April 21st, 1923, when Mr. Frank Hope-Jones was delivering his first broadcast talk on Daylight Saving from 2LO, he concluded his lecture on setting the hands of the clocks forward, by counting out the last five seconds from his watch. This was the first " Time signal " transmitted from 2LO, and the same method was followed approximately by the announcers each evening. When a decision had to be reached on the form of the Greenwich Mean Time broadcast signal, it was thought desirable that listeners should be given something simple, and also in something like the form to which they had been accustomed—hence the establishment of the " six pips."

Clocks driven from Alternating Current Power Supplies.

It is becoming well-established practice to maintain the frequency of alternating current supply systems at a constant periodicity; and one of the important results of this development is the provision of a synchronous time service driven direct from the mains. Clocks of this type have been introduced by Messrs. Everett, Edgcumbe & Company and are known as " Synclocks." The usual clock mechanism is replaced by a miniature motor which is removable from the interior of the case. The motor is synchronous in action, in that it's speed is directly proportional to the frequency, and it drives the hands of the clock through a suitable gearing. The stator consists of an electromagnet with two poles, between which the rotor revolves. The rotor is totally enclosed in an oil bath. The clock is silent in action and does not require attention when once set to correct time, provided that the periodicity of the A.C. power supply remains constant. The clocks also appear to be unaffected by vibration or disturbance, such as may arise from passing traffic affecting the walls of a building.

The time-keeping properties of " Synclocks " are entirely controlled by the power supply, and any stoppage or variation in the supply would cause considerable inconvenience and some expense in re-setting the clocks. They also suffer from the disadvantage that no indication is given of stoppage for any reason, nor of any temporary stoppage of the A.C. supply, after which a clock would re-start and therefore indicate incorrect time. In the American and German types of A.C. clocks, a disc is operated when a stoppage of any kind occurs and some device of this kind would be an improvement in the "Synclock." It is fair to say that, in practice, interruptions to A.C. power supply are infrequent.

Illustrations of various types of Synclocks are shown in Fig. 19, whilst the synchronous motor is shown in Fig. 20. The type B motor measures approximately $2\frac{1}{2}$ inches square

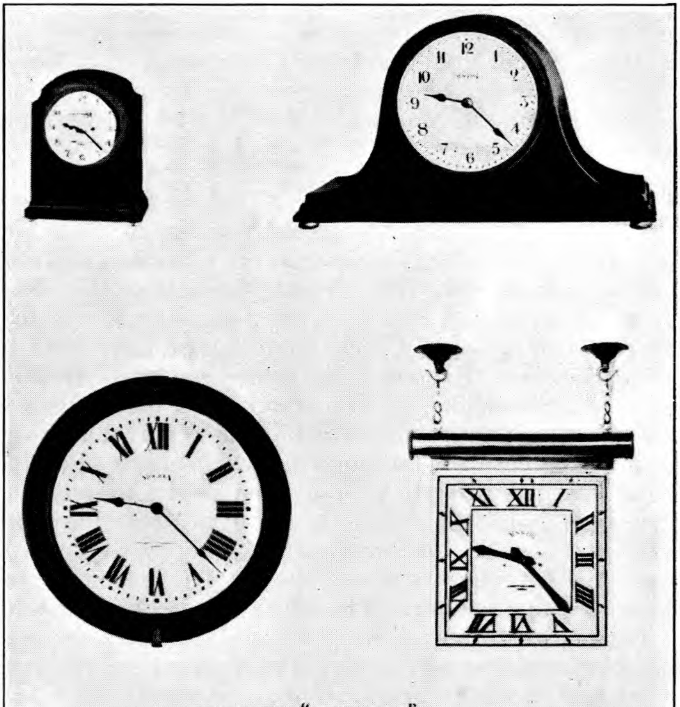

GROUP OF "SYNCLOCKS"

FIG. 19.

and, according to a pamphlet issued by the Company, it consumes about 4 watts at 110 volts. Assuming the clocks are worked from a lighting system, with an average charge of 3d. per unit, the annual cost of power per clock works out at approximately 9/-. The life of the motor is estimated by the makers at 5-7 years.

Two "Synclocks" have been under close observation

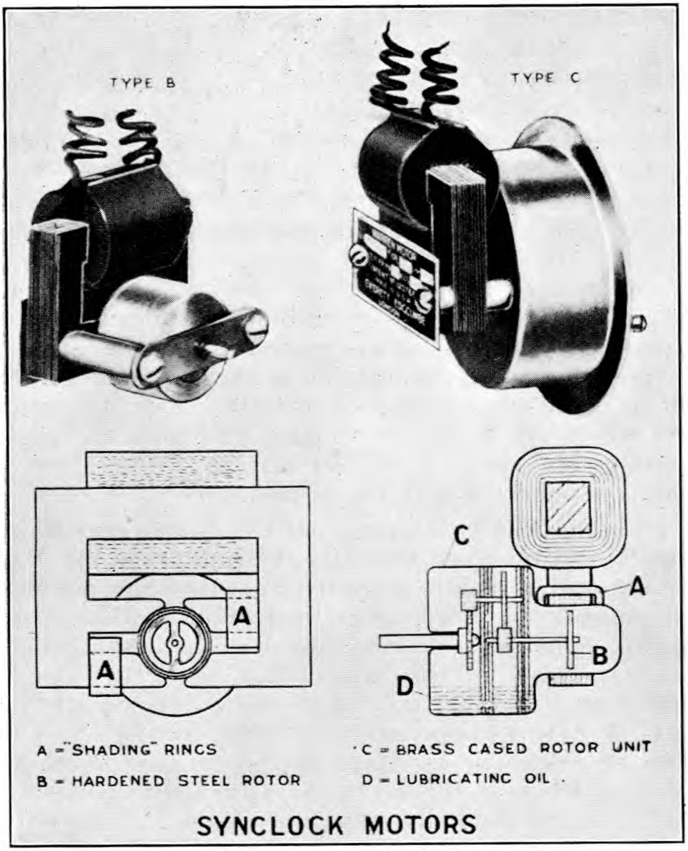


FIG. 20.

in the Engineer-in-Chief's Office for several months and a reasonably accurate record of time-keeping has been maintained. There is a field for this type of clock and arrangements have been made to instal a few of them experimentally in Post Office buildings adjacent to main roads which are subject to vibration due to heavy vehicular traffic. A careful comparison of the economics of mechanical, electrical impulse, and A.C. clocks is being made and in due course it will be possible to decide whether clocks of the A.C. type can be adopted as a standard arrangement in all Post Office buildings.

Conclusion.

There has been an interval of 18 years between the presentation of two papers before this Institution on the subject of Time. During this period there have been so many inventions and improvements in the distribution of electrical time impulses and the mechanisms associated therewith, that one is justified in using the word *marvellous* to summarize the achievements of scientists and technicians in this work. It is a wonderful conception of co-operation between Creator, scientist, engineer and craftsman, when one remembers that the clock stars, millions of miles distant from this planet, provide the basis of correct time to the astronomer who, in turn, makes calculations of the utmost accuracy in order to check the working of scientific clock mechanisms. These clocks are so nearly constant that only the slightest corrections are required, at intervals, to bring them into exact correspondence with the distant stars.

From the Standard Mean Time Clock at Greenwich, time impulses are broadcast from Rugby and from the B.B.C. stations; G.M.T. is also delivered from the same source to a wide network of Post Office and public buildings in the kingdom, either as a definite signal, or as a synchronizing agent. Included in this distribution is " Big Ben " at Westminster. Wherever master clocks are synchronized with G.M.T. this co-operation continues, through the timing devices on telephone exchange equipment, to the telephone subscriber, whose trunk and toll calls are accurately recorded, and, if an absent-minded subscriber fails to restore the telephone to its hook, an alarm brings his delinquency to light.

An attempt has been made in this brief review of Post Office practice to direct attention to the part taken by Post Office engineers in a branch of communication engineering in which all are closely concerned. If one could visualize with any degree of accuracy what will have happened by the end of another 18 years, there will probably be little change to record in the duties of the Astronomer-Royal's staff at Greenwich Observatory. They will still be checking the work of men's hands by the stars so many millions of miles away, but with us the position may be very different,—the friendly tick of the " Grandfather " clock may have given place to the " all electric " system; maybe the master clock at the telephone exchange will provide time service direct to subscribers by means of their telephone circuits; or it might be an " all mains " system operated from the A.C. supply, or, yet again, an " Æther " system of time distribution, provided on an " all-world " basis from the Rugby Radio Station. Science knows no boundaries, and in whichever direction progress lies, there will always be opportunities for co-operation between the inventor, the scientist, and the engineer in controlling electrical time services.

DISCUSSION.

SIR FRANK DYSON. (Astronomer Royal):—

Mr. Gibbon has taken us over a very wide field and I can only follow him in one or two branches of his paper. I think we are all very interested to see how many ramifications there are in this business of time control. Certainly 18,000 clocks is a large number to control, apart from whatever may be done in telephone exchanges and telegraph offices.

I read over this morning some of the reports which Sir George Airy had made on the subject of time service centred in Greenwich, beginning many years ago and continued for something like 20 years, and I found them very interesting reading. To begin with, in 1849, the idea of electric control was certainly in Sir George's mind and he remarks that "The general utility of the Observatory will be increased by the dissemination through the kingdom of accurate time signals by an original clock at Greenwich, and I have entered into correspondence with the Authorities of the South Eastern Railway."

After six or seven years—in 1856—he reports again:—"One of the galvanic clocks in the P.O. Department, Lombard Street, is already placed in connection with the Royal Observatory and is regulated at noon every day, sending also a signal before noon to inform me how far it is wrong, and in the afternoon, to assure me of the efficiency of the correction. Other clocks at the General Post Office are nearly prepared on the same lines. In a difficulty attending a new enterprise of this kind, there is caused to all parties an amount of trouble which cannot be adequately expressed by many. I can only express my thanks for the aid Sir Latymer Clark has given me in a very annoying series of experiments."

In 1860, "The regulation of the Post Office clocks has failed almost completely. I expect that all will be restored shortly to their original perfection."

In 1861, "Since our open-air galvanic wires have been established, our communications with London and Deal have been perfect. Signals are sent daily to almost every part of England."

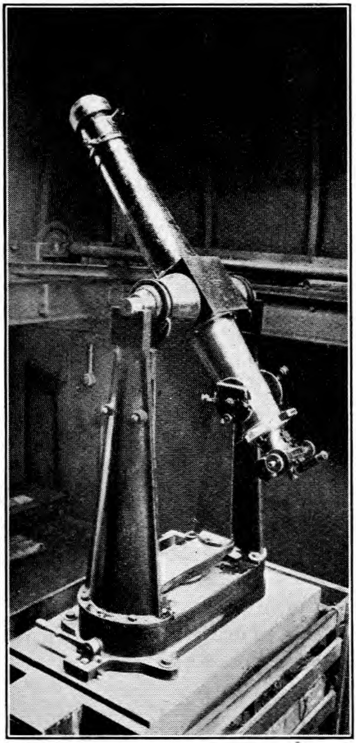
In 1865, "In the office of the Telegraph Co., the Superintendent has mounted a very beautiful apparatus for sending signals and firing signal guns at Newcastle and Shields.

In 1869, " At Lombard Street Post Office, the clock on which the others depend and which has a gaining rate, stops itself at 12 o'clock, a few seconds before Greenwich noon, and is started by our current at Greenwich noon."

In 1874, reference is made to a new chronograph establishment which can distribute the 10 o'clock signal along 60 different lines.

I have given these extracts to show how the G.P.O. Time Control has gradually grown from small beginnings.

May I now show on the screen a photograph of the telescope with which the time-determinations have been made



TRANSIT INSTRUMENT WITH WHICH TIME IS DETERMINED AT GREENWICH.

FIG. 21.

at Greenwich in recent years. It is a much smaller telescope than the one Mr. Gibbon showed on the screen, but has the advantage of being easily reversible, and also admits of the level of the axis being frequently determined. In a good night's work with observations of 10 stars interspersed by 10 readings of level, the error of the time determination should seldom exceed one fiftieth of a second. This instrument reads the time by the Astronomer's fundamental clock—the rotating earth. I don't say the rotating earth is a perfect clock, but it is not easy to find a better.

The Astronomer's clock is kept in close relationship with a mechanical clock. Every night the stars are observed, their time-indication is compared with the sidereal standard clock; "Shortt No. 3." The clock is kept at constant temperature, and no attempt is made to regulate it, but its errors are booked. To show how well it goes, I may say that last night after a fortnight's cloudy weather, we found it only one-tenth of a second different from our expectation.

But we have also another standard clock, also a "Shortt" clock. This keeps mean solar time. The solar day is four minutes longer than the sidereal day, and, if we do not want our meals at all sorts of irregular hours, we must keep solar time. Each day we compare our standard solar clock with the sidereal clock and as we know the error of the sidereal clock, can calculate the error of the solar clock. It is put right regularly every day and then the signals are sent by wire to the Post Office.

Mr. Gibbon put on the screen a table showing how much the time signals from Rugby, Nauen, Bordeaux and Annapolis were out. This is not a fair comparison, but is favourable to Greenwich. All the signals are very good, and I am not prepared to say that any one is better than the others. There are slight and there are considerable differences, and some of them are allowed for, and some are under investigation. The signals from all those big wireless stations are very accurate and are really, as Mr. Gibbon said, made up by the accurate observation of the stars combined with the excellence of the clocks.

MR. H. R. KEMPE (late Chief Electrician, G.P.O.):—

What I much admired in the paper Mr. Gibbon has read is the immense amount of matter which he has so very carefully and concisely put together. It of course requires very great study to grasp all he has said, and it is a matter of surprise to me what an extraordinary amount of progress has been made since I had the honour of being in the Post Office Service.

Mr. Gibbon—I do not say it at all in a critical spirit—has not said anything in reference to good timekeeping from the point of view of the "Man in the Street." We have scattered, as you know, all over England, a great number of clock towers, also many turret clocks in churches, and very little indeed has been done in reference to the proper synchronizing, electrically or otherwise, of such clocks. Something, of course, has been done, but it is a difficult thing to deal with such clocks. What really takes place is this: a local clockmaker who has the use of a motor car, goes round about once a week to several villages, and regulates and sets the clocks. We know that these clocks are of various kinds, good, bad, and indifferent, some distinctly bad.

I should like to draw attention to a remark made by Mr. Gibbon in the early part of his paper. He said that mechanical clocks are being replaced by electrical clocks in a large number of cases for the sake of economy. He refers to maintenance but does not refer to first cost. The actual cost of electrically driven small clocks, irrespective of the cost of the master clock, is, I believe, rather less than that of mechanical clocks, whilst the electrically driven clocks possess great time keeping advantages.

LIEUT.-COL. K. EDGCUMBE (Past-President of the Institution of Electrical Engineers):—

In dealing with synchronous time systems, Mr. Gibbon expressed the opinion that where clocks were liable to much vibration, the synchronous clock should prove very valuable. I would go further, however, and venture to think that quite apart from this very distinct advantage, the synchronous system possesses very many others, as compared with the spring-driven clock.

As regards cost, at 1d. per unit, this works out at 1/6d. per year. (I may say that the figure of 4 watts as the consumption given by Mr. Gibbon has now been reduced to about 2 watts). Even assuming 3d. per unit, the annual cost is only 4/6d., which is a very small figure compared with the expense of the weekly winding and still more frequent resetting which the spring-operated clock entails.

The only possible objection that I have heard raised is that if the supply fails, the clock will stop, but my own experience, and that of others extending over several years, is that in practice this simply does not happen. Even if it did, the only result would be that one or more clocks would have to be reset,—surely a small price to pay for the avoidance of all attention for years on end. These are days of co-operation, which the cynic has described as getting the other man to do one's job for one. Correct time is now a by-product of the modern electric power station and is to be had practically for nothing; it is up to us to " co-operate " by using it.

MR. FRANK HOPE-JONES. (Managing Director, Synchronome Company):—

I have been hypnotised during the evening by the lecturer's apparatus, winking and blinking the one dot, six dot, and thirty dot, seconds, the six dot in red. Though not intended as a time-signal, it would serve as such.

I think you might be interested to know something more than the lecturer told you about the Post Office type of master clock and the method of operating it. Mathias Hipp invented it in 1842, and it became very popular as a self-propelled independent clock. It was tried out in the Neuchatel Observatory and, before he died at the age of 80, in 1893, Hipp had three or four clocks in the Observatory which almost achieved a record.

Having spent most of my life in finding methods of taking substantial contacts off the pendulum without the latter knowing anything about it and without robbing the clock of any energy whatever, and taking that as an absolute essential of my profession, I am disappointed that the Post Office is using the Hipp clock for doing so, and have in fact turned it into a mere machine for making contacts. The pendulum, in making those contacts, barges into springs at each end of its sweep, and the whole of the contact energy is robbed from it. The efficiency of the contact is measured exactly by the extent to which highway robbery is committed and it is committed at the worst period from a horological point of view. I do feel that it is so unnecessary; all these powerful switching operations may be taken from a pendulum without the latter knowing it is giving anything, and I have shown what marvellously accurate timekeeping may be secured at the same time.

Electrical Engineers so seldom meet to discuss electric clocks that it would be deplorable if they imagined that the system described by the lecturer represented modern electric time service. Only the Post Office, with its unlimited batteries and network of wiring available for synchronization could afford to ignore all the advantages that flow from the transmission of energy through the surfaces of the contact, with uniform wave-shape of impulses, whose duration is dependent on the self-induction of the dial coils, security for every dial getting the current it wants, compensatory action, battery warning, and impossibility of stopping in closed circuit. We have achieved a standard British practice embracing all these features, far superior to foreign systems, —not my firm alone, but others who have followed these methods.

I would compliment the lecturer upon his able exposition of the Post Office timing system. The purposes fulfilled by electrical impulse movements are many and their applications ingenious.

MR. M. C. PINK. (Deputy Controller, London Telephone Service):—

There are one or two interesting points in connection with the indication of time in telephone exchanges. In many exchanges, for instance, you will notice that figures have been discarded from the clock faces, their places being taken by arrow heads. It is rather surprising that one does not miss the figures on these dials. So far as the veeder clock is concerned it is of course an enormous advantage to bring the time indicator down to the switchboard level.

The need for accuracy in timing has been emphasized very much by the change in the method of charging for telephone calls, which is now minute by minute beyond the first period of three minutes. Tolerances of even a few seconds may be queried and the value of accuracy in timing is clear.

It is very difficult for an operator to come in at the proper time to inform the public of the passage of time. According to notes on the tickets, intimations are given at 3, 6, 9 minutes, etc., but from time to time these intimations are disputed by the public. There is an advantage in giving the time intimation automatically and this is being done experimentally at present by means of a "pip" signal. If subscribers can understand this signal it will be an advantage. Another definite advance is the automatic disconnection of the time check when the subscriber replaces his receiver. It is very difficult for the operator to act in every case directly she receives the clearing signal from the subscriber.

It is now possible to convert a mechanical signal into a human voice by means of an adaptation of the talking film. I am wondering whether we can introduce, in place of the " pip " signal referred to, a voice which says at the proper time " 3 minutes," " 6 minutes," or whatever is required, used in association with the device which automatically cuts off the timing mechanism when the subscriber hangs up his receiver. I think this is a possibility worth considering.

COLONEL A. S. ANGWIN :—

Mr. Gibbon's description of the Rugby International Time Signal and the B.B.C. Time Signal is of great interest. The figures given indicate, however, that whilst accurate for all ordinary purposes, the margin of error may be quite large for more precise purposes such, for example, as frequency measurements. Whilst it is true the monthly mean error for Rugby is as low as 3 milli-seconds, the maximum daily error as shown on the chart, may be as much as 0.08 second.

It is not clear whether the same compensation factor for line delay is applied to the B.B.C. stations. They are situated at various distances from Greenwich and, without individual correction, there must be still larger errors for some of these stations than for Rugby, possibly maximum errors of the order of ½ second. I think it would be wise to correct the impression that because these signals are radiated as being Greenwich time, they are of astronomical precision. Without the adoption of special measures for cutting-out the many relays in circuit, the delay cannot be reduced, and the correction factor may be of comparatively large dimensions under the arrangements now applicable to the transmission of the B.B.C. time signals.

MR. RAY :—

The necessity for accuracy in the operation of time checks and of Veeder clocks fitted to operators positions is, of course, obvious. At first sight, however, accuracy does not seem so necessary in the case of time pulses used in automatic telephone exchanges, but it must be remembered that the circuits have all been designed and tested on the assumption that time pulses occur at certain fixed intervals and experience has shewn that difficulties arise, often in unexpected places, if the nominal time intervals do not obtain in practice.

Although, as is mentioned in the paper, time pulses to release common equipment held for an unduly long time are normally obtained from the Master Clock, there are many cases in London where this does not apply, and tests have shewn that the nominally 30 second time pulse at different exchanges varies from 28 to 36 seconds. These time pulses are not received from a clock. One of the difficulties introduced by this variation is that, although 60 seconds is nominally the longest time after the last digit for " Number Unobtainable " tone to be received, due to forced release from a director, yet in certain exchanges the real figure is 56 seconds and at others it is 72 seconds. This must always be borne in mind when considering the results of Service Observation.

Another point of interest is the change that has been made in the time in which the " A "operator must pick up the assigned junction in the case of keysender working. Originally this was 9—18 seconds, but recently this was changed to 6—12 seconds, presumably to enable the 6 second time pulse from the Master Clock to be used. This reduction is dangerous and may account for calls being routed to the auto-manual board.

It will have been noticed that relays are used for repeating the time pulses from the Master Clock. A relay that has to operate once every second, day in and day out, is subjected to wear far greater than any relay used elsewhere in a telephone exchange. Frequent inspection must, therefore, be necessary if faults are to be avoided.

Another point of special interest to telephone engineers is the S and Z relay scheme of time pulse release described in the paper. The advantages of this scheme have only recently been fully appreciated and in most of the existing exchanges, 2-step relays are employed for this purpose. I do not think it is generally known that if there is any appreciable resistence in the time pulse " common," these 2-step relays will one-step, that is, they will operate prematurely. The electrical contacts supplying the time pulse Earths must therefore possess low contact resistence, a condition that prevents the use of tungstan as a contact material, in spite of the extremely long life that this material possesses.

The use of A.C. clocks is a most important development and if sufficient reliance can be placed on the frequency of the A.C. supply, there seems to be no reason why such clocks should not be used for measuring the releasing lags of switches and relays.

MR. GIBBON in his reply to the discussion said :—

Sir Frank Dyson has given us some exceedingly interesting information from the records of the Royal Observatory concerning the distribution of Greenwich Mean Time, commencing so long ago as 1849. These records show that the co-operation between the Astronomer Royal and the Post Office in the distribution of GMT is of long standing.

In connection with the table issued by the Admiralty and shown in Fig. 17, it is true that substantially accurate signals are received from the different wireless stations :— Annapolis, Bordeaux, Nauen and Rugby, but, if I may be allowed to say so, Sir Frank modestly declines to take the credit for greater accuracy than other observatories. I think the figures in the table speak for themselves and we have reason to be proud of the work that is being done in this connection by the Astronomer Royal, aided by scientists and manufacturers, and perhaps not least by Post Office engineers.

Mr. Kempe raises the question of good time-keeping for the service of the " Man in the Street." It is quite true that the title of the paper precluded me from dealing with clocks in public buildings or in church towers.

On the subject of financial economies resulting from the substitution of electrical for mechanical clocks, it may be of interest to supply further information. The annual charge for the maintenance of mechanical clocks works out at approximately 12/- each, whilst for electrical master clocks and secondary dials the annual charge is approximately 4/6d. each. There are certain factors which preclude the Department from installing electrical clocks at all places, apart from the absence of battery plant. Among these factors is the very small recovery value of mechanical clocks.

Colonel Edgcumbe refers to the value of synchronous time systems operated from the electric supply mains. He will probably agree with the reference made to A.C. clocks in the final part of the paper. Col. Edgcumbe may count upon the co-operation of the Post Office in any development of this system which will meet our special requirements. On the subject of the cost of running the Warren motor in the " Synclock," I should point out that the consumption of

4 watts quoted in the text was obtained from documents supplied by Col. Edgcumbe's firm. I am pleased to learn that the consumption has been reduced to approximately 2 watts.

Mr. Hope-Jones has given us an interesting historical record of the "Hipp" Master Clock. I know no-one who has done so much as Mr. Hope-Jones in the scientific development of electrical clock mechanism and I regard it as a great honour to have him with us to-night.

It is true that the Post Office type of Master Clock transgresses horological rules — but the clock works, and works very well, as it proved by our specification requirements, and also from records of performance taken during the past 10 years. It may be of interest to state that approximately 10% only of our master clocks are synchronized with GMT. Clock manufacturers of the highest renown in this country make master clocks to the Post Office specification. It is possible that the P.O. specification does not always appeal to these manufacturers, but in view of our special requirements, there does not appear to be any good reason for altering the specification, in order to bring it into strict conformity with the horological point of view.

Mr. Pink, as Deputy Controller of the London Telephone Service, referred to the telephone traffic aspects of accurate time keeping, all of which are of great importance in the public service. The experiments now being undertaken in connection with the automatic intimation to the public, by the telephone operator, of elapsed time on trunk calls, is an interesting development in electrical timing operations. Mr. Pink's suggestion of automatic simulation of the human voice, in place of the "pip" signal is worthy of consideration. I hope the automatic voice will be a musical one,—preferably a lady's voice—but in any event, the automatic voice should not overlook aesthetic requirements!

Colonel Angwin raises points of importance concerning the use of wireless time signals for frequency measurements. It is impossible to transmit from a clock contact, signals of the accuracy required for the measurement of frequency. For these exact measurements, some other standard arrangement will have to be introduced.

With regard to the B.B.C. time signal, this is a telephonic transmission from the London Studio and not a telegraphic signal, therefore the line and relay lag compensations do not apply. The B.B.C. Time Signal is not regarded as one of scientific accuracy but is transmitted with the same order of accuracy as the Post Office hourly synchronizing signal. The Rugby Signal is the one introduced for scientific working, whilst the B.B.C. and the P.O. synchronizing signals are for general time-keeping requirements.

Mr. Ray has furnished some interesting data concerning the important subject of time pulses in automatic telephone exchange working. He lays stress on the work done by the master clock and also by the associated relays in the many intricate operations of automatic switching equipment. There seems to be no limit to the adaptability of our master clock in controlling these services. There would appear however to be a tendency to overload the master clock with time pulse relays, and it may perhaps be necessary to lay down some standard in regard to the maximum number of time pulse relays to be operated from one such clock, so as to avoid having "all the eggs in one basket."

In conclusion, I wish to express my grateful thanks to the Secretary of the Royal Institution for the loan of the electrical pointer used this evening, and also to my colleague Mr. Heil for operating the pointer.

BIRCH AND WHITTINGTON, PRINTERS, STATION ROAD, EPSOM.