PRACTICAL ELECTRICAL ENGINEERING

Intended for Electrical Installation Engineers, Engineers in Charge of Works and Factories, Cinema and Theatre Engineers, Students, Apprentices and Progressive Men in all Branches of the Electrical Industry

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CONTENTS

ELECTRIC CLOCKS

THERE are four main types of electric clocks, namely, self-wound clocks, synchronising clocks, A.C. motor clocks and master-clock circuits.

(1) *Self-wound clocks* measure time by means of an escapement controlled by a balance wheel or a pendulum, electricity being solely used to provide the motive power.

(2) *Synchronising systems* assume a central time station which sends out electrical impulses—at each hour, or once a day—to correct the hands of complete clocks having an independent life of their own, whether key-wound or self-wound.

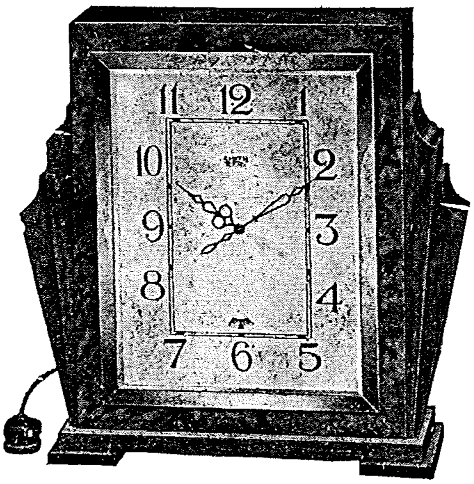

Fig. 1.—A MODERN ELECTRIC "PLUG-IN" CLOCK.

It is only necessary to connect this clock to a convenient plug, set it to the correct time, and start the motor. The motor is not self-starting, so should there be any interruption of the current there is no danger of the clock starting up and registering the wrong time (*Smith's English Clocks, Ltd.*).

(3) *Continuously running synchronous A.C. motor clocks*, plugged into the electric light supply, are really not clocks at all, since they have no escapement, and do not measure time but merely indicate on a clock dial the time kept by the alternators in the generating station.

(4) *Circuits of electrically propelled dials* consist of a "transmitter," "controlling pendulum," or "master clock," which sends out electrical impulses at short intervals—usually every half-minute or minute—to propel the hands of "receiver," "indicator," or "impulse" dials.

Self-wound Clocks.

The first named, *self-wound clocks*, are numerous and interesting, because they "go without being wound up" and do nothing to secure uniformity. They have the defect of their merit. Since they require no winding, they are apt to be neglected and allowed to run wildly out of time.

Synchronising Systems.

The second, *synchronisation*, is a system that has to be undertaken by owners of large networks of wiring, such as the Post Office. At present it is thought that the cost of such a network, if devoted exclusively to the purpose, is for practical purposes too great compared with its earning power. The only service available in England is that of the Standard Time Co., Ltd., established in London fifty years ago.

A.C. Motor Clocks.

The third, *A.C. motor or "plug-in" clocks*, were first commercially introduced in America under the name Telechron about the year 1920, and have since become popular in the U.S.A. They were based upon the Warren frequency meter, in which a very small motor running at 3,000 r.p.m. has shading rings of copper on its poles whereby the A.C. current produces a rotating magnetic field which ensures synchronous running of a small steel disc and makes it self-starting.

The recent tendency towards the adoption of A.C. supply throughout the British Isles, and its standardisation of voltage and periodicity by the Electricity Commission under the grid system, creates conditions favourable to this method of time-keeping, and when the phase frequency of the generators is maintained precisely, against really accurate clocks in the central stations, there should be a considerable demand for A.C. motor clocks, particularly for domestic use.

The idea of being able to "plug-in" a clock of this kind on one's house supply is as alluring to the householder as is the

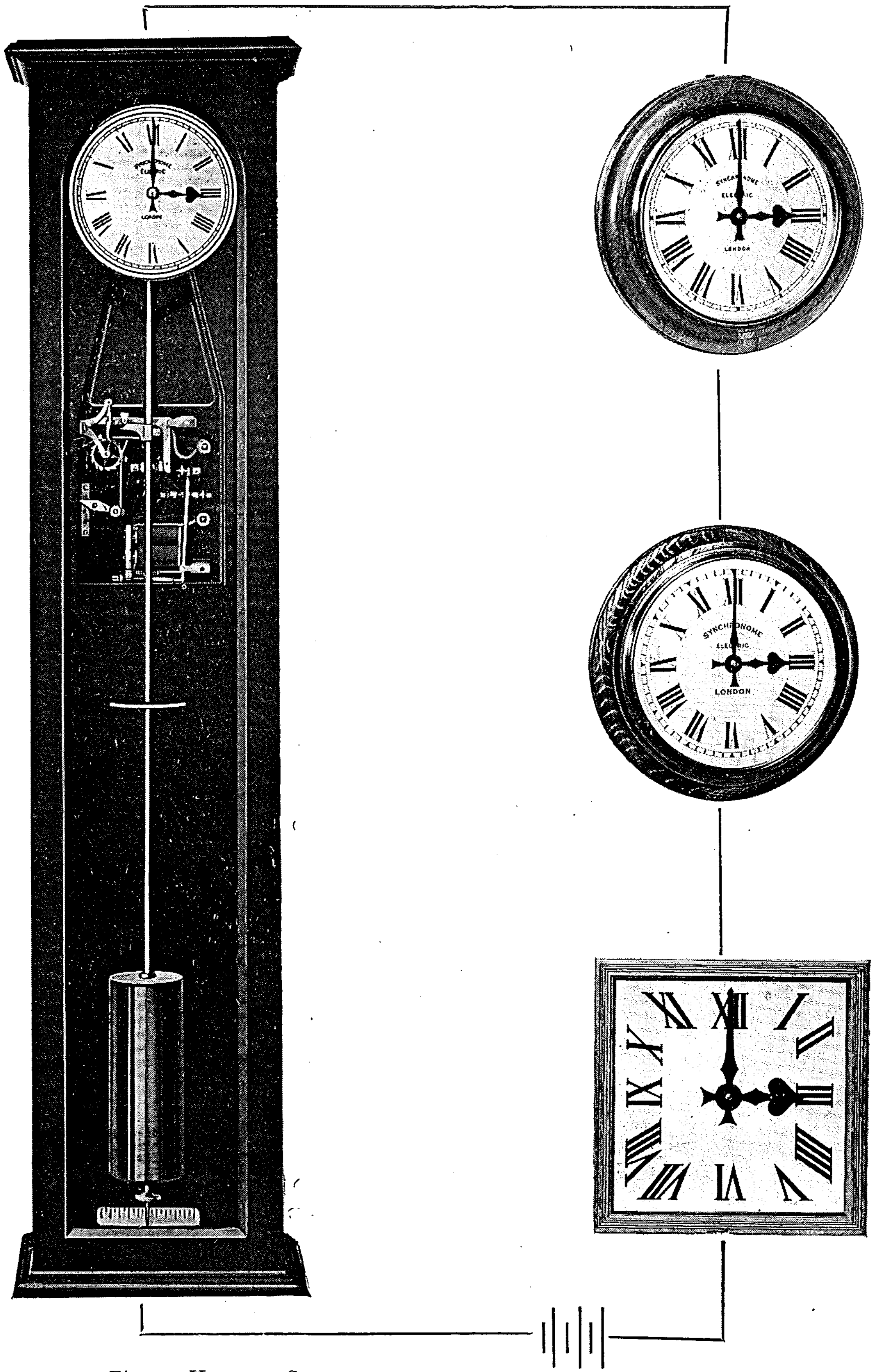

Fig. 2.—How the Synchronome Electric Clock System is Wired.
The master clock and the secondary clocks are connected in series with a battery.

prospect to the shopkeeper of selling over the counter an electric clock which does not require installation, but it cannot truthfully be said that no wiring is required, since if you monopolise a two-pin plug intended for a reading lamp or a radiator you will presumably require another. And the liability to stoppage owing to the blowing of a fuse must not be ignored, whilst the possibility of a station or mains breakdown must always remain.

Fixing a Clock in Position.

The mantelshelf will usually be considered the best place for a clock of this type, and if there is a plug at the side of the chimney breast, the easiest way to wire for it is to loop out a 2-amp. wall socket through a fuse with flex. In offices where a dial with a circular frame is required on the wall, a position may be selected over the door within reach of the switch by the side of the architrave, but it must be looped in between positive and negative and a negative wire is not always available at a switch. Temporary makeshifts of this kind will be inevitable unless and until these clocks come into such general use that special wall socket points are habitually provided for them.

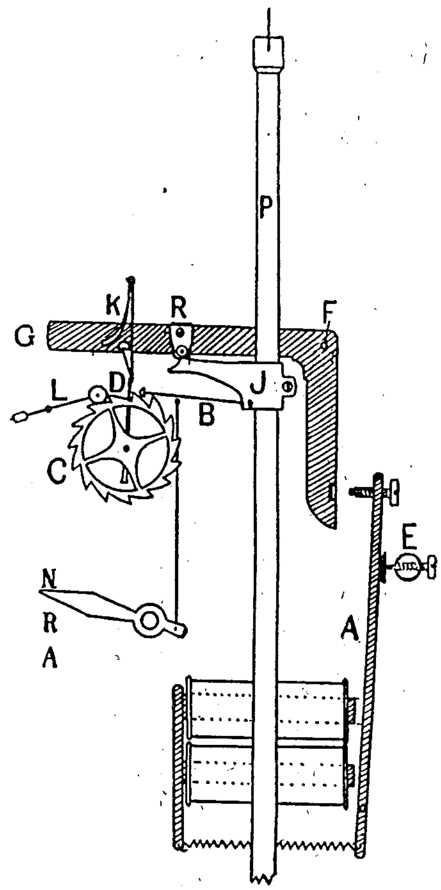

Fig. 3.—SWITCH MOVEMENT OF A SYNCHRONOME ELECTRIC CLOCK.

The gravity arm G which is held up in the catch K is released by the vane D once every half-minute when the wheel C has been pulled round one revolution by the gathering click B. The gravity arm is pivoted at F and carries a little roller R which falls upon the bracket J and gives a push to the pendulum P. When the gravity arm touches the contact screw E set in the top end of the armature A, the electro-magnet throws the gravity arm up on to its catch again.

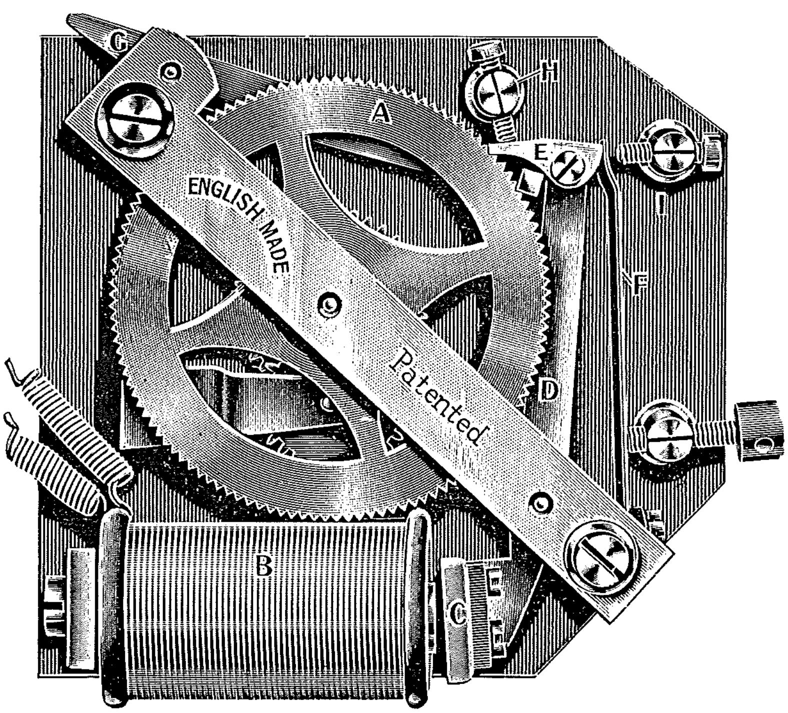

Fig. 4.—DIAL MOVEMENT OF SYNCHRONOME SYSTEM.
A—Ratchet wheel. B—Electro-magnet. C—Armature.
D—Actuating arm. E—Pawl. F—Pawl spring. H—Pawl stop.

What Happens when the Current is Cut Off.

It must not be taken for granted that it is an advantage for these little synchronous motors to be self-starting, since in the event of a temporary interruption of the supply they would be found going again and indicating the wrong time. The Warren Company provide a window in the dial behind which a red disc appears if the current has been cut off, as a warning that the clock is wrong and requires resetting.

A type which can be strongly recommended is known as Synchrono-Mains, in which the motor, which is British made, is of a comparatively slow speed and is not self-starting. Since it is always necessary to set each individual clock to time after an interruption, a setting device is provided which automatically starts the motor immediately after use.

THE SMITH SYNCHRONOUS ELECTRIC CLOCK.

The motor essentially consists of two parts—(*a*) the stator and (*b*) the rotor.

(*a*) The stator is clamped in a substantial bakelite housing and consists of two pressed steel cups enclosing the energising coil. The coil is wound on a cellulose acetate moulding which effectively protects the winding from mechanical damage. The poles are arranged on the inner periphery so that the whole unit is robust and the rotor is protected from accidental damage.

(*b*) The rotor consists of a star-shaped cobalt-chrome permanent steel magnet mounted between two brass discs and fixed to a steel spindle. The properties of this type of magnet are practically unlimited life without appreciable demagnetisation and considerably greater strength than for any other type.

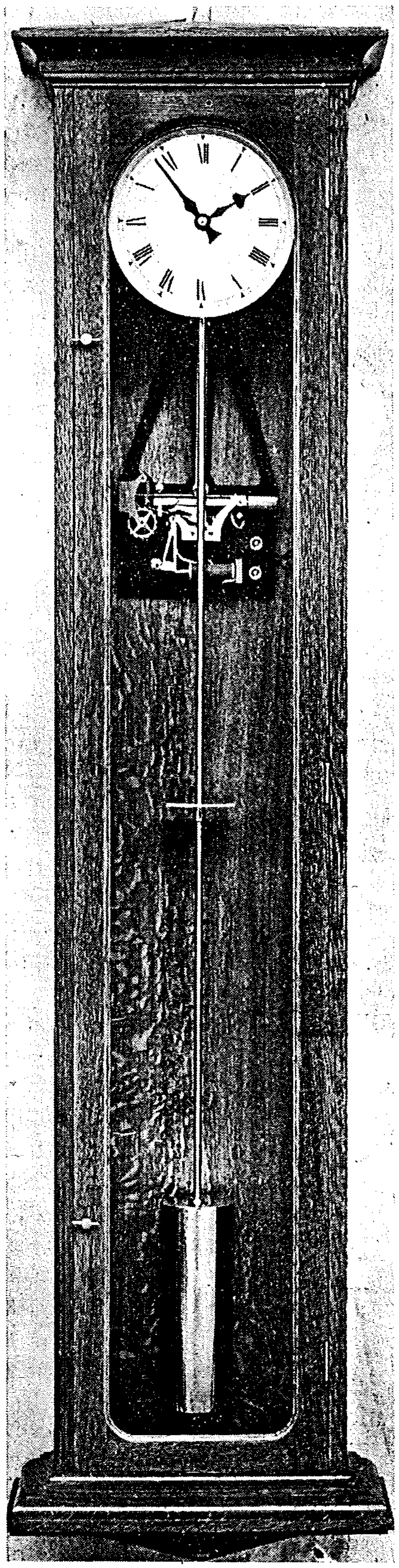

Fig. 5.—THE GILLETT-JOHNSTON MASTER CLOCK.

The distinctive feature is the patent swinging armature.

Specially ground and polished bearings are employed which ensure silent and smooth running. These are self-lubricating and, therefore, do not require either oiling or cleaning.

Setting and Starting the Clock.

The motor is not self-starting and the clock is, therefore, free from the serious objection that, in the event of a temporary cessation of the supply, it will start up indicating the wrong time, and remain so. The setting to time and starting up are performed by the simple operation of a single lever, and one cannot be done without the other.

The motor runs at the comparatively low speed of 200 r.p.m. when connected to a supply of 50 cycles (commonly known as frequency). The power consumed by this motor is only in the order of 1 to 1.5 watts. The motor provided for an ordinary $3\frac{1}{2}$-in. drum clock has ample power to operate clocks with 12-in. diameter dials.

Master-Clock Systems—

The fourth system of electric clocks is that of the *circuits of electrical impulse dials*, and time service installations of this kind have been adopted to a growing extent during the first thirty years of this century, and have reached a high standard of automatic accuracy.

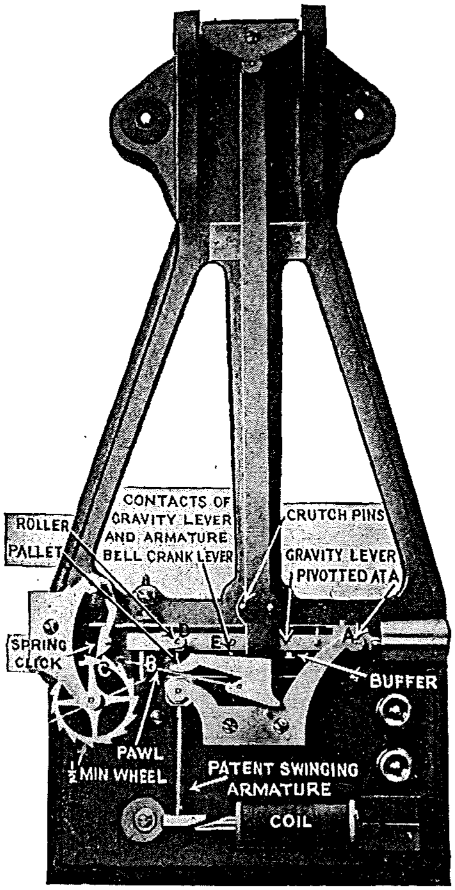

Fig. 6.—How the Master Clock Works.
In this illustration the pendulum has been removed, but it normally suspends from the top of the casting on the rod located between the two crutch pins. (*Gillett & Johnston.*)

—And How They Work.

The *synchronous propulsion of groups of clocks* dispenses with ordinary clock work and substitutes "dial movements" which propel the hands, usually by means of an armature lever pulled by a magnet and replaced by a spring. Hence the name "electrical impulse dials," the impulses being transmitted by a master clock. All attempts to produce such impulses by the application of contacts to the wheelwork of ordinary clocks have proved more or less unsatisfactory owing to the small power available and to a want of precision in the make and break. Where such contacts are used, the only safe thing to do is to reverse the direction of the current at each impulse and use polarised mechanisms in the dials. Broadly speaking, this is the Continental method, and is represented by such systems as Grau-Wagner, Siemens & Halske, Peyer-Favarger and Aron. Intermittent or "splashy" impulses can then do no harm because they can only rock the armature in one direction.

Overcoming Failure of Battery and Contact.

The "Magneta" induction system claims to overcome troubles due to failure of battery and contact, more or less inherent in foreign practice. Polarised dial movements are employed, and the master clock consists of a weight-driven dynamo whose armature makes a revolution once a minute. This is a great improvement on the induction system of Wheatstone. A master clock capable of operating a large circuit of small dials, or even a small circuit of large dials, must be both costly and cumbersome compared with one which has only to operate a switch, and will require frequent winding.

THE SYNCHRONOME SYSTEM.

At the British Horological Institute in 1895, and at the Institution of Electrical Engineers in 1899, Mr. F. Hope-Jones introduced a simple method of obtaining in connection with a pendulum a non-intermittent impulse perfectly clean in the make and break, and of a duration which automatically adjusts itself to the requirements of the dial movements in series with it. It forms the basis of the "Synchronome" switch. It may be described as a switch so combined with a pendulum that it operates every half-minute, the action of the switch being cleverly arranged to impart an impulse to the pendulum to keep it swinging for the next thirty seconds.

How the Switch Works.

The switch consists of two moving parts: (1) the right-angled lever G (see

Fig. 3) centred at F and normally supported on the spring catch K. Once every half-minute the lever is let down (in the act of giving an impulse to the pendulum P) upon (2) the armature A. Current from any available source then passes through the series circuit of dials and the magnet, which attracts the armature A and throws up the lever G on to its catch again.

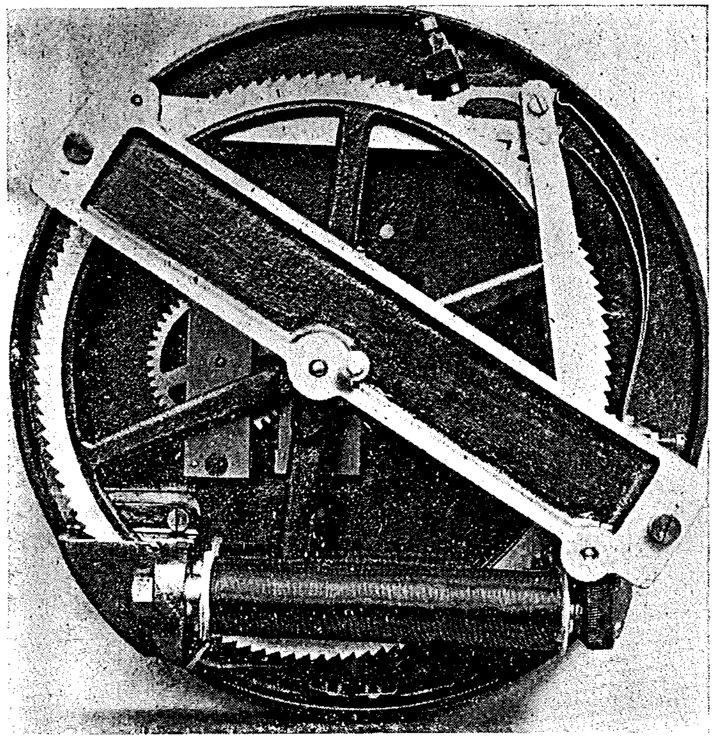

Fig. 7.—SECONDARY CLOCK MOVEMENT.
The minute hand is driven direct by the 120-toothed ratchet wheel and the hour hand is geared down 12 to 1 in the usual manner. (*Gillett and Johnston.*)

How Impulses are Imparted to the Pendulum.

The pendulum releases the switch by means of the 15-toothed wheel C, which carries a vane D engaging with the catch K at each revolution. The hook B pivoted upon the pendulum P turns this wheel once every thirty seconds. At the moment of its release the little roller R on the gravity arm G is just above the curved end of the pallet J, down which it runs, giving an impulse to the pendulum *at the moment when it passes through its zero or central position.* Thus the pendulum is free at all times except in the middle of its swing; not only is the escapement detached, but it operates at zero, a combination which horologists have always been aiming at, but had not hitherto attained.

An important development of this invention (described at the Royal Society of Arts in 1924) is the free pendulum designed by Mr. W. H. Shortt, M.Inst.C.E., which has taken all the world's records for accuracy of time measurement at Greenwich and other Observatories.

How Failure of the Battery is Indicated.

Indication of impending failure of battery is clearly given by the prolonged duration of contact which results from the switch magnet being unable to replace the weighted lever without the assistance of the pendulum, which is so arranged to render that assistance when necessary. This duration is normally about the twentieth part of a second, but is increased to a whole second when the battery is insufficient, yet the circuit will continue to run perfectly for some days before finally stopping. If this warning is neglected and the system is allowed to stop, the pendulum will hold the switch open, thereby preventing the battery from completely exhausting itself.

Using a Bell or Lamp.

If desired, a single-stroke bell or small carbon filament lamp may be included in the series circuit, so adjusted that the normal impulses of the short duration will not affect it, but the weaker the current and the longer the contact, the more loudly will the bell ring, or the more brightly will the lamp flash.

Dial Movement for Existing Clocks.

The dial movement of the Synchronome system (Fig. 4) is readily applicable to existing clocks of all kinds, from those on the mantelshelf with 3-inch dials to those in a turret with 10-feet dials. When the latter are illuminated the movements are fixed to the opal centres of the dials and are relatively so small as to be covered by the bosses of the hands,

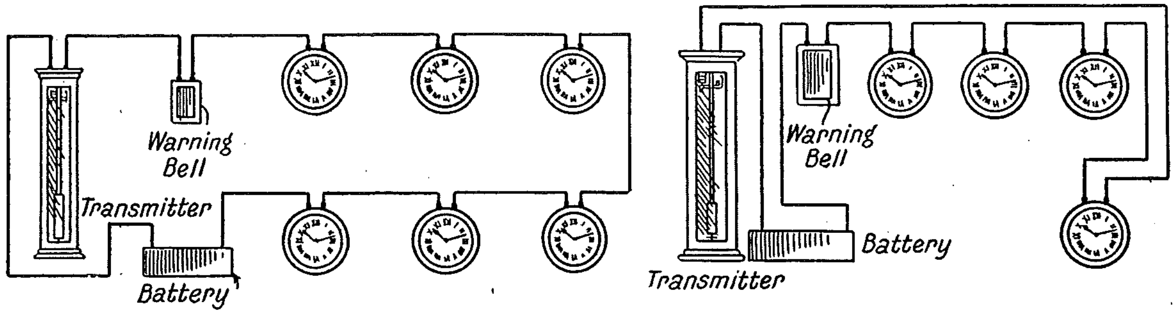

Fig. 8.—How the Pul-syn-etic Master Clock and Impulse Clocks Should be Wired. The diagram on the left shows the principle of "series wiring." Where it is not possible to arrange them in a complete ring the alternative method shown on the right should be used, and this still follows the principle of "series wiring."

consequently the clock chamber is entirely empty and available for illumination, no shadows being thrown.

Inspecting the Hands.

The central panels of the dials can be made detachable, enabling them to be drawn inwards for the inspection of hands ; the facility thus afforded for access to the outside faces of turret dials is invaluable in church steeples and towers where costly scaffolding would otherwise have to be erected whenever the dials weie cleaned.

Setting the Dials to Time.

Convenient means of setting all the dials to time is provided by the lever on the left-hand side of the controlling pendulum switch (see Fig 3.) When this lever is at *N*, *B* releases the switch once every half- minute. This is *normal* position. When depressed to *R* the switch will be put out of action altogether and the dials *retarded* for as long as may be necessary. When the lever is further depressed to *A*, the dials will be *accelerated*, because the switch will be released at every other swing of the pendulum.

This device was invented in 1909 to assist the late Mr. William Willett in his campaign for Daylight Saving by demonstrating the ease with which large numbers of clocks could be set forward or backward.

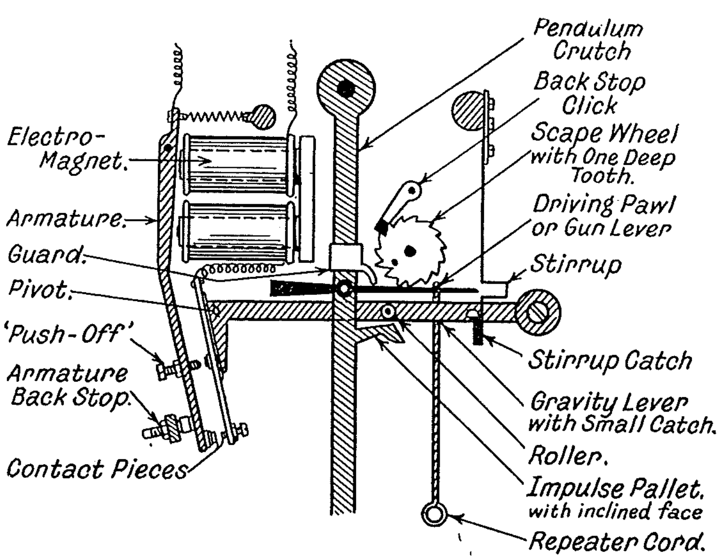

Fig. 9.—Transmitter System of the Pul-syn-etic Electric Clock.

Why the Circuits are Wired in Series.

Circuits of electiical impulse dials are wired in series in order to secure the benefit of the Synchronome principle, which uses self-induction to dictate the duration of the contact.

Why Electric Light Wire Should be Used.

Substantial wiring is therefore demanded both on the grounds of conductivity and mechanical strength ; 3/.036-inch electric light wire is recommended, and though ordinary electric bell wire of 18 gauge is electrically sufficient both for conductivity and insulation, a triple conductor should always be used in order to minimise the risk of disconnection and ensure respect for the line. All instruments being in series, care should be taken to avoid loose connections, and the terminals should invariably be screwed up with pliers.

Fitting Non-inductive Shunt Coils.

In the best systems, non-inductive shunt coils are fitted in the dial movements in parallel with the electro-magnets to absorb the spark at the break, and since the strength of a chain is that of its weakest link, these serve also as an extra path for continuity in parallel with the magnet wires which are necessarily small and weak.

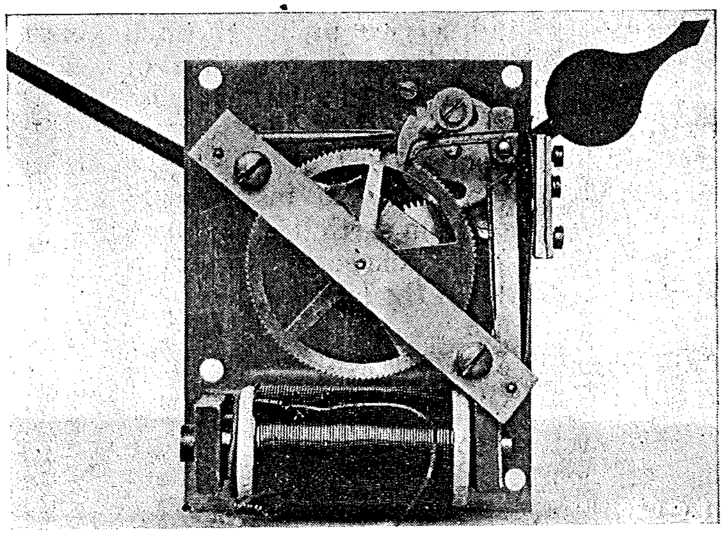

Fig. 10.—IMPULSE OR SECONDARY MOVEMENT OF PUL-SYN-ETIC ELECTRIC CLOCK SYSTEM.

Operating Series Circuits in Parallel.

The Synchronome switch can be used to operate a number of such series circuits in parallel. An outstanding example of this is the large head offices of the Imperial Chemical Industries at Millbank, where upwards of 600 dials are driven by one master clock in six series loops of about 100 on each.

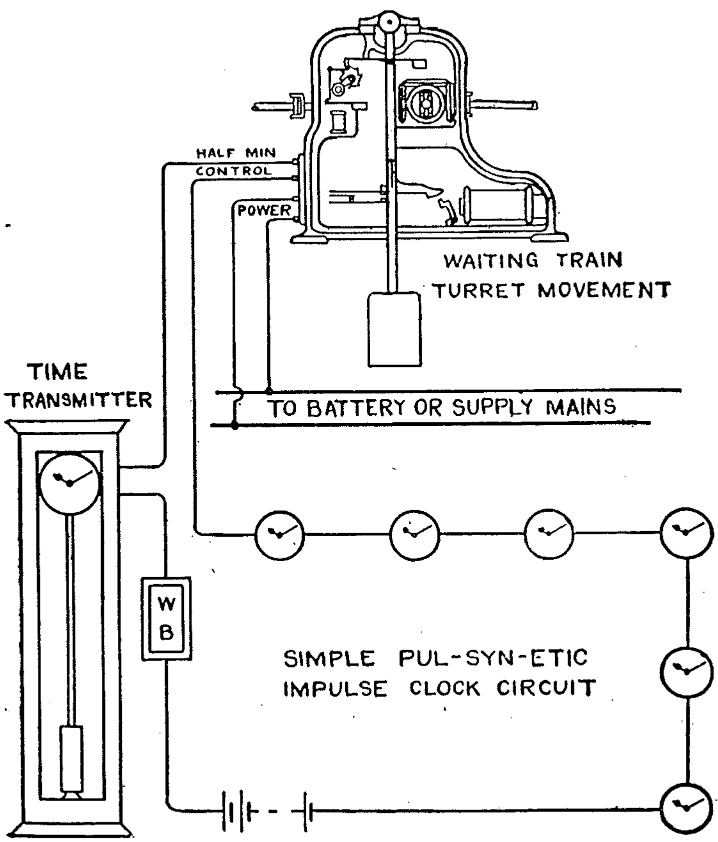

Fig. 11.—HOW THE "WAITING TRAIN" TURRET CLOCK WORKS.

This movement is designed specially for driving the hands of large clocks that are exposed to the full force of the weather.

Supplying Current from Batteries.

Any convenient source of electrical supply may be used for systems of this type, a primary battery, a set of storage cells, or electric light supply, and the current consumed is so small as to be practically negligible. Ordinary wet Leclanche cells are the least suitable on account of their high and fluctuating internal resistance, but they may be used if two series sets are provided and joined up in parallel. A good dry cell is better. A reserve battery of dry cells should never be provided, since the current consumption is so small that you are only concerned with the "shelf" life of the cells and an idle set would last no longer than those in use.

Using A.C. or D.C. Mains Supply.

An ideal arrangement for a large circuit of great responsibility is to install two sets of storage cells, one in reserve with a charging board and change-over switch. Half an hour's attention once a month will then suffice. Alternatively, they may be connected to the service mains through a carbon filament lamp in the case of D.C. and through a transformer and rectifier in the case of A.C., but it is of the utmost importance that the time circuit wiring and all the instruments are well insulated from earth, if the source of supply is also connected to other metallic networks in the building.

GILLETT AND JOHNSTON'S SYNCHRONISED ELECTRIC CLOCK SYSTEM.

This system consists of an accurate master clock, which is electrically connected through independent battery (or other source of supply) to any number of secondary clocks, all wired in series.

Every half-minute this master clock, or, strictly speaking, master *pendulum*, transmits an impulse current to each secondary clock dial, through a simple magnetic coil and pawl-and-ratchet mechanism, thus putting forward the dial hands.

Master-Clock Movement.

The distinctive feature of the Gillett and Johnston master clock is the *patent swinging armature* (see Fig. 5), which eliminates noise and gives a remarkably smooth action, all contributing to accuracy and general reliability.

A reference to Fig. 6 will explain the action, and in this illustration the pendulum has been removed, but it normally suspends from the top of the casting and the rod locates between the two crutch pins indicated on the photograph.

The pawl C, engaging with the ratchet wheel E, causes the latter to revolve once every half-minute. At each revolution the horizontal gravity lever A, pivoted at B, is released from its catch F, and, in falling, the following sequence of operations takes place :—

(*a*) The roller G drops on to the crutch pallet H, thus giving an impulse to the pendulum as it swings to the right.

(*b*) The gravity lever contact J touches that on the swinging armature bell crank lever K, thus closing the battery circuit, and

(*c*) Energises the coil, causing the armature L to swing over, thus breaking the circuit just made, then

(*d*) From the " tail end " of the armature bell crank lever the gravity lever A is clicked back into position, ready for the next half-minute's impulse.

This movement is practically silent; there is no actual contact of armature with pole piece ; all parts are buffered against shock, and there is ample time-contact for safe working of the largest clocks.

Secondary Clock Movement.

The minute hand is driven direct by the 120-toothed ratchet wheel, and the hour hand is geared down 12 to 1 in the usual manner. Fig. 7 shows the secondary clock movement.

Every time the master clock makes electrical contact, the current energises the magnet, which then attracts the armature, thus allowing the pawl to fall into the next tooth of the ratchet wheel.

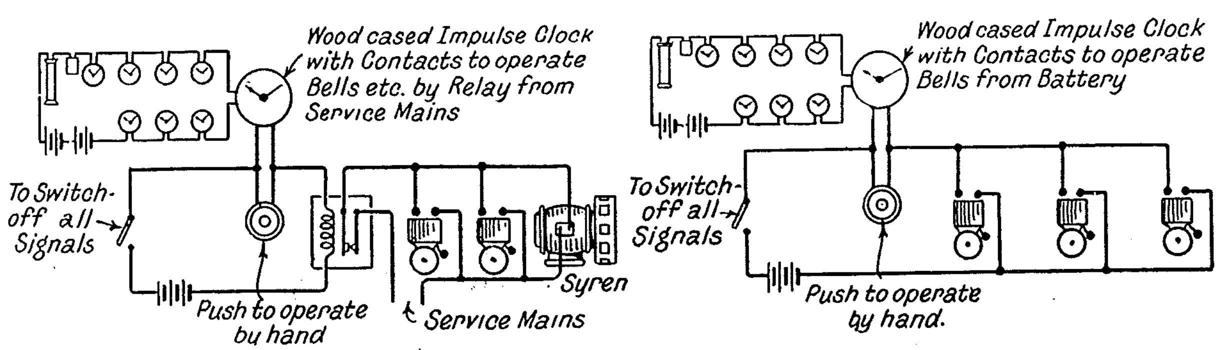

Fig. 12.—HOW A CLOCK CAN BE USED TO OPERATE SOUND SIGNALS.

On the left an impulse clock is shown connected up to operate bells and sound signals by relay from the service mains. On the right the clock is shown connected up to operate bells from a battery. (*Pul-syn-etic.*)

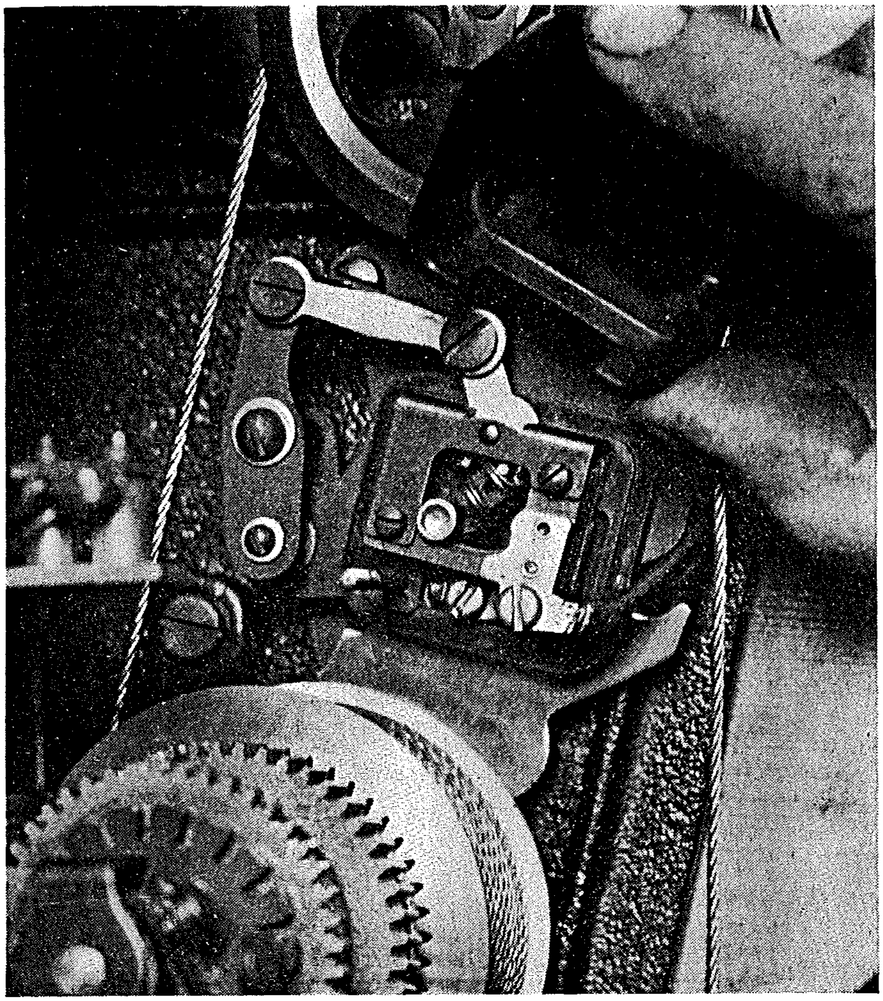

Fig. 13.—SWITCH CONTROLLING THE MOTOR ON THE INTERNATIONAL MOTOR-WOUND MASTER CLOCK (SUPERVISED SYSTEM).
Showing how the cover can be removed for inspection of the switch.

The breaking of the electrical contact on the master clock—with consequent cessation of the energising current—allows the pawl to be pushed forward by the tension springs, and in this operation the ratchet wheel is pushed forward a distance of one tooth, i.e., one half-minute. A backstop prevents reverse rotation of ratchet wheel.

There is no winding, and the battery current consumption is only 0.4 of an ampere for one-fifth second, every half-minute, so that the total current consumption is negligible, and there is practically no attention required, beyond the watching of the battery after two years' use, when obsolescence will reduce the voltage.

Erection and Maintenance.

It is quite a simple matter for any intelligent electrical engineer to do this work, after careful reading of printed instructions sent out with the clocks.

Once the installation is completed and the pendulum regulated the three main points to attend to are as follows :—

(1) Check the indicated time and correct it with "Greenwich"; this can be done in a few seconds and should be necessary at intervals of four or five weeks only. Any correction is made by adjustment of the ratchet wheel in the master clock, all the secondary dials responding automatically.

It is important never to interfere with the pendulum adjustment once this has been regulated.

(2) (*a*) Set all clocks back to "Greenwich" time at the expiration of "summer" time by stopping the master pendulum for one hour.

(*b*) Set all clocks forward to "summer" time by means of the accelerator in the master-clock case, an operation that takes four minutes.

(3) Battery. Two years after a dry battery is first installed it needs strengthening. Connect up to this battery about ten per cent. additional cells; this will maintain the current for a further six to nine months, after which the battery will have to be replaced by a new one, at nominal cost.

Accuracy.

The master clock, under suitable con-

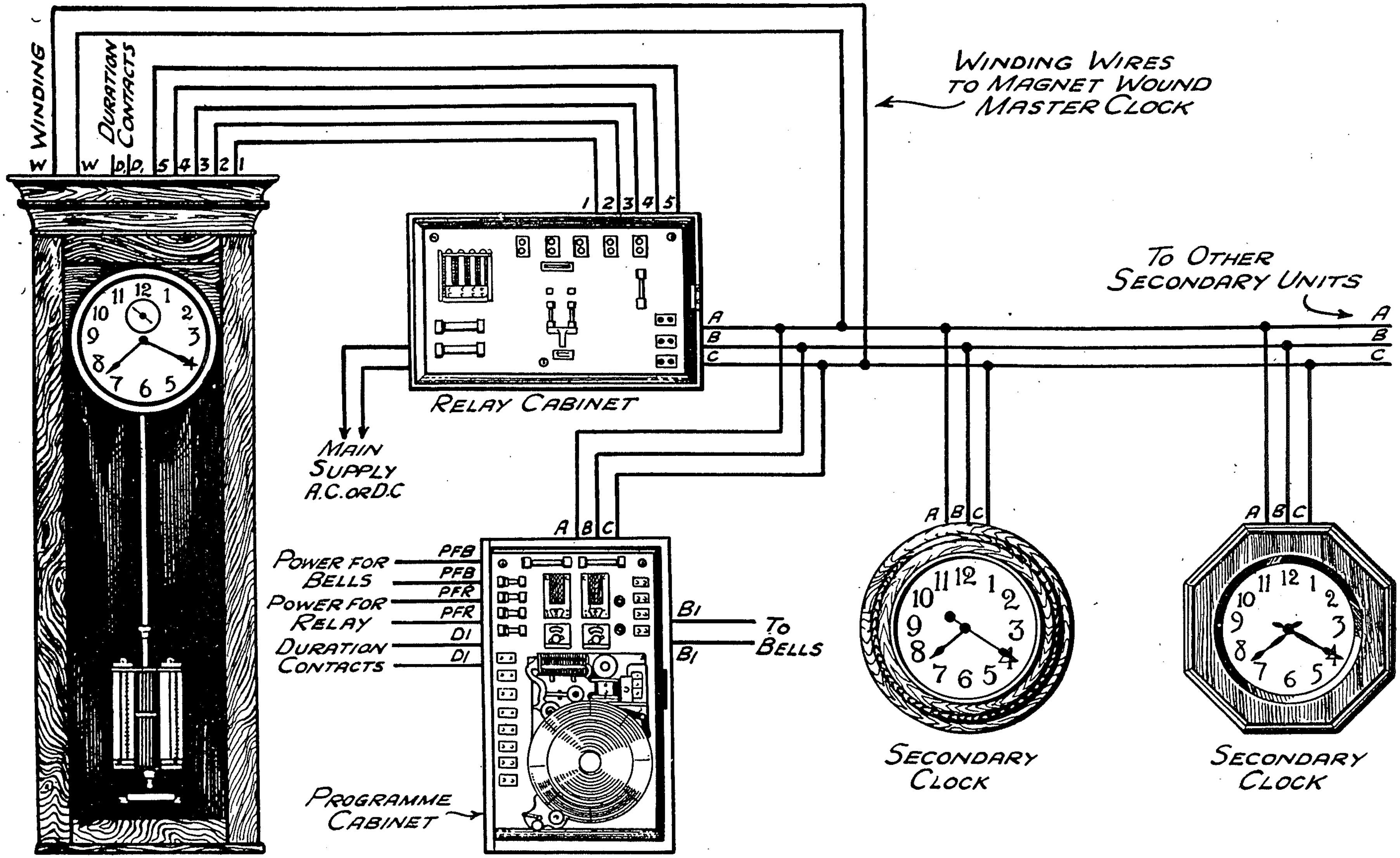

Fig. 14.—Wiring of International Fully Automatic Supervised Electric Clock System.
Each unit must have its terminals connected to the corresponding terminals of another unit. No joints are permissible.

ditions of freedom from vibration and reasonably constant temperature, etc., can be regulated to a commercial error not exceeding one second per week from Greenwich mean time. This error is not necessarily cumulative and is for all practical purposes dead accurate time-keeping. If desired, a time signal attachment, operated direct from Greenwich, can be additionally fitted, but, for general purposes, this is quite unnecessary.

This system is very suitable for outside public clocks, avoiding winding and weight falls. A good example of this is the new *Daily Telegraph* clock, 19 feet overall in height, which with 120 clocks within the building is operated from a "seconds" pendulum master clock.

THE PUL-SYN-ETIC ELECTRIC CLOCK SYSTEM.

The simplicity of the transmitter mechanism of the Pul-syn-etic system is shown in Fig. 9, and this mechanism is described with reference to the named parts and operates as follows :—

The pendulum crutch beats with the pendulum, which is of "seconds beat." It is kept in vibration by the pivoted gravity lever, which is supported normally on the stirrup catch. In vibrating, a driving pawl rotates the scape wheel tooth by tooth, and, normally, the point of the driving pawl passes through the stirrup shown. The scape wheel has teeth corresponding with 15 double swings of this pendulum. Every half-minute the driving pawl engages a tooth deeper than the rest of this wheel, enabling the point of the driving pawl to rise and charge into the upper part of the stirrup (instead of passing through it). This action releases the gravity lever. The roller drops on to the impulse pallet, and on running down the inclined face, imparts to the pendulum an impulse which maintains it in vibration. In descending, the contact piece of the gravity lever meets the contact piece of the armature and, therefore, the gravity impulse to the pendulum is terminated.

How the Clock Hands are Advanced.

The circuit (including the impulse clocks) and the electrical source is now completed, the electro-magnet is energised and the armature, while being attracted, replaces the gravity lever. Meanwhile, all the electro-magnets fitted to the impulse clocks have been energised, and all clock hands are advanced a half-minute.

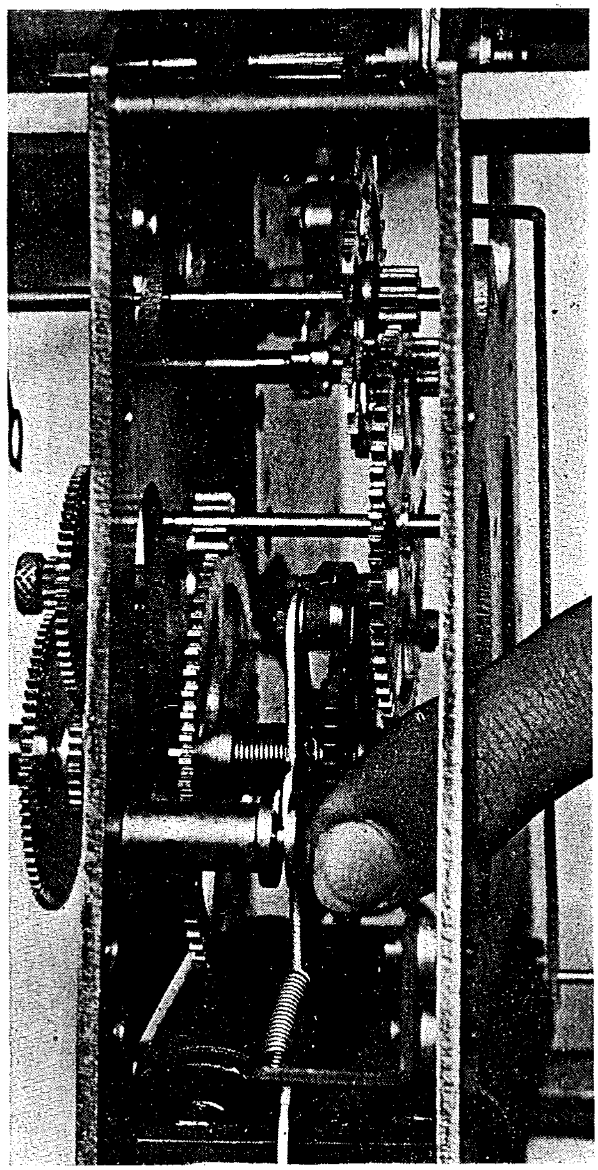

Fig. 15.—GIVING INITIAL WINDING BY HAND TO INTERNATIONAL MAGNET-WOUND MASTER CLOCK.

A slight downward pressure of the finger on the wheel turns it and this winds up the main spring. This master clock has a reserve of one to two hours.

The pendulum of the transmitter will probably be found to be fitted with a rod of special steel known as "Sinevar," which has practically no coefficient of expansion and, therefore, temperature errors are reduced to the minimum.

Dirty oil should occasionally be wiped away from the wheels and a little good

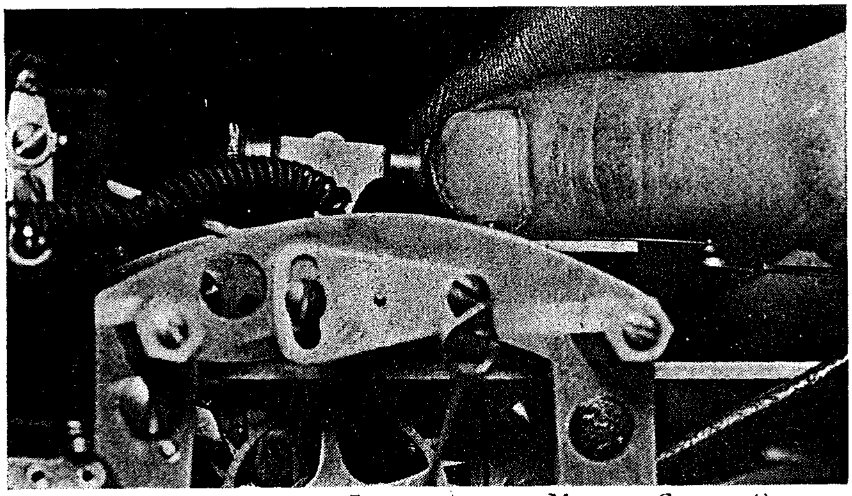

Fig. 16.—How to Set the International Master Clock (Supervised System) Accurately in Beat.

The screw indicator is turned to left or right until the clock is in beat. When once accurately carried out no further adjustment is needed.

operate as close to the armature as possible in order to obtain maximum efficiency. When the adjustments are properly set, the armature facing should just touch the magnet at the same time as the top end of the driving lever touches the top spring.

The necessary electric energy taken by the Pul-syn-etic electric clock circuit is 0.22 ampere for approximately one-twentieth second at every half-minute.

clock oil or good typewriter oil should be applied.

How Insufficient Current is Indicated.

With such a transmitter, when working normally, the gravity lever is lifted instantly the contact pieces meet and while the pendulum is yet swinging to the left. If the gravity lever remains down until the pendulum (and consequently the impulse pallet) returns to the right and assists it, this assisting action is a positive indication that the current flowing through the circuit is insufficient and must be augmented.

What the Impulse Movement Does.

The function of an impulse movement is to advance the hands one tooth only at each electrical impulse. Therefore, adjust the motion of the driving pawl and back-stop pawl so that this mechanical action takes place. Give that clearance to the adjustments to ensure definite and reliable operation.

The electro-magnet must

Automatic Sounding of Signals.

The automatic sounding of signals may be effected by means of an adjustable contact maker. This instrument is driven in half-minute steps by including same in the time circuit. Upon inserting pins in appropriate holes in the large 24-hour dial, any programme of times can be made by it in 5-minute positions throughout the 24 hours. Signals may be automatically cut out at week-ends by fitting to the instrument a 7-day wheel and cut-out contact.

Syrens, hooters and bells are sometimes fitted in various sizes and with varying carrying powers.

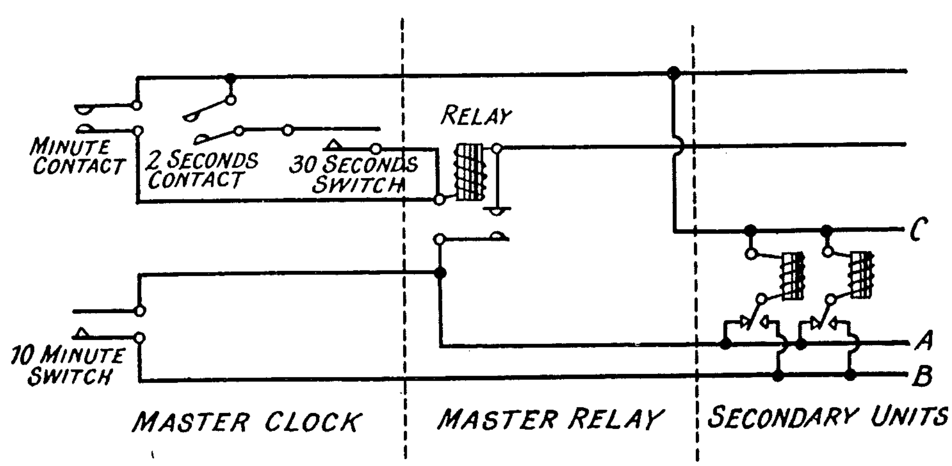

Fig. 16A.—Wiring and Connections Inside Master Clock, Master Relay and Secondary Units. (*International Time Recording Co., Ltd.*)

The "Waiting Train" Turret Clock.

An interesting development is the "waiting train" turret clock, the movement of which is shown in Fig 11.

It is constructed specially for driving the exposed hands of large clocks. It will be understood that the hands of such clocks are exposed to the full force of the weather, and unless a powerful driving force is applied to the hands, the clock would be liable to be stopped, or the time-keeping seriously interfered with. With the "waiting train" movement, however, the mechanism automatically adjusts the driving force to suit weather conditions.

Working of the "Waiting Train" Movement.

This movement contains an electrically driven pendulum (termed a motor pendulum), the function of which is not to keep time, but to drive a ratchet wheel, the ratchet wheel, in turn, by means of worm gearing, driving the hands of the clock. The motor pendulum is re-energised by an electro-magnet when its oscillations fall below a predetermined arc. Under normal working conditions re-energisation takes place about once per minute, but on heavy work being thrown on to the movement, due to resistance and wind pressure on the hands, the motor pendulum becomes energised more often. On being energised at each complete vibration, it then develops, say, 30 times its normal power, which result is not given by any other clock mechanism.

By it the minute hand is driven through a half-minute space on the dial in approximately 27 seconds. The pawl of the motor pendulum is then automatically lifted out of engagement so that, although the motor pendulum maintains its action, the hands remain stationary for two or three seconds, locked by the worm gear. A current impulse from the transmitter, dead on the half-minute, releases the pawl, and the hands are driven forward for another half-minute on the dial. As a rest of two to three seconds is inappreciable, the hands appear to move with absolutely regular progression.

Current Supply for the Motor Pendulum.

The electrical connections are shown in Fig. 11. The control is connected in the impulse time circuit, and the motor pendulum is kept oscillating by a separate battery, or by the supply mains.

If trickle charged accumulators are used and the relay of turret clock also in the circuit and the accumulator voltage is high enough, the pendulum motor of the turret clock can be operated by the same battery, a resistance being used if voltage s too high.

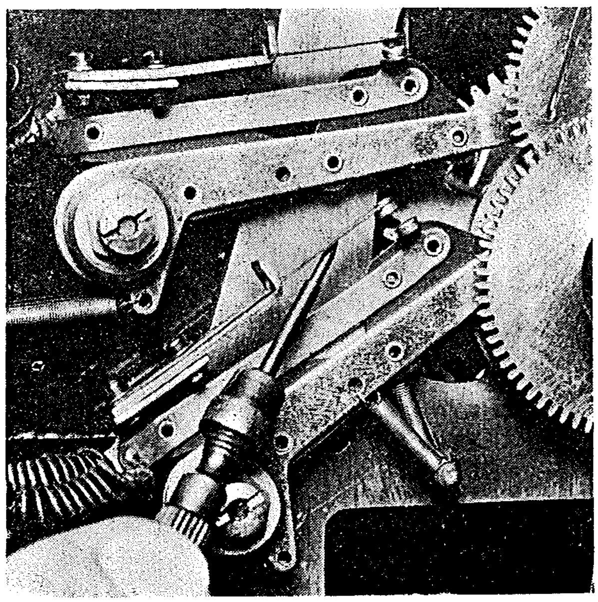

Fig. 17.—INSPECTING THE CONTACTS OF THE INTERNATIONAL MOTOR-WOUND MASTER CLOCK.
The impulse contact does not deal with the current required for the whole system, but is connected with the coil of a relay, with the result that these contacts break a circuit in which flows but a few milliamps.

Time-keeping by the master clock renders an accuracy on even the largest turret clocks of a second or so per week easily obtainable. The most striking feature of the "waiting train" movement is the entire absence of the heavy weights so necessary for the propulsion of mechanical turret clocks.

INTERNATIONAL FULLY AUTOMATIC SUPERVISED ELECTRIC TIME SYSTEM.

The International Supervised system of electric time indicating, recording and

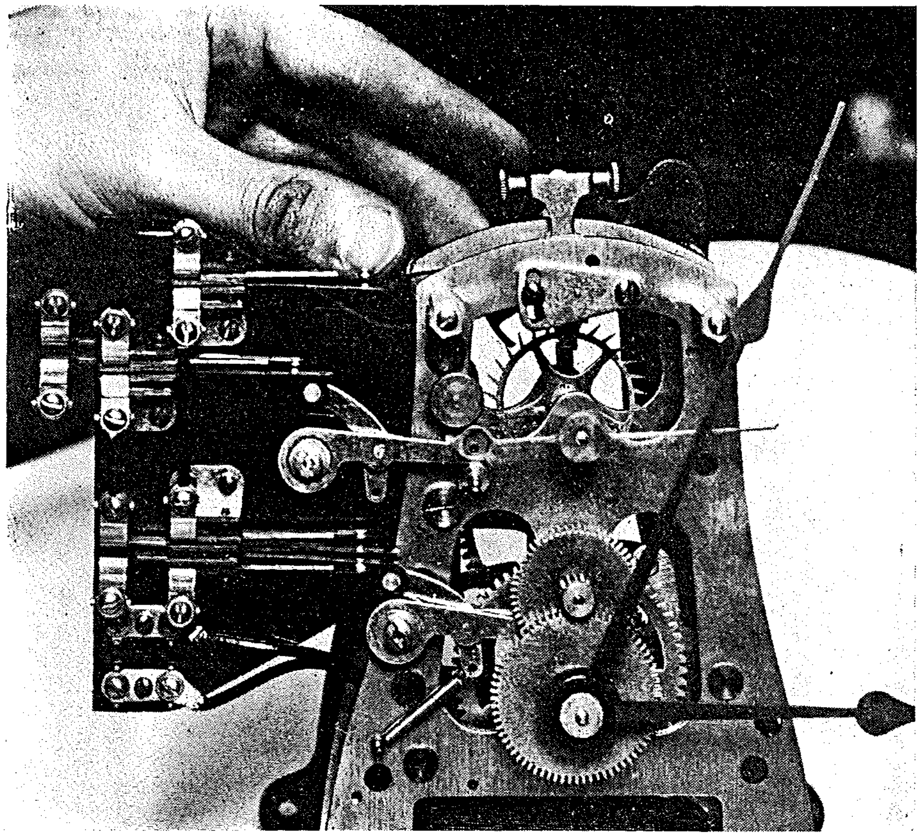

Fig. 18.—Section of Mechanism of International Magnet-wound Master Clock.
The thumb indicates the position of the contacts (to the left of clock movement) in connection with hourly supervising device.

rived from mains or batteries. As the chief function of electric clock installations is to give uniform time always, it is essential to have some means of supervision, and in the International system this is secured automatically.

The Master Clock.

Fig. 14 shows the wiring of the International motor-wound master clock system. Regularly each minute the master clock releases an electric impulse to the secondaries, but in addition each hour the master clock checks the delivery of exactly sixty impulses an hour to each unit it controls and *supervises* the perfect agreement. The clock is double-weight driven, with a total of eight days' operating power, or seven days' reserve over its daily winding cycle. Once a day the weights are rewound to their initial position by a small 1/70th h.p. General Electric Company's motor connected through an enclosed reduction gear to the winding drums. The drums are themselves geared to a mechanical limit switch of the double-break type, which throws the motor on the regular lighting or power current, after a day's unwinding, and off at the fully wound position.

The movement has a Graham dead-beat escapement with an extremely accurately cut verge, hardened pallets and a micrometer adjustment for balancing time beats. With a mercurial compensating pendulum, true time to within ten seconds a month can be secured.

signalling, possesses many features that are distinctive and, in many ways, radical departures from previously accepted standard practice in this branch of electrical engineering.

The master clock in this system is not only a transmitter of impulses to other clocks in the system, but is a supervisor and controller. Previous to the introduction of the International supervising principle, electric time systems possessed no means by which each secondary could automatically compare itself with the master clock, and there was no automatic method of correction.

It implies no criticism of any electric clock system when it has to be admitted that secondary units are liable at times to get out of step. Weak impulses, dust, volt-drop, local disturbances of units, are only a few of the possible causes of such errors. Added to these are possible interruptions of current supply, whether de-

Automatic Supervision: How It is Effected.

All secondary units are connected up with three wires instead of two. One "common return" (*c*) and two "operating" wires (*a*) and (*b*). Each secondary unit is provided with a selector switch which, once an hour, automatically connects the coil of the driving magnet to the proper one of the two "operating" wires, which transmit the corrective action, if necessary, to the secondary. Such corrective action is supplied by the master clock and its relays. One of the "operating" wires speeds up the secondary units that may be slow, and the other holds up the ones that may be fast—once each hour during the time correction is available.

The Selector is so arranged that the secondary clock magnet is shifted from one operating wire to the other only between impulses so that the Selector contacts will never spark. The master clock is fitted with an ingenious but surprisingly simple system of contacts, which, once each hour, cuts out impulses on the (*b*) "operating" wire causing it to hold up any fast secondary units that are ahead of the master clock, until the master clock reaches the hour point, when they are allowed to proceed as usual. It also, between the 59th and 60th minute of each hour, steps up by a series of impulses (two seconds apart) sent through the (*a*) "operating" wire, any secondary units that are behind the master clock providing a maximum of 15 minutes each hour. At the hour point all units in the system must show correct time and move forward together.

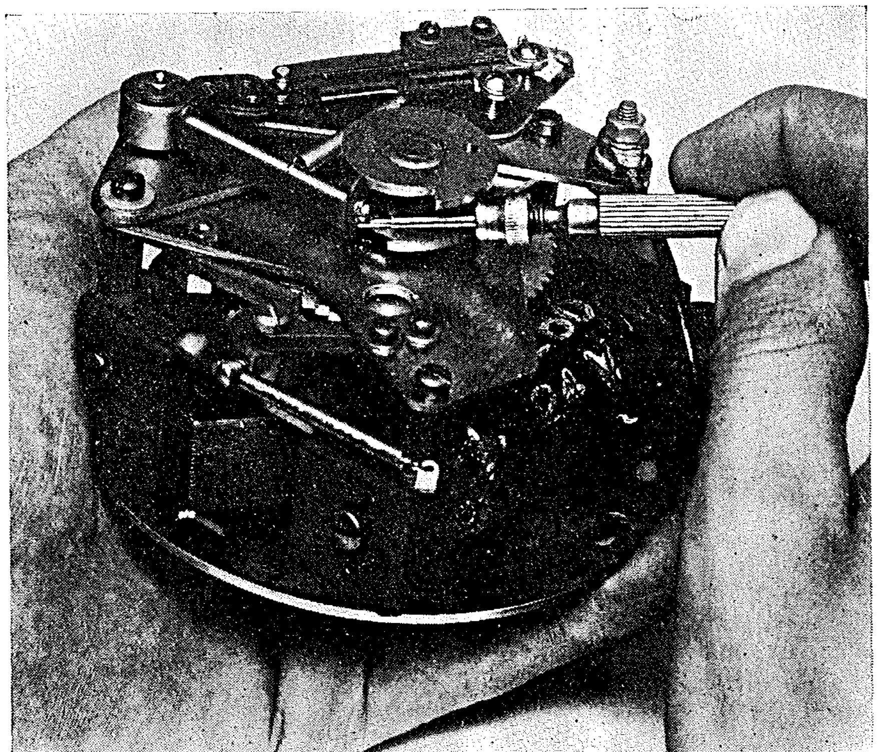

Fig. 19.—Secondary Clock Movement. (*International Fully Automatic Supervised Electric Time System.*)
The screwdriver indicates the position of cams, rocker and hourly supervising switch. The rotor, oscillating between the pole pieces of a magnet, is shown to the lower left of the movement. When the mechanism is fixed to the clock dial, the rotor is at the top.

Wiring in Parallel.

As will have been noted from the preceding paragraph, in the International system the usual series method of connecting electric clocks, is replaced by a parallel system of distribution. One advantage of this is the elimination of the possible failure of one clock becoming the cause of the stoppage of the whole system. Another great advantage of this method of distribution lies in the fact that it is possible to connect various pieces of apparatus such as time recorders, time stamps, programme devices, which may vary in their individual current consumption.

The International is an "all mains" system.

The serious objection to connecting electric clocks to the service mains that has hitherto prevailed, is the fact that an interruption of the current would cause a

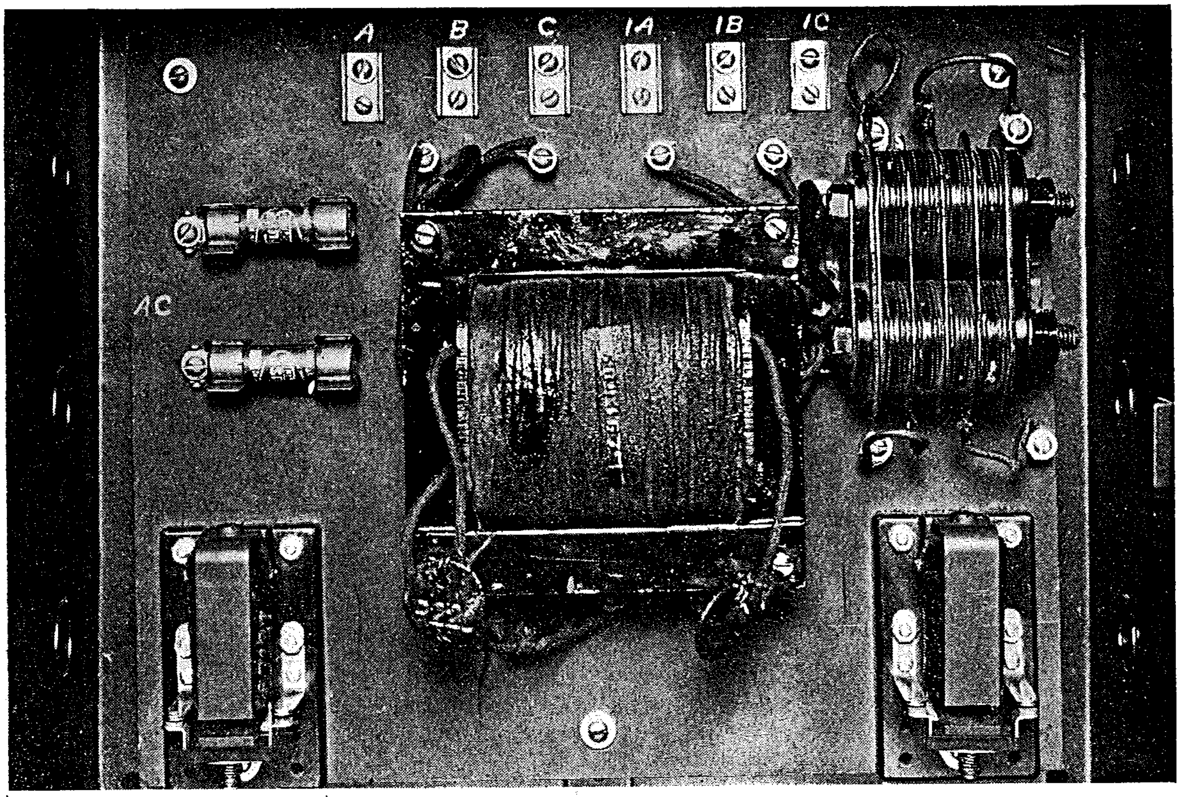

Fig. 20.—A.C. Distribution Board (*International Supervised Time System.*)
Distribution boards are required to distribute the load on large installations. Bottom left and right, relays; centre, transformer; top right, rectifier.

stoppage of the whole system, but in the International self-supervising type this is overcome by the supervising devices described, by means of which all units are brought to correct time on return of the current.

Secondary Clocks.

In the secondary clocks the usual ratchet and pawl mechanism is replaced by a device consisting of a rotor, oscillating between the pole pieces of a magnet, resulting in that much appreciated boon, a silent secondary clock. (See Fig. 19.)

Time Recording and Time Signalling.

The International Time Recording Company has specialised in the equipment of factories, works, offices, institutions and commercial houses, although the merits of the supervising principle is extending their electric clock system to every type of building. The mechanism in time-recording machines and similar devices obviously requires much more power than wall clocks, and the satisfactory electrical direct operation of such equipment is a feature of the International system.

The mechanism in an electric time-recording machine is shown in Fig. 22. Fig. 23 shows a programme cabinet, which is a machine for controlling time schedules for signalling—ringing bells, blowing whistles, etc. This type of programme cabinet is specially suitable for schools where the schedule of time varies from day to day.

The merits of the parallel system of wiring in connection with these units has been referred to above, and the construction in general of the International master clock and secondary units, is designed to meet all possible demands. The duration of the impulse contact is adjustable, making it possible to allow sufficient time to overcome the reluctance and inertia of moving armatures in mechanisms, such as those mentioned above, that possess large magnets. The impulse contact does not deal with the current required for the whole system, but is connected with the coil of a relay, with the result that these contacts break a circuit in which flows but a few milliamps. This method ensures long life to the impulse contacts; the full load relay current being dealt with by the relay contact which may carry as much as five amps. When the system requires more than that quantity, auxiliary relays can be installed. (See Figs. 17 and 18.)

Installation and Maintenance.

The installation of this system presents little difficulty. A blue print is supplied by the manufacturers in which all connections are shown and numbered. These numbers correspond with numbered terminals on each unit rendering it possible for the average electrician to carry out a successful installation.

The wiring is usually VIR in

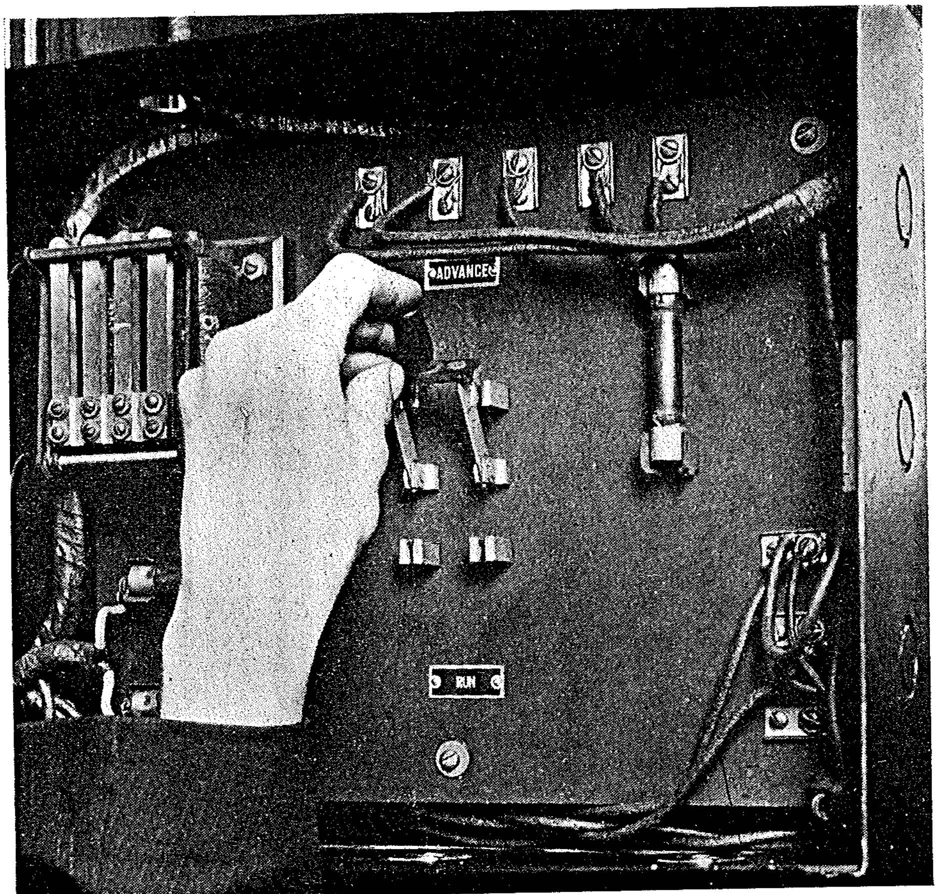

Fig. 21.—How to Advance the Secondary Clocks by Hand from the International Master Relay.

This stepping-up lever is only used as a rule on installation of the system and when it is necessary to advance from winter to summer time. The normal place for the lever shown is the downward position.

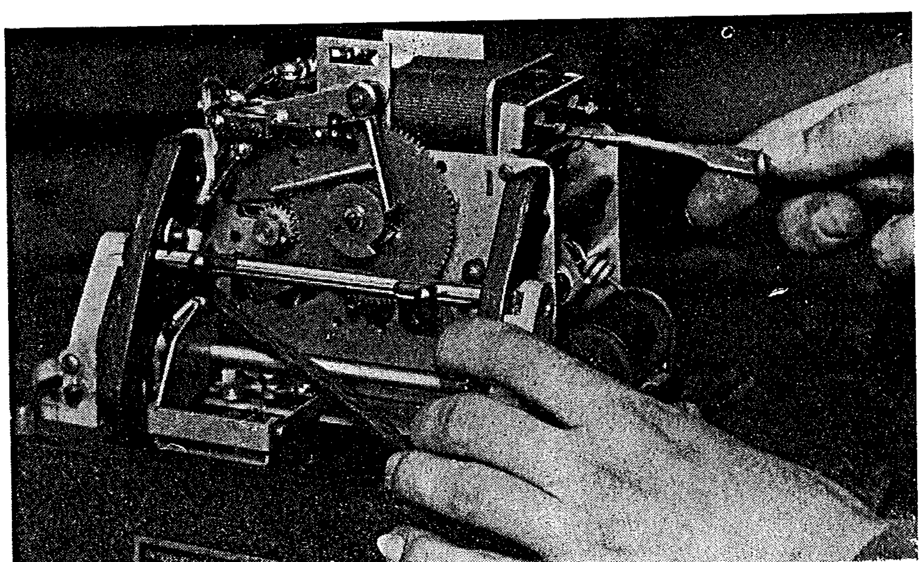

Fig. 22.—Adjusting the Air Gap of International Time Recording Machine.

The air gap for the armature can be reduced, or widened, as required by turning screw indicated to right or left respectively.

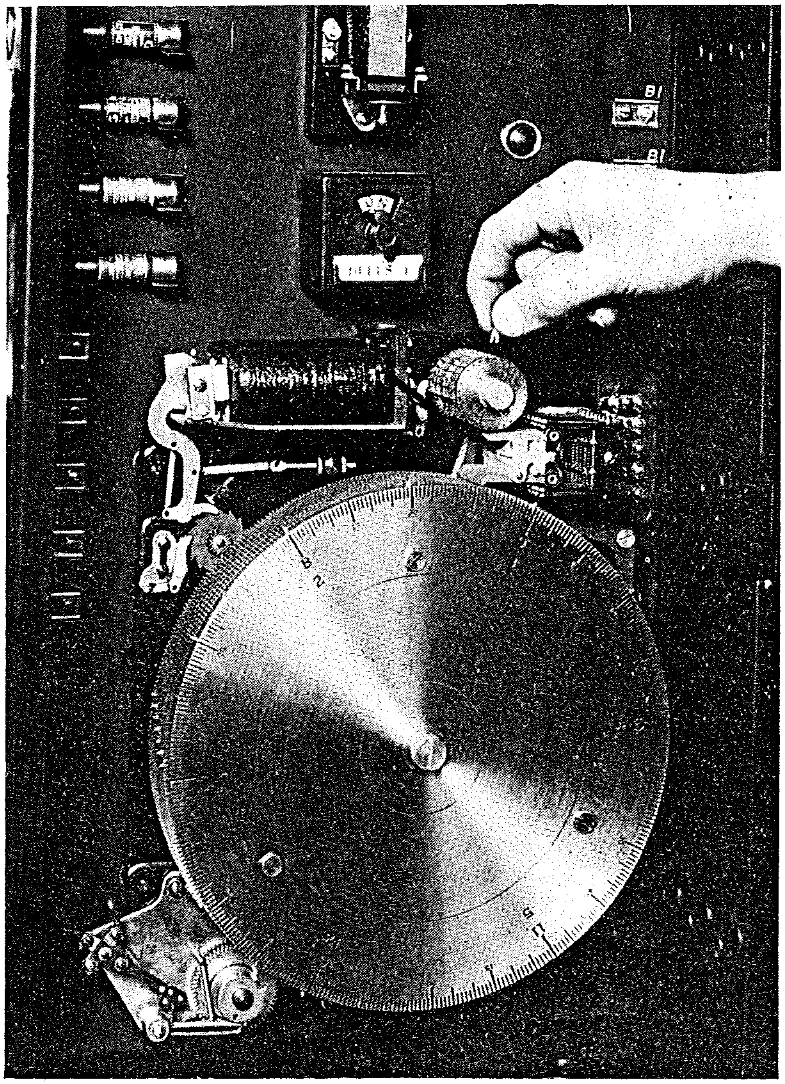

Fig. 23.—PROGRAMME CABINET FOR CONTROLLING TIME SCHEDULES FOR SIGNALLING. (*International Supervised System.*)
The large drum is made up of a series of brass discs with slots at interval spaces of one minute each. Metal pins are inserted into these slots according to the programme schedules. Each disc governs six hours of time. The insertion of metals pins into the the series of smaller discs decides the day on which signals are to be obtained. The pins are placed in position by hand and then gently tapped in.

conduit, or CTS and the International Company will always give full wiring specification for an actual installation to any electrical contractor without cost.

Fig. 16A illustrates the wiring and connections in master clock, master relay and secondary units.

Maintenance costs are reduced to a minimum. The only contacts that break a " live " circuit are the impulse contacts and those in the relay. The description that has already been given of these contacts is sufficient to indicate that little trouble can be anticipated from this source.

The ample power of the master clock, the certainty of a plentiful current supply owing to the elimination of batteries, coupled with the supervising feature, the simplicity of which renders it practically unfailing; leave little that need be done under the heading of maintenance excepting an occasional oiling, and cleaning of contacts.

MAGNETA BATTERY-DRIVEN MASTER CLOCK.

This master clock is driven by a specially designed cell of the Latimer Clark type enclosed in the master-clock case, and this cell should have a life of approximately three years. The clock is a very accurate time-keeper, being fitted with mechanical and magnetic adjustment. The magnetic adjustment is an important feature in that it allows regulation of the pendulum without manual interference therewith. Normally it should not be necessary to regulate the pendulum by means of raising or lowering the bob. The magnetic adjustment covers an error of up to 12 seconds. If the error is in excess of this figure it is necessary to obtain the approximate regulation by raising or lowering the bob. This bob is scaled on the under side, and movement over one division represents a gain or loss of two seconds per 24 hours. The scale for magnetic regulation covers an error of 12 seconds and each division represents a gain or loss of one second per 24 hours.

The pendulum receives an electrical impulse from the Latimer Clark cell every second through the solenoid coil. This ensures a constant amplitude on the

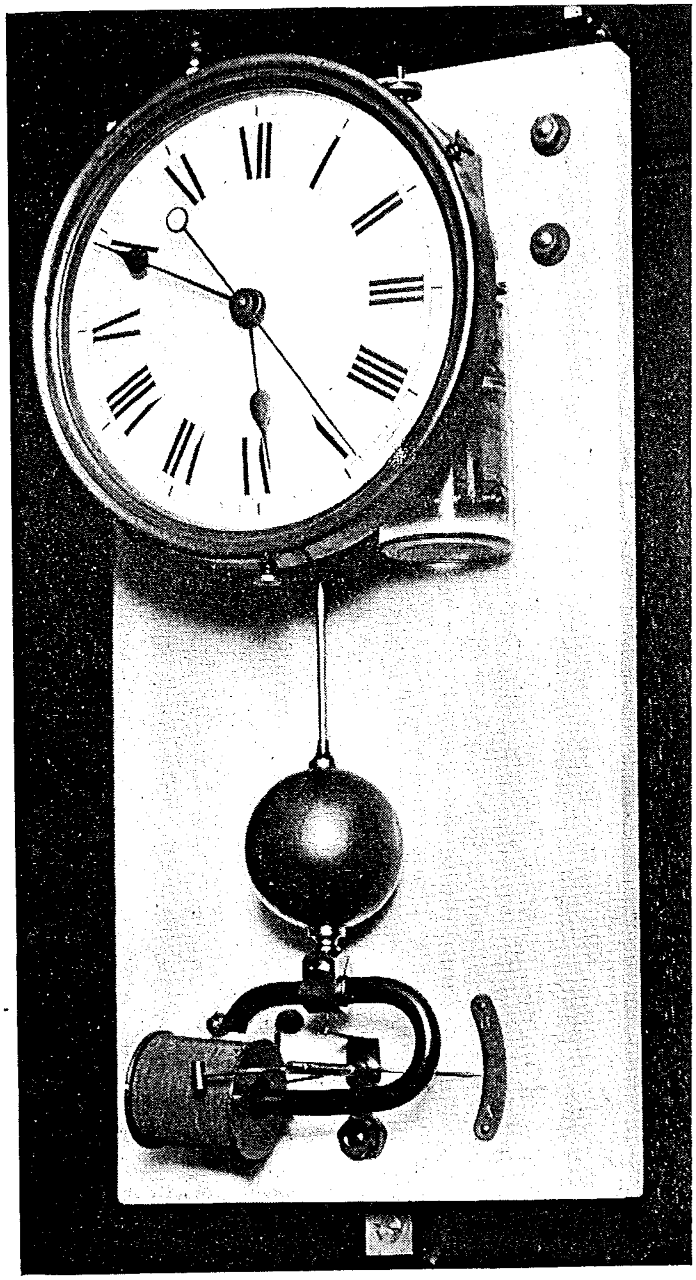

Fig. 24.—Magneta Battery-Driven Electric Clock System.

pendulum, as the output of the cell is constant.

The current required to do this is in the neighbourhood of 2 milliamps., consequently the demand on the cell is particularly small.

The master clock transmits reversing impulses each minute or half-minute as may be required for the operation of the polarised secondary clock movements. As in the case of the Magneta non-battery master clock, a centre seconds hand is provided. This is mechanically driven by the pendulum, and shows pendulum time as distinct from circuit time.

MAGNETA NON-BATTERY MASTER CLOCK.

This system differs fundamentally from all other systems in that no outside source of current is resorted to, consequently there are no maintenance expenses. The Magneta master clock is a particularly accurate time-keeper, the full seconds pendulum being of Invar steel and therefore not affected by changes in temperature. The Magneta master clock incorporates a Graham dead beat escapement, and the pendulum is mechanically maintained by a remontoir spring, which has sufficient power to maintain the pendulum for approximately 30 minutes. This spring is, however, rewound each minute, which results in the arc of the pendulum being kept at a constant amplitude. The pendulum has no additional work.

The current required to actuate the various secondary clocks is generated by the master clock itself, and transmitted precisely at the sixtieth second of each minute, these impulses are always of precisely equal strength and duration. Every minute the weight falls a fraction of an inch, and by so doing turns the armature of the inductor in a strong magnetic field and generates an electric current, which passes through the whole circuit and propels simultaneously the minute hand of every secondary clock in the circuit.

The secondary clocks are of a polarised type. There is consequently no gravity or spring replacement of the armature, which is magnetically locked between impulses.

The master clock has a centre seconds hand mechanically driven, thereby providing pendulum time as distinct from circuit time.